Vegetation, Wildlife, and Human Foraging in Prehistoric Western Virginia

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(ABSTRACT)

To improve the study and management of Havens Wildlife Management Area (HWMA) in Roanoke County, Virginia, the ecological history of the Ridge and Valley Province of Virginia was investigated. Palynological, paleontological, archaeological, and historical data were synthesized into a comprehensive history of the region's vegetation, fauna, and humans from 25,000 B.P. to Euroamerican settlement. A linear programming model was developed to examine the relationship between the energy demand of a human band and the food resources of HWMA 2,500 years ago. The model was based on the assumption that prehistoric human foraging was impelled by the need to satisfy energy requirements and that prehistoric human foragers strove for maximum energetic efficiency. The model was driven by an objective function, that minimized the cost (expressed in hours of labor) of the human foragers' diet. Constraints on the achievement of this goal were the available metabolizable energy in selected mountain food resources and the energy demand of a 25-person band. The product of the model was a regimen of food resources that met the band's annual energy requirement at the lowest cost. The model predicted that fall was the dominant foraging season on HWMA. Chestnut was the major food resource, satisfying 54% of the band's annual energy demand. Additional primary resources were opossum and raccoon, elk, woodchuck, white-tailed deer, and black bear. Secondary and tertiary resources were passenger pigeon, bitter acorns, hickory nuts, and false Solomon's seal rhizomes. Marginal food resources were wild turkey, Jack-in-the-pulpit corms, eastern cottontail, gray squirrel, sweet acorns, and box turtle. An annual foraging strategy with a fall-winter focus in mountain ecosystems and a spring-summer focus in lowland ecosystems was suggested by the model. A comparison of the model results with archaeological data indicated that hickory nuts were overrepresented and chestnuts underrepresented at archaeological sites, and that clothing, not food, limited human population density in upland western Virginia ecosystems.

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Objectives

1. To prepare a history of the vegetation, fauna, and humans of the Ridge and Valley Province of Virginia from 25,000 B.P. to Euroamerican settlement.

2. To determine the food needs, seasonal harvesting and processing strategies, and the energy budget of prehistoric Indian band.

Introduction and Justification

This project is based on the premise that an understanding of the history of a tract of land will illuminate its present and future ecological relationships and thereby allow its improved management and study. A comprehensive history of plants, animals, and humans in the Ridge and Valley Province of Virginia present was prepared to provide general information on the ecology of this region from 25,000 B.P. to Euroamerican settlement. The focus of the project was then narrowed and the relationship between the energy demand of a prehistoric human band and the food resources of an upland and mountain ecosystem investigated. This relationship was selected for two reasons: there is little information on the subject, and the study had the potential of providing fresh insight to a variety of natural resource management problems.

The anticipated relevance of this project was that the results may help practicing natural resource managers to (1) develop long-term plans that take into account the mutability of ecosystems, (2) assess an ecosystem's ability to support plant and animal populations, (3) evaluate an ecosystem's capacity to sustain human use, and (4) educate users of a management area. Below are examples of how an understanding of the past can help achieve these goals. I also have provided projections on how this project will satisfy these goals.

Long-term Planning. The development of long-range natural resource management plans requires projections into the future. Demographic and natural resource data that forecast trends have typically been used to achieve this goal. Knowledge of past events also can be used to increase the accuracy of the forecasting component of a planning system. In this era of rapid environmental change, many changes that previously have occurred over geologic time are now being compressed into human time (Clapham 1973). Because ecological events often have analogs in the past, ecological history can be used to predict the nature and extent of environmental change. For example, an understanding of vegetational responses to global warming between 16,500 and 4,000 B.P. has been used to anticipate biotic responses to increased carbon dioxide concentration in the atmosphere (Delcourt and Delcourt 1983). Binford et al.'s (1987) paleolimnological study of the impact of prehistoric humans on lake-drainage basin ecosystems in Guatemala, Haiti, and Florida has revealed the rate and degree of tropical ecosystem recovery following intensive human disturbance and may contribute to ecologically sound development projects in the tropics.

Although information derived from ecological histories has not been widely used by natural resource managers, there have been a number of instances in which an understanding of past events has aided management decisions. In the early 1970's, the U.S. Army Corps of Engineers planned to construct a massive dam at the mouth of Tahquitz Canyon near Palm Springs, California (Dixon 1977). Immediately prior to construction, an archaeological survey revealed that there were no major floods in the vicinity of the proposed dam during the past 450 years. Because of this information, the Corps of Engineers decided not to build a single, large dam and instead opted to construct a series of small, stream-flow control structures up the canyon (Dixon 1977). If the Corps of Engineers had conducted archaeological fieldwork in the initial stages of the planning process, 1 million dollars might have been saved (Dixon 1977).

Another instance of the past furnishing practical insight for the future is provided by the Pilcher Creek archaeological site in Oregon. Excavation of this site enabled the U.S.D.A. Soil Conservation Service to establish the rate and nature of soil formation and erosion in the region (Gelburd and DeBloois 1986). This information was subsequently used to develop effective soil conservation measures (Gelburd and DeBloois 1986).

Physical evidence is not the sole source of information regarding past ecological relationships. Thousands of years of experience in a given environment have furnished many traditional cultures with a wealth of ecological information. Knowledge of the traditional relationship between Paiutes and the pandora moth (*Coloradia pandora lindseyi*) has helped shape U.S. Forest Service policy in the Inyo National Forest, California (Blake and Wagner 1987). Severe defoliation of Jeffrey pine (*Pinus jefreyi*) forest by the pandora moth sparked a public outcry, and forced the U.S.F.S. to consider chemically controlling the outbreak. Paiute elders told the U.S.F.S. that based on their experience and the experience of their ancestors, the pandora moth would not damage healthy trees. The U.S.F.S. followed this advice and did not attempt to manage the infestation. Subsequently, the moth population collapsed, trees refoliated, and little, if any, mortality or growth loss occurred (Blake and Wagner 1987).

One way in which this project may aid in the long-term planning process, is through a reconstruction of the American chestnut's (*Castanea dentata*) role in the Appalachian forest. Recent research has indicated that blight-resisitant chestnut trees may be developed (Miller 1987). Information on the role of chestnut mast in the energy flow of the Appalachian forest may help forest planners determine if reestablishment of this species is warranted.

Carrying Capacity. Insight into the ability of ecosystems to support plant and animal populations can be acquired from the prehistoric record. Humans are believed to have substantially altered the distribution and abundance of plant and animal species. Much of this disturbance has occurred prior to detailed biological inventory. Archaeological and paleontological sites are important repositories for evidence of past species distribution and abundance.

Prehistoric middens from the Chickamauga Reservoir of the Tennessee River have been examined to establish the historic abundance of freshwater mussel species (Parmalee et al. 1982). This research revealed that 28 extinct or extirpated species were abundant between 600 A.D. and 1600 A.D. and 4 species rare in prehistoric times have greatly increased in abundance. This information can be used to determine the effects of shelling operations and impoundment, and the recovery potential of commercially valuable species (Parmalee et al. 1982). In addition, knowledge of past abundance can help natural resource managers determine if an endangered and threatened status for a given mussel species is justified.

Knowledge of Washington and Oregon's forest carrying capacity for Columbian white-tailed deer (*Odocoileus virginianus leucurcus*) has been provided by prehistoric evidence. Archaeological sites in this region have revealed that the geographic range of the Columbian white-tailed deer prior to Euroamerican settlement was substantially greater than wildlife professionals previously believed (Livingston 1987).

Biologists have also considered archaeological evidence in the California sea otter (*Enhydra lutris*) controversy (Dixon 1977). According to Woodhouse, sea otter-laden prehistoric middens "provide valuable insight to interspecific relationships and long-term changes in species populations and would be useful in understanding and possibly predicting population trends in contemporary populations" (Dixon 1977).

The California fishing industry has used prehistoric middens to obtain information on fish distribution, life history, and catastrophic events. These data have been used to explain both long and short-term population changes among certain species.

This project will directly assess the ability of an upland ecosystem to support human populations. Not only will this information provide natural resource managers with a fresh perspective on this ecosystem, but it may also highlight resources that presently are not utilized (e.g., acorns, opossum). The economic value of wild foods has been demonstrated by the success of American Spoon Foods (Neill 1987). Within 5 years this corporation has become a 1 million-dollar-a-year operation by selling wild berries, greens, tubers, and mushrooms gathered on state and private lands in Michigan (Neill 1987). In addition, a reconstruction of the prehistoric environment may aid in understanding the status of rare species. For example, knowledge of the presence or absence of grassland in prehistoric western Virginia may help explain the current marginal status of the loggerhead shrike (*Lanius ludovicianus*) (James Fraser, pers. comm.).

Human Use. Knowledge of past interactions between humans and their environment has been recognized as essential to effective natural resource management. Maril (1986) was convinced that an undertstanding of the relationship between the now-extinct Karankawa Indians and their enviroment would greatly improve management of the Gulf Coast of Texas and stated, "The wisdom that would guide us in the future uses of the Texas coast lies, at least in part, in shell middens yet uncovered." This philosophy was also held by Shepherd (1987) who stated that developing a management strategy for one of the last undeveloped wetlands in Riverside County, California required establishing the impact that indigenous people had on this resource. Shaw (1985) stated that an understanding of past relationships between people and wildlife is fundamental to wildlife management. This view is exemplified by McAdams and McAdams (1984) work on the relationship that Native Americans and early Euroamericans had with the white-tailed deer (*Odocoileus virginianus*) .

The utility of such information for natural resource management has been demonstrated. Archaeological fieldwork has revealed that intensive cultivation during the Bronze Age prevented tree growth in many British moors and heaths (Dixon 1977)). This information provided land managers with an important base for silvicultural prescriptions (Dixon 1977). In addition, recognizing the role human-generated fire played in maintaining prehistoric ecosystems in the western United States contributed to the revision of fire management practices in this region (Mutch 1980).

Intensive human activity's ability to conceal natural processes, necessitates knowledge of pre-Euroamerican environmental parameters for an understanding of the effect more recent human activity has on natural ecosystems. This has been effectively demonstrated by Livingston's (1987) faunal analyseis of archaeological sites in the American Northwest. Previously, it had been assumed that the decline of the Columbian white-tailed deer in the late 19th century was solely a response to the pressures associated with Euroamerican settlement and that the tremendous rebound of this species in the mid-20th century was entirely due to effective game management (Livingston 1987). However, Livingston's (1987) analysis of archaeological sites with Columbian white-tailed deer remains suggests that the population decline and increase may have been part of a natural, cyclical phenomenon (Livingston 1987).

This project's focus on human-plant and human-animal interactions may aid in assessing the impact prehistoric humans had on ecosytems within the Ridge and Valley Province of Virginia. This information can be used to define the "natural state" of a management area in the Ridge and Valley Province of Virginia.

Education. An understanding of a region's ecological history can be used by natural resource managers to increase the benefits users derive from a management area. The popularity of museums, historic sites, and pioneer festivals attest to the public's interest in the past. Despite this interest, natural resource managers have left vast reservoirs of local ecological history untapped. Brochures, presentations, guidebooks, and televised interviews may be used to enhance the recreational experience of current users and attract new users. The potential of this approach has been recognized by Potter (1984) who maintained that tours focused on the historical exploitation of wild game resources would be popular among various groups of hunters. In fact, the New York City Parks Department has recently instituted a guided foraging tour of Central Park's edible plants in which information regarding prehistoric human uses has a central role.

The results of this project will enable the development of on-site interpretive displays and provide the information necessary to develop guided tours on wildlife, vegetation, and human foraging in prehistoric western Virginia.

Informing the public of the past may enable managers to obtain acceptance for initially unpopular management practices. For example, disapproval of the more liberal fire management policy in the west may be diminished by educating the public to the integral role lightning and human-generated fire previously played in maintaining healthy and stable ecosystems. In states such as Wisconsin, the required inclusion of archaeological sites in fish and wildlife master plans has been perceived as a potential obstacle. However, an understanding of these sites and their relation to wildlife may transform an apparent deficit into a genuine resource.

An Ecological History of Virginia's Ridge and Valley Province

Vegetational History

Full-Glacial Interval

The vegetational history of Virginia's Ridge and Valley Province is intimately connected with the Late Wisconsin Laurentide ice sheet. Although the glacial margin was never closer than 250 km, the climatic conditions associated with the ice sheet largely determined the region's floral composition (Mickelson et al. 1983). A major glacial advance began approximately 25,000 years ago and culminated in a glacial maximum, known as the full-glacial interval, 23,000 to 16,500 B.P. (Mickelson et al. 1983; Delcourt and Delcourt 1985). During this period, zonal atmospheric circulation produced a fixed Polar Frontal Zone that maintained stable floral communities south of the Laurentide ice sheet in eastern North America (Delcourt and Delcourt 1984).

There are no fossil pollen sequences from the Ridge and Valley Province of Virginia during this period. However, there are pollen sequences from mountainous Maryland, Kentucky, and Tennessee that indicate the composition of full-glacial vegetation in western Virginia. Fossil pollen evidence from these sites reveal the presence of an open boreal forest dominated by jack pine (*Pinus banksiana*) (Davis 1976; Watts 1980; Delcourt and Delcourt 1985). Delcourt and Delcourt's (1985) paleo-isophyte maps indicate that the forest composition of western Virginia was 50-70% jack pine, 10-40% spruce (*Picea*), and 0-10% fir (*Abies*).

Delcourt and Delcourt (1986) have maintained that the physiognomy of full-glacial vegetation was largely determined by geomorphic processes. During the full-glacial, interval frequent freeze-thaw episodes produced an accelerated mechanical weathering regime in which large quantities of regolith and rock debris moved downslope (Connors 1986). According to Delcourt and Delcourt (1986), these geomorphic disturbances "reset plant succession" creating pioneer communities of herbs and shrubs. The higher frequency of periglacial-type features (e.g., stone stripes, stone polygons, and block fields) in the northern sector of the Ridge and Valley Province of Virginia (38°N) indicate the presence of a more intense mechanical weathering regime than in the southern sector of the province (36°N) (Connors 1986). Thus, the landscape of Virginia's northern Ridge and Valley Province is believed to have contained a higher percentage of open and early successional environments (Delcourt and Delcourt 1986). In the south, open patches were more typically muskegs associated with poorly-drained valley bottoms (Delcourt and Delcourt 1986).

Fossil pollen evidence from high elevation sites along the Alleghany plateau in Maryland and West Virginia indicate that trees were probably absent from comparable high elevation sites in the Ridge and Valley Province of Virginia. Sedges (Cyperaceae), grasses (Gramineae), and herbs apparently dominated these alpine tundra environments (Maxwell and Davis 1972; Watts 1979).

Comparisons of mid-latitude eastern United States fossil pollen sequences with modern boreal pollen samples yield high similarity coefficients for the full-glacial interval (Delcourt and Delcourt 1985). Thus Delcourt and Delcourt (1985) maintained that the composition of eastern full-glacial forests "was within the range of variation in species occurrence and abundance within modern boreal forests of southern Manitoba and east-central Ontario."

The presence of jack pine suggests that the full-glacial climate of the Southeast was similar to the present climate of northern Minnesota, or at least that of central Maine (the nearest location where jack pine and spruce occur together) (Watts 1979). This indicates a very short growing season and a severe winter. The annual number of frost-free days would be less than 120 and a January mean of -10°C to -16°C and a July mean of 20°C could be expected. This scenario was supported by Barry (1983) who estimated that full-glacial temperatures in western Virginia were 7°C cooler in the summer and 18°C cooler in the winter when compared with the present. Delcourt (1979) stated that mean annual temperatures were 15°C lower than today with most of the change occurring in winter.

Support for such cold conditions is evidence of tundra 225 km south of the glacial margin at Cranberry Glades, West Virginia, elevation 1000 m (Watts 1979). At Buckle's Bog, Maryland, 175 km south of the glacial margin, tundra evidence occurs at an elevation of only 814 m (Barry 1983). Full-glacial alpine tundra, according to Delcourt and Delcourt (1985), was present at elevations above 1,450 m throughout the southern Appalachians.

The full-glacial pattern of fir distribution indicates the presence of abundant moisture throughout the growing season (Delcourt and Delcourt 1985). Modern weather patterns suggest that the Polar Frontal Zone, which separates prevailing Arctic and Pacific airmasses from the Maritime Tropical Airmass, was stationed at 34°N latitude, corresponding with the southern limit of the full-glacial boreal forest. The full-glacial Polar Frontal Zone anchored the position of storms along a narrow latitudinal belt (34°N to 37°N) providing increased available moisture that would have favored fir populations (Delcourt and Delcourt 1985).

Late-Glacial Interval

An increase in solar radiation between 17,000 and 16,000 B.P. permitted the Maritime Tropical Airmass to move north. When it reached the southern flank of the Laurentide ice sheet, significant glacial melting occurred. This climatic event initiated the late-glacial interval (16,500-12,500 B.P.) which was characterized in the southeast by an increase in temperature and precipitation (Delcourt and Delcourt 1984).

Vegetational response initially occurred between 34°N and 35°N at approximately 16,500 B.P., indicating that vegetational changes in the Ridge and Valley Province of Virginia (36°N to 39°N) occurred somewhat later. Warmer temperatures and a longer growing season induced the gradual replacement of jack pine by temperate species that differentially migrated from refugial areas to the south (Davis 1976; Delcourt and Delcourt 1985). The percentage of spruce and fir increased during this period, indicating the persistence of cool climatic conditions and increased precipitation during the summer growing season (Delcourt and Delcourt 1985). Low temperatures and frequent geomorphic disturbances (e.g., freeze-thaw soil churning) probably permitted the persistence of alpine tundra at isolated high elevation sites (Delcourt and Delcourt 1986). The geomorphic processes of the full-glacial interval continued during the late-glacial interval (Connors 1986). Freeze-thaw episodes initiated the flow of block streams, debris avalanches, and solifluction lobes that, according to Delcourt and Delcourt (1986), enabled patches of land to remain devoid of mid- and late-successional forest.

Fossil pollen sequences from the Saltville Valley (elev. 525 m) of Smyth County that date back to 15,500 B.P have permitted a remarkably detailed reconstruction of late-glacial vegetation in the southern Ridge and Valley Province of Virginia. Delcourt and Delcourt (1986) maintained that there was a "species-rich mosaic of [closed] boreal coniferous and hardwood forests." Upland sandstone ridges supported forests that were dominated by jack pine and included aspen (*Populus balsamifera* and *P. tremuloides* type), birch (*Betula*), and oak (*Quercus*). Mesic slopes were occupied by ash (*Fraxinus*), maples (*Acer saccharum* and *A. pennsylvanicum*), beech (*Fagus grandifolia*), hickory (*Carya*), elm (*Ulmus*), and cherry (*Prunus*). Red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), and tamarack (*Larix*) dominated poorly-drained alluvial bottomland. Open glades were present and contained "boreal shrubs, grasses, and sedges, with a rich assemblage of boreal woodland and herbs (Delcourt and Delcourt 1986)."

According to Delcourt and Delcourt (1986), the species-rich floral communities of the Saltville Valley were not representative of late-glacial Ridge and Valley Province of Virginia vegetation. Rather, they occupied one end of south-north vegetational gradient in which closed species-rich forests characterized the south and more open species-poor forests characterized the north (Delcourt and Delcourt 1986).

Fossil pollen sequences extracted from Hack Pond (elev. 451 m) in the southern Shenandoah Valley (Craig 1969) support Delcourt and Delcourt's (1986) hypothesis. A large basal zone dated prior to 12,720 B.P. indicates that jack pine (55%) and spruce (40%) were the dominant arboreal elements. Since pine is overrepresented in pollen samples Craig (1969) believed that spruce was the dominant tree taxa. Small, but steadily increasing percentages of oak, alder (*Alnus*), and birch were also present. Non-arboreal elements were extremely abundant in this segment of the pollen core and include burnet (*Sanguisorba canadensis*), grasses, sedge, and quillwort (*Isoetes*). Burnet, the dominant herb, was restricted to this zone and gradually decreased in abundance throughout the segment. Quillwort was extremely abundant, rising to a peak in the middle of the sequence and declining sharply, thereafter (Craig 1969). According to Craig (1969), this entire assemblage represented "some form of boreal woodland" with considerable open spaces. Watts (1979) provided a more elaborate interpretation. He asserted that the spruce-burnet community should be classified as forest tundra, and envisioned an environment with "discontinuous permafrost, marked by stands of spruce, probably predominantly *Picea glauca*, mingled with dwarf shrubs, especially dwarf birch, and by wet meadows with tall herbs" (Watts 1979).

Fossil pollen found in the skull of an extinct musk ox in Saltville, Virginia, dated at 13,460 B.P., is believed to represent late-glacial vegetation (Ray et al. 1967). The composition of the sample was 53% jack pine, 42% spruce, 3% fir, and trace amounts of oak and birch. Approximately 40% of the pollen was non-arboreal with sedge and grasses predominating (Ray et al. 1967). The high percentage of non-arboreal pollen led Ray et al. (1967) to characterize the late-glacial environment of the region as spruce parkland with "marshes, ponds, and prairies dotting the landscape between knolls and ridges and spruce in parklike or locally dense stands."

Early-Holocene Interval

During the early-Holocene interval (12,500-8,500 B.P.) in the Ridge and Valley Province of Virginia there was increased seasonality with modern temperatures being reached about 11,000 B.P. (Delcourt and Delcourt 1984). A rapid increase in temperature and decrease in moisture at this time is believed to have initiated a period of vegetational disequillbrium (Carbone 1976; Davis 1983). Support for this view is found in the synchroneity of floral changes througout the Appalachian Mountains, and the disappearance of such hydrophylic species as burnet and quillwort (Craig 1969; Delcourt and Delcourt 1985). Boreal tree taxa migrated northward, and were rapidly replaced by by temperate deciduous tree species (Delcourt 1985). Between 13,000 and 12,000 B.P., fluvial processes replaced colluvial processes as the dominant erosional regime (Delcourt and Delcourt 1986). This transition is believed to have permitted tree colonization on previously unstable upland slopes (Delcourt and Delcourt 1986). The development of extensive root systems and large quantities of organic litter enhanced slope stability and diminished erosional capabilities. The net result was that open space and park-like habitats were substantially reduced with treeless patches relegated to alluvial glades and bogs (Delcourt and Delcourt 1986).

Fossil pollen evidence from the Saltville Valley indicates that during the first half of the early-Holocene interval (12,500-10,000 B.P.) a mixed conifer-northern hardwoods forest was present, one dominated by oak, spruce, white pine (*Pinus strobus*), and jack pine that included hemlock (*Tsuga*), fir, birch, hornbeam (*Carpinus/Ostrya* type), and maples. After 10,000 B.P. jack pine, white pine, and oak declined, while hemlock rose to dominance (Delcourt and Delcourt 1986).

The Hack Pond pollen-core zone dated between 12,720 and 9,520 B.P. reveals a steady decline in spruce with a concomitant increase in alder and hazelnut (*Corylus*). The percentage of jack pine remains constant throughout most of the zone, but declines precipitously at approximately 9,500 B.P. This decline corresponds with a dramatic increase in oak, which becomes the dominant tree taxon. Quillwort and burnet disappear during this period (Craig 1969).

Carbone (1976) maintained this floral shift revealed the transformation of an open boreal forest to a closed boreal woodland. He asserted that the lower portion of this core (12,500 B.P to approximately 11,000 B.P.) suggests a vegetational mosaic with a diverse biomass (Carbone 1976). According to Carbone (1976), the open boreal forest consisted of six microenvironmental zones in the Shenandoah Valley: 1) mixed-deciduous gallery forests along rivers, 2) bogs on low floodplains and near sinkholes, 3) mixed coniferous-deciduous forests on the valley floor, 4) grasslands, 5) coniferous forests on the slopes of higher ridges, and 6) alpine tundra at the higher elevations.

By 9,500 B.P. there was an increase in deciduous species and a reduction in open grassland and park-like habitats. Subarctic woodland replaced tundra, hemlock and pine forested the upper slopes and ridges, a mixed-conifer-deciduous forest expanded over the valley floor and foothills, and the floodplain gallery was dominated by mixed hydrophytics (Carbone 1976).

This floral transformation was also reflected in fossil pollen cores from Potts Mountain Pond (elev. 1090 m), Alleghany County, Virginia (Watts 1979). The bottom of the core's lower zone (11,140-9,140 B.P.) indicates the presence of a mixed coniferous-northern hardwood forest that was dominated by oak, red spruce, and pine and included fir, hazelnut, and birch. The core also indicates that green alder (*Alnus crispa*), beech, hickory, hop hornbeam (*Ostrya* sp.), and sugar maple were present in lesser numbers. Pine constitutes 10% of the pollen in this strata, and was overwhelmingly white pine. This is the only known site where white pine is contemporary with both a spruce-fir community and an assemblage of deciduous trees (Watts 1979). Watts (1979) asserted that the vegetation of Potts Mountain Pond 11,000 years ago is similar to the vegetation now found only on the high elevation peaks in the southern Appalachians.

The mixed coniferous-northern hardwoods forest persisted until approximately 9,100 B.P. when spruce and fir disappeared and oak dramatically rose to dominance. Hemlock also increased significantly, peaking at this time (Watts 1979). The transformation of the Potts Mountain Pond flora 400 years after Hack Pond may have been due to its ridgetop location and higher elevation.

Middle-Holocene Interval

During the middle-Holocene interval, or Hypsithermal Interval, (8,500-4,000 B.P.) a peak of prevailing westerlies increased warmth and aridity, shifting the climate from cool-temperate to warm-temperate (Delcourt and Delcourt 1985). Deciduous species completed their rise to dominance and produced a near total closure of the forest.

The fossil pollen sequences from Hack Pond and Potts Mountain Pond reveal that in the beginning of this period hickory expanded and chestnut (*Castanea dentata*) and black gum (*Nyssa sylvatica*) entered western Virginia in significant numbers. The percentage of oak continued to increase, culminating in a peak of 82% of total arboreal pollen at Hack Pond and approximately 75% of total arboreal pollen at Potts Mountain Pond by the end of the interval. Hemlock was a major arboreal element at the beginning of this period, but declined rapidly thereafter (Craig 1969; Watts 1979). In the Saltville Valley the hemlock populations "collapsed" at approximately 4,700 B.P. while oak, ash, and chestnut rose to dominance (Delcourt and Delcourt 1986).

The rapid expansion and subsequent decline of hemlock led Carbone (1976) to characterize the early middle-Holocene interval as mesic. He hypothesized that the Shenandoah Valley supported mesic forests from floodplain to ridgetop with extensive boggy areas on the floodplain (Carbone 1976).

As the middle-Holocene interval progressed, mean annual temperature increased and precipitation diminished with maximum warmth and dryness occurring between 7,000 and 5,000 years ago (Davis 1983; Delcourt and Delcourt 1985). The fossil pollen sequences from Hack Pond, Potts Mountain Pond, and Saltville Valley suggest that xeric conditions induced the decline in hemlock, aquatics, and semi-aquatics and the dramatic rise in oak, hickory, chestnut, ash, and black gum (Craig 1969; Watts 1979; Delcourt and Delcourt 1986). Carbone (1976) asserted that drier conditions in the Shenandoah Valley restricted mesic forests to floodplain and higher elevation locations, expanded the oak-hickory forest on the valley floor and hillsides, and induced the reappearance of grassy areas.

The floristic changes during the middle-Holocene interval may be particularly relevant today. The continued input of carbon dioxide into the atmosphere has been projected to produce a significant global warming trend within the next 50 years that may persist for 2,000 years (Delcourt and Delcourt 1983). Prediction of the biotic response to this "super-interglacial" can be enhanced with an understanding of a past analog (Delcourt et al. 1983).

Temperatures during the middle-Holocene interval were 1-2°C warmer in temperate regions than today (Delcourt et al. 1983). The increase in temperature significantly affected the abundance of arboreal species and altered the migrational trajectories of vegetation. Future climatic warming is predicted to occur much more rapidly and, according to Delcourt et al. (1983), may produce "a rapid turnover of species composition, resulting in local and regional changes in dominance, displacement of species ranges, and local extinctions of species." The present fragmentation of the previously contiguous eastern North American forest may inhibit the migration of species since most past migration corridors have been eliminated. Thus it may be desirable for the federal government to establish and acquire missing "forest links" (nature preserves and protected forested areas) to insure the continued presence of reasonably spaced forest in eastern North America (Delcourt et al. 1983).

Late-Holocene Interval

Pollen cores from various locations in the cental and southern Appalachians reveal that by the beginning of the late-Holocene interval (4,000 B.P. to present) cooler and moister conditions had returned (Delcourt and Delcourt 1985). Oak continues as the dominant taxa at Saltville Valley, Hack Pond and Potts Mountain Pond, though it declines at Hack Pond. Pine increases steadily throughout the period, composing 30% of the assemblage of the most recent strata at Hack Pond and Potts Mountain Pond (Craig 1969; Watts 1979; Delcourt and Delcourt 1986). At Hack Pond the dominant pine species was identified as pitch pine (*Pinus rigida*) (Craig 1969). Although spruce and fir have been shown to expand at mid- to high-elevation sites in the central and southern Appalchians, there is no evidence of this change at these western Virginia locations (Craig 1969; Watts 1979; Delcourt and Delcourt 1986).

By 3,500 B.P. the modern oak-chestnut forest type was established in Virginia's Ridge and Valley Province. Fossil pollen cores have indicated that this vegetational complex remained relatively stable until the chestnut blight and/or initial timber harvest. Oak-chestnut forests dominated the ridges except in sheltered ravines and coves where mixed-mesophytic (species-rich forests of predominantly broad-leaved deciduous trees with a diverse understory layer) or hemlock communities were present (Braun 1950; Strahler 1972). Chestnut typically composed 30% of the canopy trees. White oak (*Quercus alba*) was more prevalent on lower slopes with numbers of chestnut oak (*Quercus prinus*) and black oak (*Quercus velutina*) increasing with elevation (Braun 1950; Strahler 1972). The shrub and herbaceous layer was dominated by blueberry (*Vaccinum* spp.), flame azalea (*Rhododendron calendulaceum*), bush-clover (*Lespedeza* spp.), and tick-trefoil *(Desmodium*) and was low in diversity and biomass (Braun 1950). The valley floors were oak-dominated with white oak frequently composing 60% of the forest (Braun 1950; Strahler 1972). Other important valley species were hickory, yellow poplar, and black oak and white pine in the northern part of the province (Braun 1950). Timber harvest records, interviews with older people, and precipitation and soil data indicate that prior to initial timber harvests, red spruce was present in western Virginia forests at an elevation above 914 m and may have dominated forests above 1,219 m (Pielke 1981).

It is important to note that there were distinct regional differences in forest species composition within Virginia's Ridge and Valley Province. Along the western edge of the province from Rockingham County south to Alleghany County there was a high percentage of mixed-mesophytic communities on the most mesic sites. In fact, stands of beech, hemlock, yellow poplar (*Liriodendron tulipfera*), red oak (*Quercus rubra*), white oak, red maple (*Acer rubrum*), sugar maple, basswood (*Tilia americana*), hickory, black gum and black walnut (*Juglans nigra*) frequently covered the valley floors (Braun 1950). East of this region mixed-mesophytic communities were less common, and beech and sugar maple were only present in highly localized stands. South of Giles and Pulaski counties white oak was less abundant, and chestnut occupied the dominant position in mesic slope forests (Braun 1950).

Scattered throughout the province are limestone outcrops that supported primary red cedar (*Juniperas virginiana*) communities. In these locations, there were patches of xeric herbs that often included butterfly weed (*Asclepias tuberosa*), lyre-leaved sage (*Salvia lyrata*) and a few tall grasses. There were also occasional oaks, hophornbeam, and redbud (*Cercis canadensis*) in these locales (Braun 1950).

Although uncommon, there are a number of streams that have become entrenched below the valley floors throughout the Ridge and Valley Province of Virginia (e.g., Cedar Creek at Natural Bridge). The slopes above these streams contained rich mixed-mesophytic communities. White basswood, (*Tilia heterophylla*), sugar maple, and yellow poplar were the dominant species. Northern red oak (*Quercus borealis maxima*), eastern hemlock, and white ash were also present in significant numbers. The herbaceous layer was rich in biomass and diversity and included an abundance of ferns and spring geophytes (Braun 1950).

Red spruce communities, similar but not identical to late Pleistocene communities, have persisted at isolated high elelvation Ridge and Valley Province sites in Russell, Tazewell, Giles, and Highland counties (Woodward and Ruska 1986). Balsam fir and Fraser fir (*Abies fraseri*) are occasionally present as are such boreal forbs as corn-lily (*Clintonia borealis*), lily-of-the-valley (*Maianthemum canadense*), and common wood-sorrel (*Oxalis montana*). High elevation sphagnum bogs in Shenandoah, Giles, Craig, Washington, Tazewell, Alleghany, Augusta, and Smyth counties contain such boreal relicts as Canadian burnet and large cranberry (*Vaccinum macrocarpon*) (Woodward and Ruska 1986).

Unfortunately, quantitative descriptions of pre-chestnut blight virgin forest in the Ridge and Valley Province of Virginia are exceptionally scarce. In fact, the only quantitative descriptions that were encountered are a stand table compiled by Foster and Ashe (1908) in which part of the data was from Lee County and Braun's (1950) species composition tables of virgin forest tracts in Giles County (Salt Pond Mountain), Rockbridge County (Cedar Creek Gorge), and Bath County (Wilson Creek drainage).

Vegetational Impact of Prehistoric Humans

Early historic accounts indicate that prehistoric humans did not substantially alter the vegetational communities of western Virginia. In fact, the available evidence suggests that human disturbance was confined to the area immediately adjacent to large agricultural villages.

The first Europeans to view the landscape west of the Blue Ridge were Thomas Batts and Robert Fallam in 1671 (Briceland 1987). The Batts and Fallam expedition entered the Ridge and Valley Province near present day Shawsville. They travelled southwest to the New River and followed this waterway until they reached Narrows at the Virginia-West Virginia border (Briceland 1987). Having traversed the entire width of the south-central Ridge and Valley Province of Virginia, Batts and Fallam made no mention of the presence of savanna or prairie. This was probably not an oversight, for once in West Virginia they described small, circumscribed areas with early successional tree species that were believed to be abandoned living sites of native people and "old fields" (Alvord and Bidgood 1912; Briceland 1987). According to Alvord and Bidgood (1912), "old fields" was a 17th century expression for abandoned Indian agricultural land. Although abandoned villages and "old fields" were not described by Batts and Fallam in the Ridge and Valley Province of Virginia, remains of large, agricultural villages (circa 1450-1650) suggest their presence.

The nature and extent of the impact that Indian villages and agriculture had on Ridge and Valley Province landscapes has been documented for a section of the Little Tennessee River Valley (Delcourt et al. 1986). Although this information may not be entirely applicable to Virginia's Ridge and Valley Province, numerous similarities between the physical environs and prehistoric human cultures of the 2 regions justify its presentation.

The Icehouse Bottom site in Monroe County, Tennessee is located in the Ridge and Valley Province and was occupied from 9,400 B.P. until historic time (Delcourt et al. 1986). There is little evidence of human ecological disturbance prior to 3,000 B.P. Although minimal cultivation and firewood collection occurred, it was on a scale sufficiently small to leave no trace in the paleoecological record. After 3,000 B.P. wood-charcoal evidence and pollen samples indicated marked human disturbance. Disturbance-favored tree taxa composed 10% of wood charcoal between 9,400 and 3,000 B.P. and 25% after 3,000 B.P. The increase in wood-charcoal of early successional species has been attributed to the develoment of semi-permanent settlements and small-scale slash and burn horticulture (Delcourt et al. 1986). Evidence of a substantial increase in human disturbance was coincident with the introduction of corn, approximately 1,500 B.P. A high percentage of non-arboreal pollen 1.5 km from Icehouse Bottom indicated the deforestation of several lower stream terraces. This was probably due to either land clearance or firewood collection (Delcourt et al. 1986). Disturbance has also been reflected in the wood-charcoal spectra, revealing a substantial rise in the use of early successional species. Human impact on vegetation intensified throughout the Late Woodland period. With the development of large fortified villages by 800 B.P., the original closed-canopy deciduous forest within 1.5 km of the Icehouse Bottom site had become "a mosaic of (1) croplands near permanent settlements (2) early successional forest with disturbance favored taxa invading both disturbed fields and areas of timber exploitation and (3) deciduous forest remnants on high terraces" (Chapman et al. 1982). This vegetational mosaic may have affected the local distribution and abundance of game species, since an increase in forest edge may have increased carrying capacity for deer, rabbits, and quail (*Colinus*). Early successional food plants, such as blackberry and raspberry (*Rubus* spp.) may also have become more abundant (Chapman et al. 1982). The Late Woodland component of the Icehouse Bottom site is very similar to large Late Woodland villages in the Ridge and Valley Province of Virginia. Hence, the environmental changes recorded at Icehouse Bottom might well have occurred at such large Late Woodland sites as Sullins, Crab Orchard, Shannon, and Trigg (See pages 47-50 for descriptions of these sites).

Numerous authors have asserted that human-generated fire markedly altered the vegetational communities of western Virginia prior to Euroamerican settlement (Maxwell 1910; Ashe 1922; Day 1953). In fact, Maxwell (1910) stated that "no portion of Virginia was more terribly burned" than the Shenandoah Valley. However, Robison's (1960) critical examination of the primary sources used to develop these claims revealed gross misinterpretations. Descriptions of non-forested land in the Coastal Plain by John Smith in 1608 and in the Piedmont by John Lederer in 1670 were carelessly applied to mountainous Virginia. Furthermore, the "savanae" that Lederer described in the western Piedmont was not a continuous savanna, but rather small areas of marshy land that were prevalent within the forest (Robison 1960). Widespread belief in an Indian-generated prairie in the Shenandoah Valley appears to have originated from works by Kercheval (1833) and Foote (1850). Both of these authors obtained their information from the recollections of individuals living in the Shendandoah Valley during the late 18th century. However, the informants were not identified and the nature and extent of the observed grasslands were not clearly defined. They may merely have been abandoned village sites or bottomland that was subject to frequent flooding. Moreover, accounts of expeditions that explored the Shenandoah Valley in 1716, 1728, and 1751 have no mention of prairie or savanna (Robison 1960). Thus, unless additional evidence is uncovered, it appears that prairie in the Shenandoah Valley was a creation of careless historians, not native people.

Furthermore, recent research indicates that the effect human-generated fire had on the vegetation of the entire eastern United States was minimal. Of the 35 first-hand accounts that describe Indian activity prior to 1700 A.D., half have no mention of fire (Russell 1983). The most frequently mentioned use of fire is for cooking. There are 3 accounts that describe fire-based hunting practices. Yet there are no first-hand descriptions of systematic forest burning or the use of fire to clear land for agriculture (Russell 1983). This should not be surprising; unlike much of the grasslands and coniferous forests of western North America, the mature hardwood forests of the east were difficult to burn. The presence of prehistoric humans undoubtedly increased the frequency of fires, for although deliberate burning may have been miminal, accidentally-set fires certainly occurred. Human-generated fires, however, did not in all likelihood substantially alter the vegetational communities of the eastern United States.

Table 1. Vegetational periods in western Virginia (23,000 B.P. to present).

Full-Glacial Interval	23,000-16,500 B.P.	Open jack pine forest
Late-Glacial Interval	16,500-12,500 B.P.	Open spruce-pine forest (deciduous elements)
Early Holocene Interval	12,500-8,500 B.P.	Open mixed conifer-northern hardwood forest
Middle Holocene Interval	8,500-4,000 B.P.	Closed deciduous forest
Late Holocene Interval	4,000 B.P.-Present	Closed oak-chestnut (hickory) forest

Faunal History

Detailed knowledge of Virginia's Ridge and Valley Province vertebrate fauna begins with observation made about conditions in the late Pleistocene. Western Virginia is located in Martin and Neuner's *Symbos-Cervalces* Pleistocene Faunal Province whose hallmark genera are *Symbos* (musk ox), *Cervalces* (stag-moose), and *Sangamona* (fugitive deer) (Lundelius et al. 1983). Graham's (1979) regionalization scheme has western Virginia in the Eastern Mammalian Region which is characterized by eastern chipmunk (*Tamias striatus*), northern bog lemming (*Synaptomys borealis*), giant beaver (*Castoroides ohioensis*), Harlan's musk ox (*Bootherium*), long-nosed peccary (*Mylohyus nasutus*), and woodland musk ox (*Symbos cavifrons*).

Between 15,000 and 10,000 B.P. there was remarkable faunal diversity in the Ridge and Valley Province of Virginia. The late Pleistocene fauna included the species present before Euroamerican settlement and an additional 25 species of mammals, 5 species of birds, 4 species of reptiles, and 2 species of amphibians (Lundelius et al. 1983; Guilday 1984; Eshelman and Grady 1986). Faunal remains from other eastern locations suggest that as many as 20 additional mammal species may have been present in western Virginia (Lundelius et al. 1983).

A variety of large grazers--woodland musk ox, complex-toothed horse (*Equus complicatus*), brother horse (*Equus fraternus*), mammoth (*Mammuthus primigenius*), Harlan's musk ox, and bison (*Bison*)-- were supported by the boreal parkland (Lundelius et al. 1983; Guilday 1984; Eshelman and Grady 1986). A diverse assemblage of large browsers and specialized herbivores was also present: stag-moose (*Cervalces scotti*), caribou (*Rangifer tarandus*), white-tailed deer, moose

(*Alces alces*), elk (*Cervus elaphus*), vero tapir (*Tapirus veroensis*), mastodont (*Mammut americanum*), long-nosed peccary (*Mylohyus nasutus*), flat-headed peccary (*Platygonus compressus*), Leidy's peccary (*Platygonus vetus*), fugitive deer (*Sangamona fugitiva*), giant beaver, and Jefferson's ground sloth (*Megalonyx jeffersonii*) (Handley and Patton 1947; Lundelius et al. 1983; Guilday 1984; Eshelman and Grady 1986). Carnivore diversity was also at an unparalleled height. Dire wolf (*Canis dirus*), gray wolf (*Canis lupus*), American Pleistocene lion (*Panthera atrox*), red fox (*Vulpes vulpes*), black bear (*Ursus americanus*), raccoon (*Procyon lotor*), fisher (*Martes pennanti*), ermine (*Mustela erminea*), coyote (*Canis latrans*), eastern spotted skunk (*Spilogale putatorius*), gray fox (*Urocyon cinenoeoargentus*), bobcat (*Lynx rufus*), long-tailed weasel (*Mustela frenata*), least weasel (*Mustela nivalis*), mink (*Mustela vison*), and striped skunk (*Mephitis mephitis*) have all been discovered in late Pleistocene deposits (Handley and Patton 1947; Lundelius et al. 1983; Eshelman and Grady 1986). During the late Pleistocene, there were 2 cricetine rodent species and 10 microtine rodent species. This assemblage included the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), yellow-cheeked vole (*Microtus xanthognathus*), least chipmunk (*Eutamius minimus*), northern bog lemming (*Synaptomys borealis*), and the round-tailed muskrat (*Neofiber leonardi*) (Guilday 1984; Eshelman and Grady 1986).

Late Pleistocene faunal diversity was characterized by the coexistence of species that are presently allopatric and apparently ecologically incompatible (Graham and Lundelius 1984). These "disharmonious associations" were present among megafaunal herbivores, carnivores, birds, rodents, and herpetofauna in western Virginia. Striking examples of disharmonious associations have been found at Natural Chimneys, Augusta County and Clark's Cave, Bath County.

At Natural Chimneys, a late Pleistocene assemblage included boreal species (arctic shrew, yellow-cheeked vole, northern bog lemming) and temperate species (thirteen-lined ground squirrel; deer mouse, *Peromyscus maniculatus*; smoky shrew, *Sorex fumeus*) (Guilday 1971). A disharmonious avifauna assemblage was obtained from Clark's Cave, where such boreal species as spruce grouse (*Dendragapus canadensis*), rock ptarmigan (*Lagopus mutus*), pine grosbeak (*Pinicolor enucleator*), magpie (*Pica pica*), and gray jay (*Perisoreus canadensis*) have been found with more southerly species, including red-bellied woodpecker (*Melanorpes carolinus*), wild turkey (*Meleagris gallopavo*), and red-headed woodpecker (*Melanerpes erythrocephalus*) (Guilday 1984).

Herpetofauna from late Pleistocene deposits in both Natural Chimneys and Clark's Cave contained species present prior to Euroamerican settlement and species that presently have southern and western affinities, including the map turtle (*Graptemys geographica*), ground skink (*Scincella lateralis*), plainbelly water snake (*Nerodia erythorogaster*), southeastern crowned snake (*tantilla coronata*), and the tiger salamander (*Ambystoma tigrinum*). The only species in these deposits with a northern affinity was the northern leopard frog (*Rana pipiens*) (Holman 1986).

Disharmonious faunal associations have been attributed to climatic equability during the late Pleistocene. Cool summers and warm winters are believed to have permitted "unnatural associations" between northern, southern, and western forms (Eshelman and Grady 1986). Another prominent theory maintains that a diverse vegetational mosaic enabled northern fauna pushed south by glacial advances and indigenous southern fauna to coexist (Graham and Lundelius 1984; Guilday 1984).

Between 12,000 and 9,000 B.P., faunal richness drastically declined, resulting in an "impoverished residuum" of the late Pleistocene fauna (Semken 1983). In

Virginia's Ridge and Valley Province 16 large mammal species and 2 small mammal became extinct. Extirpated forms include 7 small and 2 large mammal species, 5 bird species, 4 reptile species, and 2 amphibian species (Eshelman and Grady 1986). Of the species present prior to Euroamerican settlement, 3 were rare and local boreal relicts (rock shrew, *Sorex dispar*, snowshoe hare, *Lepus americanus*, water shrew, *Sorex palustris*) while 9 others were more scarce and/or experienced range reductions (Guilday 1984). The most striking change during the early Holocene was the loss of virtually all large herbivores. Large grazers were completely eliminated and the assemblage of large browsers was reduced to elk and white-tailed deer.

These faunal changes coincided with 2 major events-- dramatic climatic change and the entry of Paleo-Indian big-game hunters (Clovis culture) into the region. The synchroneity of the Late Wisconsin interglacial and the appearance of Clovis hunters has provided the basis for a heated and long-running debate, with each event being posited as the unique cause of the late Pleistocene extinctions. Supporters of the Clovis-hunter-hypothesis assert that the extinction episode was a direct result of human over-exploitation. Supporters of the climatic hypothesis maintain that changes in climate induced extinctions by substantially altering vegetational communities.

Those favoring the Clovis hunters as the extinction vector have been led by Martin (1967, 1984, 1986) who developed the well-known and controversial "blitzkrieg" version of the overkill hypothesis. Martin (1967, 1984) argued that entering Clovis hunters produced a "sudden predatory burst" that decimated large mammals that had no prior exposure to evolving hominids. The hunters appeared to wipe out local populations within 10 years and regional populations in 200 years (Martin 1984, 1986).

A significantly higher proportion of large mammals were lost during this extinction episode than small mammals. This differential extinction pattern has been attributed to the selective hunting practices of the Clovis people and the greater vulnerability of k-strategy species. The survival of such megafauna as the bison (*Bison bison*), elk, and caribou is attributed to their long previous conditioning to people in Eurasia and behavior that reduced vulnerability to hunters (Martin 1984). The "blitzkrieg" aspect of Martin's (1984) model is derived from the remarkable paucity of sites that contain extinct megafauna with cultural artifacts. According to Martin (1984), this indicates "maximum prey destruction in minimum time" leaving little chance for archaeological overlap between megafauna and invading humans. Therefore, the blitzkrieg model requires the extinctions to have occurred within 1000 years (Martin 1986). Carbon-dating evidence supports this claim by revealing widespread occurrence of extinct large mammals before 11,500 B.P. with few survivors after 10,500 B.P. (Martin 1986).

Although the overkill hypothesis has an attractive simplicity, there is a large body of evidence that suggests climate, not humans, was the driving force behind late Pleistocene/early Holocene faunal changes. The retreat of the Laurentide ice sheet and subsequent major changes in floral composition have been well documented (Craig 1969; Davis 1976; Watts 1979; Delcourt 1981). Between 12,500 and 9,500 B.P., warmer temperatures and shorter growing seasons transformed the ecologically diverse boreal forest into an essentially homogenous, closed-canopy deciduous forest. This transformation, according to upholders of climatic models, shattered the equilibrium of the late Pleistocene biota.

Animal species responded individualistically to the changing vegetational community (Graham and Lundelius 1984). These responses disrupted coevolutionary relationships between plants and animals and pushed a stable biotic system into disequilibrium (Graham and Lundelius 1984). Coevolutionary disequilibrium may have created detoxification problems for certain herbivores. Unable to adapt to the new plant communities some species may have poisoned themselves into extinction (Graham and Lundelius 1984; Guthrie 1984).

However, the major source of faunal changes in the coevolutionary disequillibrium model is heightened competition due to reduced niche differentiation (Graham and Lundelius 1984). The complex plant associations of the late Pleistocene favored a diverse assemblage of herbivore "generalists" (e.g., stag-moose and mastodont) that had mixed food diets and made use of a variety of local habitats (Guthrie 1984). When floral communities became relatively homogenous during the Pleistocene/Holocene transition, these generalists were out-competed by more specialized herbivores (Guthrie 1984). Homogenous plant associations favored species that were adapted to a specific habitat and able to thrive on relatively monocultural diets. Thus, herbivore specialists were able to exploit more efficiently the new vegetational communities, driving many herbivore generalists into extinction (Guthrie 1984; Graham 1986).

Unlike the overkill hypothesis, this model is not restricted to animal size category, trophic class, or taxonomic group, and is thus able to account for the extinctions and local extirpations of small mammals, birds, and herpetofauna (Graham and Lundelius 1984). The low rate of small animal extinctions is attributed to their lesser individual demands, smaller home ranges, and greater reproductive capacities, all of which enable them to survive in small areas of primary habitiat and recover rapidly from catastrophic events (Guilday 1984). The coevolutionary disequilbrium model is supported by the presence of boreal relicts surviving in the spruce-fir ecosystem, for remnants of late Pleistocene fauna would be expected to be associated with floral groups compositionally similar to those of the late Pleistocene (Graham and Lundelius 1984).

Although the debate over the cause of the late Pleistocene extinction episode is unresolved, the current evidence appears to favor the climatic change hypothesis.

Substantial changes in floral communities during the extinction period are undeniable. The extinction episode corresponds with both the timing and nature of this change. Although the human overkill hypothesis is intriguing, it does not adequately explain the changes that occurred to small animal populations. More importantly, this model suffers from lack of archaeological support. There are hundreds of sites containing extinct megafauna during the extinction period, yet only 20 have any documented human association. In fact, most extinct megafauna species are not represented at these archaeological sites (Lundelius et al. 1983). Although the blitzkrieg model requires few kill sites, rapid human-generated extinctions in other locales (e.g., New Zealand) have produced a huge body of physical evidence (Anderson 1984). Thus, until there is significant archaeological support for intensive human predation, the climatic change model remains the most plausible single-factor explanation for the late Pleistocene extinctions in eastern North America. However, it must be noted that an integrative model has yet to be developed. There is a possibility that both climate and humans may have simultaneosly, sequentially, or synergistically produced changes that many animal species could not withstand.

The Pleistocene/Holocene faunal transition was complete by 9,000 B.P., and faunal communities remained relatively stable until Euroamerican settlement (Semken 1983). The Holocene mammalian fauna has been comprised of predominantly forest product consumers (mast-feeders and browsers), insectivores, and carnivores. Grazers have been limited to small rodents and lagomorphs able to subsist on restricted, and frequently temporary areas of grassland. Mast- feeders--5 species of sciurids, wild turkey, passenger pigeon (*Ludovicianus migratorius*), and ruffed grouse (*Bonasa umbellus*) have been primarily arboreal. Large mammals have been limited to white-tailed deer, elk, black bear, timber wolf, and eastern cougar (*Felis concolor*) (Guilday 1984).

Stratified faunal deposits from Russell Cave, Alabama, have revealed virtually no change in species compositon between 8,500 and 370 B.P. (Semken 1983). In the Stanfield-Worley Bluff shelters in northern Alabama, frequencies of white-tailed deer and gray squirrel (*Sciurus carolinensis*) were similar throughout the Holocene (Semken 1983). Although warming during the middle-Holocene interval produced faunal changes west of the Mississippi River, archaeological sites in western Virginia have indicated no change in abundance and variety of animal species. However, an increased riverine orientation by prehistoric humans during the middle-Holocene interval has led Catlin et al. (1982) to assert an increase in faunal richness in the floodplain. Species unable to tolerate xeric conditions are believed to have migrated to the more moist riverine zone. Anadromous fish are believed to have become more abundant on the basis of a dramatic increase in fishing-related artifacts (Catlin et al. 1982). Although these claims are intriguing, it must be stressed that they are simply hypotheses that have yet to be tested.

Archaeological sites, however, do indicate that during the early Holocene both gray fox and eastern spotted skunk invaded western Virginia from the south (Guilday 1984). Between 1000 and 1200 A.D., bison reentered the region after a 9,000 year hiatus (Carbone 1979). This range expansion has been attributed to the drier conditions associated with the Pacific I climatic episode. Although the bison was present in the region until 1800 it was never abundant in western Virgina and was probably a transient species (Semken 1983).

Evidence of the impact that humans had on animal populations during the Holocene interval in western Virginia is not available. However, there is evidence that humans have affected the distribution and abundance of populations in other

North American locations. In the lower and upper layers of the Sheep Rock Shelter in Pennsylvania, flying squirrels are a dominant faunal element. However, in the middle levels flying squirrels are rare and rabbits are abundant. The dominance of rabbits coincides with the period of heaviest occupation in the shelter. The shift from flying squirrels to rabbits has been attributed to the clearing of the original forest for agriculture. The reversion to flying squirrels coincides with the abandonment of the shelter by people (Semken 1983). At the Malibu site in California, the California mussel (*Mytilus californianus*) was initially the dominant molluscan species. Over time, however, the importance of the California mussel declined substantially while the little-necked clam (*Protothaca staminea*) rose to dominance (Botkin 1980). The decline of the California mussel has been attributed to human predation (Botkin 1980).

Human Prehistory

Paleo-Indian Period

The earliest evidence of human existence in the Ridge and Valley Province of Virginia is that of the Clovis culture, approximately 11,500 years ago. However, humans may have inhabited this region as early as 100,000 B.P. (West 1983). The presence of a pre-Clovis culture in North America is an unsettled and controversial issue within archaeology. Much of the debate focuses on 32 sites that have been dated between 100,000 B.P. and 13,000 B.P. A number of researchers have maintained these sites indicate a technologically unadvanced, pre-Clovis tradition that was dominated by pebble tool or chopping tool-industries (West 1983). However, virtually all of these sites have problems in either dating or determining whether materials are true human artifacts. The only site that appears to withstand scrutiny is the Meadowcroft Rockshelter in southwestern Pennsylvania. An artifact assemblage that includes unifacial knives, bifacial cutting tools, small prismatically shaped blades, one lanceolate point, and a basket fragment have been dated at 19,600 B.P. (Adovasio and Carlisle 1986). The close proximity (240 km) of the Meadowcroft Rockshelter to Virginia's Ridge and Valley Province does suggest that humans may have inhabited this region prior to 11,500 B.P.

The discovery of 59 Clovis points in western Virginia has provided unequivocal evidence of human presence in this region by 11,500 B.P. Clovis points are "fluted", having a flake removed from one or both faces from the base to about 1/3 the way to the tip (Adovasio and Carlisle 1986). The distribution of this highly distinctive point across North and Central America indicates a single, large tradition (West 1983). The progenitor of the Clovis culture is believed to be the Beringian traditon, which entered central Beringia approximately 20,000 years ago (West 1983). Climatic warming between 14,000 and 11,000 B.P. broke down the megafauna-rich steppe tundra biome and likely triggered the emigration of a band of these inland hunters who became direct Clovis ancestors (West 1983).

Archaeological evidence in the western United States has revealed that Clovis people were probably nomadic hunters dependent on now-extinct megafauna, with a particular emphasis on mammoths (West 1983). There are no Clovis sites in western Virginia containing the remains of extinct megafauna. In fact, the only eastern site having this association is in Kimmiswick, Missouri (West 1983). Yet the intensively studied Flint Run Complex, a series of Paleo-Indian and Early Archaic sites centered around jasper outcrops in the southern Shenandoah Valley, has provided substantial archaeological evidence for determining the settlement/subsistence system of Paleo-Indian people in western Virginia. The Clovis culture (11,500-11,000 B.P.) is located in the earliest phase of the Flint Run Complex, and is followed by the Mid-Paleo phase (11,00-10,500 B.P.) and Dalton-Hardaway tradition (10,500-10,000 B.P.). These three Paleo-Indian traditions constitute a cultural continuum in the Shenandoah Valley (Gardner 1977)

Five functionally distinct site types have been identified in the Flint Run Paleo-Indian Complex: quarries, quarry reduction stations, quarry-related base camps, periodically visited hunting sites, and sporadically visited hunting sites (Gardner 1977). Quarries were located at upland and bluff jasper outcrops. These sites were occupied solely for jasper procurement. Lack of surface water and restricted food resources limited the duration of quarry visits (Gardner 1977). Quarry reduction sites were an intermediate location where large jasper cores were reduced to easily transportable forms. These sites were generally situated at the first available water source away from the quarries, and were occupied briefly (Gardner 1977). Quarry-related base camps were multi-purpose activity sites where blanks were fashioned into their final forms (points, scrapers, knives, and gravers) and daily maintenance activities occurred (Gardner 1977). Dwellings were present at these sites, indicating a somewhat stable hamlet existence. Base camps were in floodplain locations where daily sunlight exposure and accessibility to plant and animal resources was maximized and wind exposure was minimized (Gardner 1977). Periodically-visited hunting camps were located along alluvial fans and interfan areas that overlooked backwater swamps. Game was procured and processed at these sites (Gardner 1977). Sporadically visited hunting sites are situated along small streams close to the junction of larger tributaries. Both types of hunting camp sites were located near favorable game habitats and generally provided maximum sunlight exposure, minimum wind exposure, and are believed to have furnished food resources while people resided at base camps (Gardner 1986).

The Flint Run Complex indicates that Paleo-Indian people were engaged in seasonal hunting rounds that included stable periods of hamlet life (Gardner 1977). Small bands, no larger than 20 individuals, are believed to have followed large mammals (e.g., mammoth, horse) throughout much of the year, exploiting a territory of approximately 3,120 square kilometers (Boyer 1983; Gardner 1986). When tool kits became depleted, these bands returned to base camps and their associated quarries (Gardner 1977). The base camps were occupied for extended periods, possibly the entire winter, and were supported by hunting and gathering forays (Gardner 1986). Indeed, the continuous occupation of the Thunderbird base camp for 2,000 years suggests that once a desirable region was discovered, relatively permanent settlement ensued (Gardner 1977). This settlement/subsistence pattern challenges the notion of a purely nomadic Paleo-Indian culture.

The Flint Run Complex is the sole source of detailed information regarding Paleo-Indian culture in western Virginia, and the applicability of this material outside the Shenandoah Valley is unknown. However, insight to Paleo-Indian existence in other areas of western Virginia can be derived from the distribution of Clovis points. The discovery of only 59 points in mountainous Virginia indicates this region was only marginally utilized, relative to the Piedmont and Coastal Plain where 620 Clovis points have been located (Turner 1984). The distribution of the 59 western Virginia points supports the big-game orientation of the Clovis culture. Twenty-five points have been found near Saltville, Smyth County, a locale that would have provided an ideal hunting site, as numerous megafauna fossils attest (Turner 1984). Thirteen points have been found within the Shenandoah Valley which is also believed to have supported high density populations of large mammals during the Paleo-Indian era (Carbone 1976). The concentration of Clovis points in two locations in western Virginia provides further support for Gardner's (1977) belief that Paleo-Indians in this region had a territorially restricted mobility and were not truly nomadic.

Archaic Period

During the Early Archaic (10,000-8,000 B.P.), human populations faced a dramatically changing environment. Many large mammals became extinct while others migrated north. A closed-canopy deciduous forest rapidly replaced the open boreal forest. Not surprisingly, human settlement and subsistence routines changed significantly.

With the loss of most big-game taxa, Early Archaic people shifted to an incipient hunter-gatherer existence. Although hunting continued to provide the major source of food, plant resources became increasingly important (Geier 1978; Boyer 1983). Unlike their predecessors, Early Archaic people did not confine their subsistence activities to the floodplain, but also exploited the upland and mountain zones (Gardner 1977). The adoption of a vertically oriented subsistence system came in response to the diversification of upland/mountain resources, including the expansion of nut-bearing trees. Dependence on seasonal resources, such as nuts, led to seasonally-based settlement patterns. Increased density and decreased mobility of resources allowed larger social groups to forage in more restricted territories and remain at base camps for longer periods. The profusion and widespread distribution of Early Archaic sites throughout the Ridge and Valley Province indicates a substantial population increase (Gardner 1977).

Technological innovations may have contributed to the restricted mobility and expanding population of the Early Archaic. The development of the corner-notched point, which defines the beginning of the period, is believed to indicate the use of the spear-thrower (atlatl) (Gardner 1984). The greater accuracy and range that could be obtained with this device greatly increased hunting efficiency (Howard 1974). The chipped stone axe and drill were additional technological innovations that may have improved foraging strategies (Gardner 1984). Arguably, the most important technological advance was the use of a diverse array of lithic materials. (Gardner 1984). Silicified slate, chert, quartzite, quartz, and rhyolite all were used to manufacture projectile points (Hranicky and MaCord 1984). The ability to use a wide variety of relatively abundant lithic materials significantly contributed to the Early Archaic culture's ability to exploit the entire Ridge and Valley Province and helped increase the flexibility of the settlement/subsistence system.

During the Middle Archaic (8,000-6,000 B.P.) the foraging strategy became increasingly generalized and seasonally oriented. This change coincided with an increase in mesic forests and an abundance of nuts, semi-aquatic plants, and aquatic plants. Exploitation areas included numerous temporary upland collecting and hunting camps centered around more permanent floodplain base camps. Macro-bands composed of several extended families inhabited the floodplain base camp during the spring and summer where wild seed plants, fish, mussels, and other aquatic resources were exploited (Gardner 1984; Custer 1980). During the fall and winter these macro-band base camps split into smaller extended family micro-bands and moved into the uplands and mountains to concentrate on collecting nuts and hunting deer (Custer 1980). Numerous upland and mountain settings were exploited, including high ridges, saddles, gaps, and hollow terraces (Boyer 1982). These locales merely served as loci for transient camps or hunting stations and were not permanently occupied. Transient camps tended to be located in sheltered areas with a southern exposure and close to springs. Hunting stations were most frequently located at the upland/floodplain interface, an area of habitat overlap that was particularly attractive to game (Custer 1980). Technological innovations that permitted efficient exploitation of upland and mountain zones were ground-stone tools that included seed and nut processing implements (manos, metates, abraders), axes, adzes, hammerstones, and atlatl weights (Barber 1980; Boyer 1982).

The Middle Archaic period's settlement cycle of dispersal in the fall and winter and coalescence in the spring and summer period was a significant adaptation. Not only was there a dramatic population increase, but the groundwork was established for a period of "primary forest efficiency" beginning in the Late Archaic (6,000-3,000 B.P.) and persisting in some areas of western Virginia until historic time (Geier 1978).

The Late Archaic period coincides with the climatic warming that peaks with the height of the Xerothermic Interval (6,000-4,000 B.P.). According to Catlin et al. (1982), the warm dry climate of this period altered the distribution of plants and animals in the riverine zone. Although there is no direct evidence supporting faunal changes during this period, Catlin et al. (1982) maintained there was an increase in faunal diversity as species intolerant to xeric conditions migrated to the moist riverine environment. An expansion in the range of anadramous fish has also been asserted (Catlin et al. 1982). Although these faunal changes have not been documented, there *was* a greater human focus on riverine settings. Archaeological excavations have indicated that larger populations were spending longer periods of time on the floodplain and were engaged in increasingly diverse economic activities (Catlin et al. 1982). Seed procurement intensified during this period and became a major subsistence activity. There was also a dramatic increase in fishing, indicated by net sinkers and other fishing related artifacts (Catlin et al. 1982). Nuts and game resources were exploited in the upland and mountain zone. Nuts became a major component of the Late Archaic food base (Brashler 1984).

Although the seasonal dispersal and coalescent cycle established in the Middle Archaic continued, there was a marked decrease in mobility with less time spent travelling to and from temporary hunting and collecting stations (Custer 1980; Brashler 1984). The introduction of the steatite (soapstone) bowl, and the development of storage pits, coupled with the possible greater abundance of riverine resources allowed Late Archaic people to remain at floodplain base camps for longer periods (Custer 1980). Decreased mobility, however, induced greater dependence on trade, particularly for such locally restricted items as steatite (Catlin 1982; Custer 1980).

The increase in sedentism during the Late Archaic coincided with a significant population increase. A reduction in travelling time from one foraging area to another may have provided a greater supply of energy for reproduction and a higher surival rate for infants. Levels of stored body fats are higher with a more sedentary lifestyle, and have been shown to shorten periods of adolescent sterility, improve reproductive success, increase duration of lactation, and raise the age of menopause (Catlin et al. 1982). The disadvantage of carrying smalll children also diminishes with increased sedentism and may have led to a decrease in the birth interval (Catlin et al. 1982).

Woodland Period

The appearance of pottery is used to separate the Early Woodland period (3,000-2,500 B.P.) from the Late Archaic period. However, in western Virginia there is no evidence of ceramics until the end of the Early Woodland period (Gardner 1984; Geier 1984). The northeastern North Carolina Coastal Plain appears to be the birthplace of ceramics in the Middle Atlantic (Gardner 1984). This technological innovation subsequently spread to the near Northeast where it was modified, and then diffused south and west, reaching the Ridge and Valley Province of Virginia by the end of the Early Woodland period (about 2,500 B.P.) (Gardner 1984).

The specialized hunter-gatherer economy of the Late Archaic persisted throughout the Early and Middle Woodland periods in western Virginia (Geier 1982). This continuation of an earlier economic orientation contrasts sharply with areas to the west, such as the Ohio River Valley, where horticulture and large-scale sedentism distinguished Early Woodland culture (Geier 1979). Western Virginia's insularity from major cultural changes to the west has been attributed to the barrier created by the Appalachian Mountains (Geier 1979). However, Carbone (1982) maintained that inhabitants of western Virginia had no need for horticulturally-based, centralized villages. He asserted that the efficiency of the seasonal, specialized foraging strategy had reached a "par excellence climax" during the Early and Middle Woodland periods, making cultural change unnecessary.

Despite the relatively stable continuum between Late Archaic and Early Woodland culture, there were changes in the settlement and subsistence system in this region. An increased floodplain orientation has been noted throughout western Virginia (Geier 1979; Gardner 1982; Boyer 1982). Although most base camps were located on outer levee settings, an increasing number of camps were situated on the inner floodplain (Gardner 1982). The more pronounced riverine focus significantly increased sedentism. The dispersal and coalescent settlement pattern of the Late Archaic was no longer operable (Gardner 1982). Hamlets supporting several households were established. These had storage pits and were supported by a series of small exploitative foray stations (Gardner 1982). This settlement and subsistence system was located where food was abundant and hamlets were situated on the floodplain locations where the harvest of fish, mussels, turtles, and seeds could be maximized (Gardner 1986). Resources procured at foray stations were primarily obtained to enrich the food base of the hamlet. Archaeological evidence indicates that white-tailed deer was the dominant animal resource obtained from these stations (Buchanan 1980).

The population supported by this system is believed to have been small, making overexploitation of wildlife populations more difficult (Gardner 1979). The use of foray stations occupied by few people for short periods, coupled with the increased storage capabilities of ceramics, appear to have been the innovations necessary to transcend the local ecological limitations and permit increased sedentism (Gardner 1984).

The settlement/subsistence system of the Early Woodland period continued throughout most of the Middle Woodland Period (2,500-1,200 B.P.) (Gardner 1984). However, distinctions have been noted in the Shenandoah Valley. There was a settlement shift to floodplain sites with good access to backwater swamps. Using these areas may have been a strategic use of aquatic resources (Gardner 1984). Stone burial mounds appeared about 2,400 B.P. These mounds may have indicated a ranked society, which would represent a major change in social structure (Gardner 1984). The development of mounds has been attributed to interactions with moundbuilders from the Ohio Valley in West Virginia. According to Gardner (1984), this suggests the presence of a loosely organized polity that extended from the Ohio Valley to the Shenandoah Valley which maintained trade between the upper echelons of participating communities (Gardner 1984).

The Late Woodland period (1200 B.P. to historic time) was characterized by the development of the bow and arrow and the emergence of agriculture (Geier 1981). During the early portion of this period, human settlement/subsistence systems experienced little change in much of Virginia's Ridge and Valley Province. Extensive archaeological surveys along the Jackson River, Bath County, have revealed no evidence of agriculture before 1000 B.P. Floodplain hamlets and upland hunting and gathering stations indicate the persistence of the Early and Middle Woodland subsistence strategy (Geier 1984).

The Shenandoah Valley was an exception to this pattern. Small horticultural villages of 2-6 houses appeared by 1100,B.P. (Gardner 1986). These communities were located on the outer levee, not the inner floodplain, a shift that was apparently due to the need for easily tilled and fertile land (Gardner 1986). Although such cultigens as corn (*Zea mays*), beans (*Phaseolus*), and squash (*Cucurbita*) increased the size and stability of the resource base, intensive local foraging continued to provide the bulk of the food base (Gardner 1984). This settlement/subsistence system persisted in the Shenandoah Valley until 1400 A.D. (Gardner 1984).

Outside the Shenandoah Valley there is evidence of large, permanent horticultural villages by 1000 B.P. Along the Jackson River, Bath County, a village of 150-200 people was occupied from 1000-800 B.P. (Geier 1983). Corn and beans were cultivated, yet game and wild plants still dominated the diet. Walnuts, hickory nuts, and seeds of knotweed (*Polygonum* sp.) and sorrel (*Rumex* sp.) have been recovered from this site. Faunal remains indicate that white-tailed deer was the dominant animal resource. Elk, raccoon, muskrat (*Ondatra zibethica*), ground hog, squirrel, box turtle (*Terrapene carolina carolina*), molluscs, and fish were also included in the diet (Geier 1983). Examination of 20 burials indicate that the community was stable and healthy with a high infant mortality (Geier 1983). The Flanary site (900 B.P.) in Scott County contains a similar Late Woodland village (MaCord 1979). There was, however, no evidence of agriculture at this settlement. Deer and bear were the major faunal resources. Snails, mussels, and fish were also important. This village was only inhabited for a brief period, possibly less than 3 years (MaCord 1979).

Despite the presence of large villges in Bath and Scott counties, semi-sedentary and sedentary hamlets were the dominant settlement form in the Ridge and Valley Province until 600 B.P (1400 A.D.) (Buchanan 1980). The only major difference betweem these communities and Early/Middle Woodland settlements was that cultivation of corn, beans, and squash may have occurred at some locations. Indeed, the Bath County village was abandoned by 800 B.P. and was replaced by a network of hamlets, base camps, and hunting and gathering stations (Geier 1983). The Hall site (800 B.P.), on the South Fork of the Roanoke River, Montgomery County, was probably typical of Ridge and Valley Province communities between 1000 and 600 B.P. (Buchanan 1980). Several families occupied this site permanently. Although corn and beans may have been cultivated, hunting and gathering continued to be important. Deer appears to be the major source of meat with raccoon, elk, grey fox, groundhog, box turtle, painted turtle (*Chrysemys picta*), frog (*Rana* sp.), and snake (*Crotalus* sp.) also utilized. Aquatic resources, including catfish (*Ictalurius* sp.), mussels (*Cyclonaia tuberculata, Elliptio complantus*), snails (*Campetoma decisum, Oxytrema virginica grelena*) were also exploited (Buchanan 1980).

After 600 B.P. (1400 A.D.), large palisaded villages appeared throughout the Ridge and Valley Province. These were floodplain settlements with a strong agricultural orientation. The Sullins site (574 B.P.) on Town Creek, Washington County, was a large fortified village, spanning 2.8 ha and supporting approximately 100 individuals (MaCord 1981). Corn and beans were cultivated. Deer and turkey were the major animal resources. Black bear, fox, rabbit, groundhog, box turtle, and squirrel were also consumed. Mussels and molluscs were important components of the food base (MaCord 1981). The Trigg site, on the New River in the city of Radford, the Crab Orchard site, Tazewell County, and the Perkins Point site, Bath County were all large palisaded villages that have been dated at approximately 400 B.P. (1600 A.D.) (MaCord 1984). All 3 sites contain faunal assemblages virtually identical to the Sullins site. At the Perkins Point site seeds of lamb's quarter (*Chenopodium*) and knotweed and nuts from walnut (*Juglans nigra*) and hickory appear to have constituted a significant portion of the diet (Geier 1981). Quantities of corn, beans, and squash were particulary high at the Crab Orchard site, possibly due to its long-term occupation.

The reasons for the development of large, fortified villages after 600 B.P. are not clearly understood. Between 1000 and 600 B.P. the human population expanded dramatically (Custer 1984; Barber 1984). Yet communities generally did not expand in size, but rather split into 2 or more smaller settlements (Custer 1984; Gardner 1984). As this process continued, optimal agricultural locations diminished, forcing some hamlets to move to somewhat marginal areas. This demographic development coincided with the "Little Ice Age", a cool, dry climatic episode between 650 and 250 B.P. (Gardner 1984). Agricultural production likely became less dependable, fostering greater reliance on hunting and gathering (Gardner 1984). This necessitated the expansion of exploitation areas, an expansion which was reflected in an increase in the number of upland foray stations. Steadily diminishing prime foraging habitat and increasing demand for this habitat made community division more difficult. In areas where continued division became infeasible, such as the New River Valley, it appears that communities increased their exploitation area and horticultural base to accomodate an increasing population. The result was centralized villages (Custer 1984). In locations where environmental factors were not limiting, such as the Mansanutten Mountain area, the proliferation of hamlets continued throughout the Late Woodland period (Custer 1984).

The development of large horticultural villages not only coincided with the "Little Ice Age", but also with a significant influx of people from the Ohio River Valley. Communities in this region were undergoing a similar population expansion and entered the Ridge and Valley Province through the New River Valley (Gardner 1984). This emigration likely contributed to hamlet coalescence and possibly the construction of villages that were fortified (Gardner 1984). Competition for increasingly scarce resources was a source of inter-group hostilities that apparently led to warfare in some locations (Gardner 1984). During this period, populations continued to increase, and by 400 B.P. (1600 A.D.) villages typically contained 120-200 people. Although trade items at numerous sites indicate indirect contact with Europeans, white settlement did not have direct impact on indigenous people. Yet mysteriously, by the end of the 17th century permanent settlements were no longer located in western Virginia. The only possible exception was the southern portion of the Ridge and Valley Province, near Tennessee, where chiefdoms may have been present. The reason the native peoples of western Virginia abandoned the region is unknown, and virtually no serious explanations have been offered.

Table 2. Prehistoric cultural periods in western Virginia.

Cultural Period	Time span	Technological Hallmark	Subsistence Hallmark
Paleo-Indian Period	11,500-10,00 B.P.	Fluted Points	Nomadic Big Game Hunters
Archaic Period	10,000-3,000 B.P.	Stemmed Points/Atlatl	Hunter-Gatherers
Early Archaic	10,000-8,000 B.P.	Lithic Diversity	Mountain Food Exploitation
Middle Archaic	8,000-6,000 B.P.	Ground-Stone Tools	Seasonal Foraging Strategy
Late Archaic	6,000.-3,000 B.P.	Steatite Bowl/Storge Pit	Nut Collecting
Woodland Period	3,000-400 B.P.	Pottery	Stored Foods Important
Early Woodland	3,000-2,500 B.P.		Increased Floodplain Orientation
Middle Woodland	2,500-1,200 B.P.		
Late Woodland	1,200-400 B.P.	Bow and Arrow	Agriculture

Early and Middle Woodland Foraging: A Linear Programming Model

Introduction and Justification

The preceding review revealed that little is known about human exploitation of upland and mountain food resources during the Early and Middle Woodland period in the Ridge and Valley Province of Virginia. I hypothesized that by knowing the type and quantity of available food resources and the mechanisms that drive human foraging, an understanding of the foraging potential of a Ridge and Valley Province ecosystem was possible. Sufficient knowledge of the prehistoric flora and fauna of western Virginia exists to permit an approximate environmental reconstruction, as does an understanding of prehistoric procurement and processing technology and the biological forces that drove human foraging. This information was used to develop a model that predicts how a band of humans would have optimally used the food resources of a 2921 ha upland/mountain locality--Havens Wildlife Management

Area, Roanoke County, Virginia--during the Early and Middle Woodland period (2,500 B.P.). This model did not attempt to determine how an Early and Middle Woodland band utilized the resources of an entire food exploitation area. The objective was simply to illuminate the role mountain localities played in the Early and Middle Woodland foraging routine.

A modeling approach was selected because there were severe deficiencies in the quantity and qualtiy of data on the diet of prehistoric humans in western Virginia (McDonald 1986). Scientific excavations west of the Blue Ridge did not begin until 1966 (Benthall 1969) and have been primarily confined to the large, rich sites of the riverine zone. Although mountain sites have been excavated recently, discoveries of plant and animal remains have been infrequent. When food items have been uncovered, differential preservation has produced biasesd samples. Moreover, slipshod collection and analysis practices have exacerbated this inherent bias (McDonald 1986). The problem is further compounded by a lack of ethnohistoric analogs. Because most indigenous people left the Ridge and Valley Province of Virginia during the 17th century, there are no ethnohistoric descriptions of the diet or foraging practices of these people (Alvord and Bidgood 1912; Geier 1983; Custer 1986). These four conditions: (1) sparse archaeological evidence, (2) differential preservation, (3) inadequate sampling and carless analyses, and (4) lack of historic accounts have, therefore, resulted in an incomplete and possibly inaccurate conception of the role of upland and mountain zones in the foraging strategies and diet of prehistoric humans in western Virginia Virginia.

To remedy this situation, I viewed the problem as one of resource allocation--determining the acquisition of limited resources by humans--and selected linear programming as the modeling technique. Linear programming is an optimization technique specifically designed to solve problems of resource allocation.

It constitutes the backbone of operations research and is widely used in economics, business, and planning. D. L. Clarke (1972), in his ground-breaking *Models in Archaeology*, noted linear programming's potential for elucidating prehistoric economic strategies. Nearly 10 years later, Reidhead (1981) and Keene (1981) confirmed Clarke's (1972) conjecture by producing works that fill significant gaps left by traditional archaeological methods. Following publication of these two works, Durham (1981) singled out linear programming as a technique with "significant value" for archaeology, and added that it is "certain to prove useful for predicting optimal patterns of resource procurement."

Linear programming models are composed of two types of linear algebraic equations which are known as the objective function and the constraints. The objective function is an equation that specifies whether a particular variable is to be maximized or minimized. For example, an objective function can maximize profit or minimize cost. It is this equation that drives the model. The constraints are equations that place limitations on the achievement of the objective function and are expressed as inequalites. An example of a constraint is the amount of capital a business can invest in a venture. The actual operation of the model occurs when an algorithm, typically the simplex method, is used to optimize simultaneously the objective function given the constraints. The result is a set of values that satisfy the objective function within the restrictions imposed by the constraints. This is known as the optimal solution.

In addition to the optimal solution, linear programming algorithms provide "postoptimal" information that permits in-depth interpretation of the results. Shadow prices are a form of postoptimal information that help establish the robustness of a model. Shadow prices are statements of marginal cost that measure the rate that the performance of the model could be increased by slightly increasing the amount of given resource. Another form of postoptimal information can be obtained through sensitivity analysis. Sensitivity analysis can be used to establish the range between which input values can vary without changing the optimal solution; providing confidence intervals for quantitative input and also illuminating the most sensitive parameters.

The objective function for this model was *to minimize the time required to meet the band's mean annual energy needs.* The constraints for the model were the energy value of selected plant and animal resources that were available to humans and the annual energy requirement of an Early and Middle Woodland band. Because the model accounted for seasonal variation, it not only selected the regimen of food items that satisfied the band's annual energy requirements with the lowest hourly expenditure for procurement and processing, but also specified the season(s) in which resources were procured and consumed.

Assumptions

Having minimization of foraging effort as the objective function was based on the assumptions that (a) Early and Middle Woodland foraging was driven by the need for satisfying human energy needs and (b) that Early and Middle Woodland people were energy budgeters who strove innately for maximum energetic efficiency. A foraging strategy based on the satisfaction of energy needs has basic biological support. Fulfillment of the human body's demand for energy has precedence over the need for other nutrients (e.g., vitamins and minerals). In fact, the body will deprive itself of vital nutrients in order to maintain a proper energy balance (Keene 1985). Anthropological research also indicates the acquisition of energy appears to drive human foraging. Among the Cree in northern Ontario, energy "effectively subsumed the complex set of variables that go into a foragers appraisal of resource opportunities: the size and quality of game species; their nutritional value; and the social rewards of their capture" (Winterhalder 1981).

The assumption of energetic efficiency is based on the "law of least effort" (Santley and Turner 1977). According to this principle, "when choice between two or more responses to a stress is possible, the response selected will be the one that produces the greatest gain with the least effort" (Santley and Turner 1977). Having this principle as the foundation for the objective function assumes the following:

1. Early and Middle Woodland economic activities were at least minimally planned (Keene 1981).

2. Early and Middle Woodland people had minimally sufficient knowledge of the distribution, foraging costs, processing costs, and energy benefits of food resources (Reidhead 1981) or were rational gamblers.

3. Early and Middle Woodland economic activity was directed toward meeting the life requirements of the band at the lowest possible cost (Keene 1981).

4. When faced with a choice between two resources of equal value, the one with the lowest net cost was selected (Keene 1981).

Determining whether Early and Middle Woodland bands actually adhered to the least-effort principle was beyond the scope of this project. However, this model may enable empirical verification of this assumption by providing a basis for comparison with archaeological data.

The principle of least effort has come close to achieving "axiomatic status" in archaeology (Reidhead 1981). In fact, Santley and Turner (1977) labelled it a "cultural evolutionary law." Support for the least-effort principle is found in numerous ethnographic accounts. Groups as diverse as the Inuit (Alaska), Ngisonyoka (Kenya), !Kung and G/Wi Bushmen (southern Africa), Cree (central Canada), Karimojong (East Africa), and Alyawara (central Australia) have economic strategies with a strong minimization-of-effort component, coupled with energetic efficiency (Lee 1968; Jochim 1976; Little and Morren 1976; Smith 1980; Connell and Hawkes 1981; Winterhalder 1981; Coughenour et al. 1985). Further support for the least effort principle is found in the widespread use of catchment analysis (Jarman 1972; Ellison and Harris 1972; Barker 1975; Flannery 1976; Zvelebil 1983), which is based on the belief that "humans exploited their environment in a rational way so as to minimize the effort expended in satisfying their needs" (Zvelebil 1983).

The constraints that were developed to limit the acquisition of food resources were based on the assumption that Early and Middle Woodland people did not excessively exploit plants and animals. In many respects, this assumption is a necessary corollary of the energetic efficiency assumption. The marginal cost of substantially depressing a resource in a patch of land are frequently high when compared with the cost of moving to a different patch and continuing to forage (Charnov 1976). Moreover, anthropological research has provided ample evidence that traditional foraging cultures did not excessively exploit plant and animal populations. For example, the Cree annually monitor the status of animal populations

(Feit 1973). A significant drop in either hunter success, number of animals sighted, or number of signs that are located signaled a change of hunting territiories. The Yanomamo of Brazil also use hunting zone changes to avoid overhunting (Smith 1983). The Waswanipi of Ontario abandon snarelines and trapsets before depleting an area of muskrat beaver (*Castor canadensis*), and hare (*Lepus* sp.) (Winterhalder 1981). Further support for foraging without excessive exploitation is found in the behavior of non-human predators. Ecologists have discovered that predators frequently leave a foraging patch or switch to an alternative resource when a prey population is reduced beyond a certain level (Charnov 1976).

A quantitative determination of the energy value of Early and Middle Woodland faunal and floral resources on Havens was required for a linear programming model. Quantitative reconstruction of prehistoric plant and animal resources is at an "infant stage" in archaeology (Reidhead 1981), yet evidence of the viability of this approach is found in its increased employment over the last two decades. One of the earliest quantitative reconstructions was developed by Zawacki and Hausfater (1969) in their report on the prehistoric plant resources in the Illinois River Valley; Munson et al. (1971) reconstructed available biomass of plants and animals in the middle Illinois River Valley; Smith (1975) reconstructed the faunal biomass available to Mississippian people in Missouri; Jochim (1976) reconstructed the Mesolithic animal resource base of the Upper Rhine River Valley; Hastorf (1980) reconstructed the subsistence base of prehistoric groups in Mimbres Valley, New Mexico; Keene (1981) provided an extensive faunal and floral reconstruction of Michigan's Saginaw River Valley during the Late Archaic; Yesner (1981) reconstructed the hunting base of prehistoric Aleuts; Zvelebil (1983) reconstructed the hunting and fishing resource base of Neolithic populations in southern Finland; and Perlman (1983) reconstructed the Late Archaic faunal resources of Martha's Vineyard.

Although the quantitative approach uses numbers, these figures are inevitably rough approximations of an unknown reality. The advantage of transforming approximations into specific quantitative values is that "techniques such as linear programming force the explicit identification of relationships among complex sets of variables"(Reidhead 1981). Even faulty quantitative input can place the researcher in a position to identify decision-making possibilities in resource allocation (Joy 1967). The use of this approach to clarify objectives, identify data gaps, isolate sensitive factors, and suggest research strategies has been well-documented in the literature of operations research. In fact, it has been specifically argued that quantitative data and models in conjunction with a set of explicit assumptions, may permit a more comprehensive analysis of prehistoric subsistence than is possible using solely traditional methods (Keene 1981).

Linear programming models require the assumption of a "closed system." Therefore, in order to determine the role a mountain locality played in Early and Middle Woodland foraging, it was necessary to assume that Havens Wildlife Management Area was the sole source of human food energy. This assumption, although unrealistic, does not detract from the purpose for using linear programming or the utility of the results. Mountain localities composed only part of the exploitation area of Early and Middle Woodland people. Hence, the raw output of the model will not accurately represent the total annual Early and Middle Woodland diet. However, the results of the model will indicate the relative importance of mountain food resources and the season in which they can be most efficiently obtained, thereby illustrating the role of upland and mountain areas in Early and Middle Woodland foraging.

Methods

Objective Function Coefficients

The objective function has the general form of

$$Z_{min} = ax_1 + bx_2 + cx_3 \ldots kx_n$$

where Z_{min} is the minimum number of hours to satisfy seasonal energy requirements and a, b, and c are coefficients for the cost in hours of obtaining 1000 kcal of each resource (x_i).

Cost Phases

The development of cost-coefficients required reconstructing the time involved in several, relatively distinct food acquisition phases: implement construction, search, procurement, transportation, and processing. Estimates of implement construction time did not include the number of hours required to obtain the necessary raw material. This phase was not deemed crucial, since most Early and Middle Woodland implements were made from resources that were relatively abundant. Search time for plant resources was dependent on density, location, and productivity. Search time was calculated by estimating the number of hours necessary to walk from a base camp to the plant resource. A base camp was selected at a terrace adjacent to Mason's Creek at the foot of Fort Lewis Mountain (Lat. 37° 19′ 30″ Long. 80° 09′ 45″, elev. 546 m). Artifacts uncovered from this site suggest its function as a base camp from the Early Archaic period to the Late Woodland period. Search time for animal resources was largely a function of animal mobility, abundance, habitat preferences, activity patterns, and critical flight distance. This estimate was primarily obtained from interviews with informants. The location of the base camp provided the departure locus necessary to fine-tune these estimates.

The time engaged in procurement, the taking of a resource, was largely technology-dependent. Unfortunately, current understanding of Early and Middle and Woodland foraging technology is incomplete. Implements of wood and vegetal material were undoubtedly made, but have rarely been preserved. It is clear, however, that wood spears tipped with stone projectile points and launched with an atlatl were a major component of Early and Middle Woodland foraging technology. An atlatl is a spear-thrower manufactured from wood that is typically 0.61 m long, 5 cm wide, and 1.3 cm thick (Olsen 1973). There is prong at one end that is designed to fit the butt of a spear and it has two loops at the opposite end through which the fingers pass (Olsen 1973). The spears were generally 1.5-1.8 m long and tipped with a 15 cm hardwood foreshaft that held the stone point (Olsen 1973). Experiments have revealed that an atlatl provides a 60% increase in thrust and a marked increase in accuracy over a hand-thrown spear (Howard 1974). Inexperienced individuals have used an atlatl to throw a 1.93 m spear a mean distance of 54.5 m (n=20) (Howard

1974). Howard (1974) indicated that an experienced altlatl user could consistently hit a large animal from a distance of 30 m. This capacity was confirmed by Olsen (pers. comm.) who stated that after considerable practice he could hit a large animal-sized target 100% of attempted throws at a distance of 40 m. I used this information to develop cost estimates for procurement of the large mammals included in this study.

There is a possibility that blowguns similar to those used by such southeastern tribes as the Cherokee, Choctaw, Yuchi, Houma, Chitimacha, and Creek were also used by Early and Middle Woodland people in western Virginia (Swanton 1946). However, no blowgun remains have been uncovered at archaeological sites in this region. Furthermore, river cane (*Arundinaria gigantea*), the predominant blowgun construction material was only present in the far southwestern sector of Virginia's Ridge and Valley Province (James 1969). Therefore, I did not include the blowgun as a technological alternative. I did include such trapping devices as deadfalls, snares, and pen traps. The widespread use of these devices by virtually all native people of eastern North America, their relative simplicity, and nonspecific resource requirements led me to this assumption.

To estimate the seasonal cost of trapping, it was necessary to divide the trapping operation into four distinct phases: trap construction, trap set-up, trap checks, and transportation of trapped animals. Therefore, total trapping costs were the sum of the time spent in these four activities. Once this was established, the number of hours necessary to trap one animal were determined (total number of hours labor/ total number of captures).

Transportation cost was not only determined by the distance between the procured resource and the base camp, but also by the amount of a given resource that could be carried by a forager. This, in turn, was frequently determined by the capacity of transportation vessels. There is both archaeological and ethnographic evidence that reveals the widespread use of large baskets and hides for collecting and transporting food resources (Swanton 1946). I assumed that one individual could carry a maximum of 20 kg of a resource (e.g., chestnuts) that required a basket or hide sack for transportation. This limit was raised to 60 kg for resources that did not require a transportation vessel (e.g., a deer).

Processing, in the context of this study, was defined as the transformation of a resource to its most simple edible state (e.g., raw deer meat, fresh hulled chestnuts). A profusion of stone knives and stone scrapers have been found at Early and Middle Woodland sites in western Virginia. I assumed these implements were used to process animal food resources. Nutting stones, mortars, and pestles have also been frequently uncovered in Woodland sites. I assumed these tools were used to process plant resources.

Stored plant and animal foods were included in this model. I assumed that a resource would be stored during the season of lowest cost and would be available as a stored resource in all subsequent seasons. For example, if winter was the season of lowest cost, the stored form of a resource would be available in spring, summer, and fall.

Storing a food item increased the processing cost. Numerous ethnographic accounts of southeastern Indians have revealed that both plant and animal foods were either dried over an open fire or in the sun prior to actual storage (Swanton 1946). It seemed reasonable to assume that these methods also were used by Early and Middle Woodland people in western Virginia. During the Early and Middle Woodland period, food items were stored in steatite and clay vessels in subsurface storage pits at hamlets and base camps. Thus, estimates of stored cost included the time expended to prepare food for storage and the time required to make storage vessels.

Animals

Previous estimates of the prehistoric costs for procuring and processing animal resources have yielded limited and uncertain results. The use of historic accounts, according to Reidhead (1981), produced estimates that were "more tenuous than desirable." This same conclusion was reached in my preliminary modeling efforts. Ranked cost coefficients based on such animal population and behavioral parameters as density, mobility, social behavior, and critical flight distance were developed by Keene (1981). Although these surrogate cost values appeared to be more reliable than Reidhead's (1981) direct estimates, Keene (1981:236) was still unsure of their accuracy.

Rather than rely on a single source or approach for developing these elusive cost estimates, I acquired hunting and trapping data from 5 distinct, yet complementary sources. Information obtained from Cherokee elders, older people of the Appalachians, wildlife biologists, a survivalist, and wildlife literature was subjectively synthesized into, what is believed to be, reasonable hourly cost estimates for procuring and processing animal resources for human consumption.

I interviewed Cherokee elders (July and August, 1987) in the Snowbird community of Graham County, North Carolina, who have used or have knowledge of traditional hunting practices (see Appendix for a sample interivew transcription). Prior to the 1960's, Cherokees in this region still used traditional hunting and processing techniques and were partially dependent on wild plant and animal foods. Information on the technology and methods used to procure and process several animal and plant resources was obtained from the Cherokee elders.

Although using data about early 20th century Cherokee practices to estimate prehistoric foraging costs in western Virginia may be questionable, the similarity between the two environments and the lack of better information justify this approach. Moreover, the benefits of using information provided by native elders to reconstruct prehistoric people-land relationships has been well documented (Lewis 1977 1980; Barrett 1980; Blake and Wagner 1987).

My interviews in the Snowbird community were primarily with women since very few men born in the late 19th or early 20th century were still alive. Thus, I was unable to obtain the first-hand hunting accounts that were necessary for direct hourly cost estimates. Therefore, I also interviewed older Anglo-American men (> 65 years) of the southern Appalachians (July 1987-March 1988) who had trapped in a virtually identical manner as the native people of the eastern United States (Mason 1902; Goodwin 1977). This information provided the details necessary for the direct development of cost coefficients for a number of the species in this project.

This body of experiential data was supplemented with information obtained from wildlife biologists who had intimate experiences with a particular species. Wildlife biologists were presented with a verbal reconstruction of the Woodland-period environment of Havens that included the seasonal densities of the species in question. I then asked a series of questions that were designed to elicit the number of hours that would be required to procure an individual of a particular species.

Larry Dean Olsen, a noted survivalist, was interviewed in November 1987 and January 1988. Olsen has written books and taught courses at Brigham Young University on traditional Indian survival methods and lived in the Idaho wilderness for over two years in the early 1960's using solely traditional Indian technology. His experience with prehistoric tool construction and the hunting techniques of the native people of North America was invaluable in quantifying the cost of prehistoric food resources.

Interviews for each of the above four groups followed the "general interview guide approach" as defined by Patton (1980). This method required outlining major topics prior to a set of interviews. Questions did not follow a particular order and variations in the wording of questions occurred regularly. The function of the interview guide was to serve as a checklist, insuring that all major topics were addressed (Patton 1980). The inherent flexibility of this approach helped create a relaxed, conversational atmosphere and permitted detailed exploration of particular topics with appropriate interviewees.

I also consulted and used wildlife studies that had documented the number of hours involved in hunting or trapping a given species.

Table 6 contains cost estimates for procuring and processing fresh and stored animal resources.

Plants

Cost estimates for collecting and processing several of the plant resources in this study were obtained from experiments in the anthropological literature. Interviews with professional plant collectors and individuals formerly dependent on wild plant foods provided the basis of cost estimates for the remaining plant resources. These interviews followed the general interview guide approach (Patton 1980).

Table 4 contains cost estimates for procuring and processing the plant resources in this study.

Plant and Animal Resource Constraints

The constraints in this model have the general form of

$$x_1 \leq 1{,}000{,}000$$

where x_1 is a food resource and 1,000,000 is the available kcal on Havens during a single season.

A prerequisite for determining the energy value of plant and animal food was a reconstruction of salient features of the the Early and Middle Woodland-period forest. These characteristics included species composition, density of mature canopy trees, and the percentage of land in early successional stages. This information provided the framework for estimating animal and plant population densities. Pollen studies have revealed that the arboreal composition of the central and southern Appalachian forest remained relatively stable between 3,000 B.P. and initial timber harvest (Watts 1979; Delcourt 1985). Unfortunately, quantitative data from the presettlement forest of this region are exceptionally sparse (Shugart and West 1977). Foster and Ashe's (1908) stand tables for stands that contain at least 10% chestnut oak (*Quercus prinus*) provide one of the rare quantitative descriptions of upland "virgin" forest in the central and southern Appalachians. Data were collected from four locales--Polk and Monroe counties, Tennessee; Scott, Campbell, and Anderson counties

Tennessee; Harlan County, Kentucky and Lee County, Virginia; and Logan County, West Virginia (Foster and Ashe 1908). The forest compostion of these locales was summarized and presented in column three of Table 3 (p. 69).

For modeling purposes, the data in column three of Table 1 (p. 69) represented the Havens forest species composition during the Woodland period. I believed this to be appropriate, not only because most of the data collection sites were located in the Ridge and Valley Province, but also because the chestnut-chestnut oak community dominated upland sites in the the Ridge and Valley Province of Virginia (Braun 1950). Moreover, these data correspond exceptionally well with Shugart and West's (1977) Appalachian deciduous forest succession model, which has been used to describe the composition of the pre-settlement forest. Research on chestnut trees has revealed this species composed 20-40% of overstory trees in the Appalachians (Korstian and Stickel 1927; Keever 1953; Nelson 1955; Woods and Shanks 1959). Thus a 29.4% chestnut component appeared appropriate.

Table 3. Reconstruction of forest stocking and composition on Havens, Woodland period (3,000-1,200 B.P.), based on Foster and Ashe (1908).

		% of total	Trees/ha[1]
Chestnut	*Castanea dentata*	29.4	74.1
Chestnut oak	*Quercus prinus*	23.5	59.2
Black oaks	*Quercus* spp.	13.2	33.2
White oak	*Q. alba.*	5.5	13.9
Hickory	*Carya.* spp.	4.3	10.8
Gum	*Nyssa* spp.	3.8	9.6
Maple	*Acer* spp.	3.8	9.6
Yellow poplar	*Liriodendron tulipifera*	2.8	7.1
Pitch pine	*Pinus rigida*	2.3	5.8
Shortleaf pine	*Pinus echinata*	2.2	5.5
White pine	*Pinus strobus*	1.7	4.3
Virginia pine	*Pinus virginiana*	1.1	2.8
Beech	*Fagus grandifolia*	1.1	2.8
Basswood	*Tilia* spp.	0.7	1.8
Hemlock	*Tsuga canadensis*	0.6	1.5
Birch	*Betula* spp.	0.4	1.0
Locust	*Robinia pseudoacacia*	0.4	1.0
Other species		3.2	8.1

[1] Trees > 13 cm dbh.

Estimating Available Plant Resource Energy

Estimating the energy value of plant resources initially required establishing the density of mature, food-producing plants. It was then necessary to establish the annual yield of each plant. This information was obtained from botanical, forestry, and wildlife literature. To determine the amount of food material available for human consumption it was necessary to quantify crop losses due to wildlife, insects, spoilage, and sprouting. These estimates were obtained from the forestry and anthropological literature.

Once net yield was calculated and the percentage of edible material determined, an estimate of metabolizable energy was necessary. This information was not available for the plant resources in this study. Thus, I estimated metabolizable energy with the following procedure. Neutral detergent solubles (NDS) were used as a measure of digestible plant food. The percentage of NDS is believed to be an accurate estimate of the percentage of a food item that can be digested by humans (Forrest Thye, VPI & SU nutritionist, pers. comm.). When available, this value was obtained from the nutrition literature. Otherwise, the following procedure was used.

Sample plant foods were dried to constant weight, ground in a Wiley Mill with a 30-mesh screen, and analysed for percentages of neutral detergent solubles by the methods of Goering and Van Soest (1970) at the VPI & SU Forage Testing Laboratory.

Metabolizable energy is obtained from the fat, protein, and carbohydates in the digestible portion of a food item. For humans, there are 9 kcal/g of metabolizable energy in fat and 4 kcal/g of metabolizable energy in protein and carbohydrates (Watt and Merrill 1963; Pike and Brown 1984). The percentage of ether extract (an estimate of fat) in plant food samples was either obtained from the nutrition literature or determined with a Soxhlet apparatus at the VPI & SU Forage Testing Laboratory. The metabolizable energy in 1 g of plant food was obtained by initially subtracting the non-digestible portion (1 - NDS) from 1 g. The difference was then divided into 2 parts – fats and protein/carbohydrates. The percentage of fat in a 1 g sample was multiplied by 9 kcal/g and the percentage of protein/carbohydrates was multiplied by 4 kcal/g. These 2 products were summed to furnish the metabolizable energy in a 1 g dry weight sample. Because plant yields are typically expressed as wet weights, the wet to dry weight ratio was used to convert the dry weight caloric estimate to a wet weight estimate.

I assumed that during each season following storage, 10% of each stored plant resource became inedible due to spoilage.

Tables 2 and 3 contain the harvest and energy characteristics of the plant resources in this study.

Estimating Available Animal Resource Energy

The reconstruction of faunal resources required estimating seasonal population densities of each species. When available, this information was obtained from the wildlife literature and much effort was made to get estimates that were consistent with the environmental reconstruction of Havens. Unfortunately, accurate seasonal density estimates are not available for many of the species in this study. Seasonal density was therefore estimated by using reproductive and mortality data.

Estimating the number of individuals that can be removed consistently by humans over many years was guided by harvest data in the wildlife literature. This information is generally available for only one season, typically fall. However, reasonable seasonal harvest estimates for winter, spring, and summer were obtained by determining the vulnerability of a population to hunting during a given season, and adjusting the reported harvest percentage accordingly.

Seasonal harvest estimates represented the maximum number of individuals that can be removed from the population annually without significantly reducing the population for the next year. For example, if the fall population was harvested to the allowable limit, the species could not be exploited during the other seasons. If the maximum allowable fall harvest was not attained, the number of unharvested individuals were multiplied by the ratio of (1) allowable yield for fall to (2) allowable yield for the season under consideration. For example, if 10 animals could be harvested in fall and 5 could be harvested in winter and only 5 were killed in fall, then 2.5 animals would be available in winter ((10 - 5) x 5/10 = 2.5). This procedure was based on the assumption that hunting mortality was only partially compensatory. In addition, it was assumed that the sex ratio and age composition of the human kill followed that of the population. This was based on the assumption that hunters and trappers were opportunistic and usually nonselective.

Determining the energy value of the harvestable biomass initially required an estimate of edible meat weight (fat and viscera included) per animal. Edible meat estimates were derived primarily from White's (1953) seminal work. White's (1953) estimates for wild mammals and birds were based on butchering data from analagous domestic animals. However, White (1953) did not specify the season(s) to which his estimates apply. This omission is crucial, for the percentage of edible meat in wild mammals and birds is not constant throughout the year. Fluctuations in subcutaneous fat alter, often drastically, the percentage of edible meat from one season to the next. White's (1953) estimates were based on domestic animals, which are generally butchered when fat content is high. Therefore, I assumed that White's (1953) estimates were only appropriate for the season in which maximum weight was attained. Knowledge of the percentage of edible meat in the season of maximum weight, coupled with data on seasonal live weight fluctuations, enabled me to make estimates of edible meat for the remaining seasons. Initially, this required subtracting the weight of an animal in the season of minimum weight from its weight in the season of maximum weight. This established the amount of fat that was added during the course of the year. This figure was then subtracted from the edible meat weight in the season of maximum weight. The result was the amount of edible meat in the season of mimimum weight. Dividing this figure by the live weight for that season provided the percentage of edible meat per animal in the season of minimum weight. This procedure was followed for the remaining two seasons.

The kilograms of edible meat per individual were multiplied by the number of harvestable animals to obtain the edible seasonal biomass. The metabolizable energy in lean animal meat was available in the nutritional and anthropological literature for most of the species in this project. These values were adopted for the season that animals were at their minimum weight.

Seasonal weight fluctuations in adult animals are almost entirely due to variations in the amount of fat. Therefore, seasonal caloric density estimates for adult animals were obtained by adding the product of the caloric value of fat (9 kcal/g) and the mass of fat (MF) in each season to the product of the lean meat caloric estimate (LMCE) and the mass of edible meat at the time of minimum weight (MEM) and dividing the total by the edible meat weight (EMW). The following equation was used:

$$\frac{(9 \text{ kcal ME/g} \times \text{MF}) + (\text{LMCE} \times \text{MEM})}{\text{EMW}} \times 1000 = \text{kcal ME/kg}$$

I assumed that seasonal weight fluctuations in animals less than 1-year old were solely due to increases in protein. I, therefore, used the lean meat caloric estimates for these animals. To obtain the mean seasonal caloric value for a given species, the product of the caloric value of adult meat and adult edible biomass was added to the product of the caloric value of juvenile meat and juvenile edible biomass and divided by the total edible biomass.

I assumed that during each season following storage, 5% of each stored animal resource became inedible due to spoilage.

Table 5 contains the harvest and energy characteristics of the animal resources in this study.

Energy Requirement Constraint

There are several factors that determine the metabolizable energy requirement of a prehistoric band, the most important of which are band size and the age and sex of its members. Twenty-five was selected as the band size, because this was the average number of individuals in hunter-gatherer bands (Jochim 1976). In fact, the occurrence of 25 is so frequent that anthropologists have labelled it a "magic number" (Jochim 1976). When formulating the energy requirements for a 25-member band, it was necessary to know the age and gender of each individual. The age and gender of the band members was obtained from a life table developed by Weiss (1973) that were based on data from censused traditional populations and from aged prehistoric skeletal populations. Additional information that would increase the precision of the estimate of the band's annual energy needs are weight, physiology, activity level, and the health of each individual (Wing and Brown 1979). Because these factors can only be approximated for prehistoric populations, Wing and Brown (1979) suggested adopting caloric requirements for theoretically healthy modern humans living in temperate climates. Recent medical and anthropological research supports this approach, because the diets of prehistoric hunter-gatherers conform remarkably well to the nutritional recommendations of government health agencies (Boyd et al. 1988) Following Wing and Brown's (1979) recommendation, I used the National Research Council's recommended daily dietary allowances (in Wing and Brown 1979).

In winter, 8% was added to the seasonal metabolizable energy requirement, due to to the additional energy necessary to perform in temperatures below 57°F and carry the extra weight of cold-weather clothing (Wing and Brown 1979).

Plant and Animal Resource Parameters

Plant Resource Estimates

Arboreal Resource Estimates

Determining the density of mast-producing trees was a prerequisite for estimating the energy value of arboreal resources. Because virtually all stands of virgin forest in the eastern United States were cut prior to scientific study, information on this subject is exceptionally sparse. The available studies revealed that climax deciduous forest contained 191 to 322 mature trees/ha (Reed 1905; Griffin 1948; Lorimer 1976). Reed's (1905) and Lorimer's (1976) work on virgin forests in western North Carolina provide the only density estimates for climax upland oak stands in the Appalachians. Because Reed's (1905) study was prior to the chestnut blight, his estimate (252 trees/ha > 13 cm dbh) was used in this study. Woodland period Havens' 2,921 ha, therefore, had a total of 736,092 mature trees. Based on the forest species composition data presented in Table 1 (p. 69), there would have been 216,411 chestnuts, 172,982 chestnut oaks, 97,164 "black oaks," 40,485 white oaks, 31,652 hickories, and 177,398 other trees with little food value for human foragers.

Acorns

Acorns were placed in two separate categories, sweet and bitter. The reason sweet and bitter acorns were treated independently is the substantial differences that occur in their period of availability, production, physical characteristics, and processing time. Acorns from white oak and chestnut oak have lower tannin content than those in the black oak group and were labelled "sweet;" acorns from black oak (*Quercus velutina*), scarlet oak (*Quercus coccinea*), and northern red oak (*Quercus rubra*), were labelled "bitter".

Summary harvest data for sweet acorns (wet weight) on Havens

Season	No. Trees	Edible Biomass/ Tree (kg)	% Available	Edible Yield (kg)	Kcal ME/Kg	Kcal ME Available
Fall	213,467	1.97	10.0	41,961	1,829	76,747,000

I estimated that there were 213,467 trees producing sweet acorns on Woodland period Havens. Downs' (1949) and Beck and Olsen's (1979) studies of acorn crops in the southern Appalachian both revealed that chestnut oak acorn production varies markedly among years. "Bumper" crops typically occur every fourth year, with 1-2 years of mast failure and 1-2 years of moderate crops in the intervening years (Downs and McQuilkin 1944; Beck and Olsen 1977). During an "average" year, Downs (1949) recorded an average yield of 0.4 kg/tree for chestnut oaks that were 25.4 cm dbh and 4.9 kg/tree for trees 76.2 cm dbh. He also noted a strong positive correlation between chestnut oak yields and dbh. Because old growth Appalachian forests contain trees of all ages (Lorimer 1976), I assumed that the majority of mature trees on Woodland period Havens were evenly distributed between 25.4 and 76.2 cm dbh. According to Downs (1949), these chestnut oaks would have produced 3.1 kg/trees during an "average" year. Chestnut oaks between 13 and 25.4 cm dbh usually produce less acorns than trees greater than 25.4 cm dbh (Downs and McQuilkin 1944). Trees greater than 76.2 cm dbh generally produce more acorns than trees less than 76.2 cm dbh (Downs and McQuilkin 1944). I assumed that these gaps in Downs' (1949) data cancel each other out. Therefore, I adopted a 3.1 kg/tree estimate without adjustment. This would have resulted in the production of 536,244 kg of chestnut oak acorns during a moderate yield year.

White oak production also fluctuates considerably. Downs and McQuilkin (1944) and Beck and Olsen (1977) have recorded "bumper" crops at four-year intervals, with alternating poor and moderate crops in the intervening years. Assuming an equal diameter distribution, white oaks 25.4-76.2 cm dbh produce 3.0 kg/tree during an "average" year (Downs 1949). White oak acorn production declines in trees that are greater than 76.2 cm dbh (Downs and McQuilkin 1944). Therefore, I used a slightly lower average yield of 2.7 kg/tree. The 40,485 white oaks would have produced 109,310 kg of acorns during a moderate yield year. Combining the acorn production of chestnut oaks and white oaks resulted in a sweet acorn crop of 645,554 kg.

Only a small percentage of the sweet acorn crop would have been available to humans. Studies have shown that only 46% of acorns that reach the ground are mature or undamaged by insects and wildlife (Downs and McQuilkin 1944). Once on the ground, acorns are consumed by nut weevils, moth larvae, gall-forming cynipids and 186 species of birds and mammals (Downs and McQuilkin 1944). These animals may damage or eat 57% to 100% of the sound acorns (Keene 1981; Reidhead 1981). Therefore, the percentage of acorns available to humans is between 0 and 20% of the total crop (64,555 kg) as a measure of acorn availability. Since 35% of an acorn is inedible (Reidhead 1981), 41,961 kg could have been consumed by the Havens foragers.

Dry sweet acorn meat contains approximately 84% neutral detergent solubles (Servello et al. 1987). I estimated the percentage of fat in sweet acorn meat by averaging the results of Lund and Sandstrom's (1943), Wainio and Forbes' (1944), Smallwood and Peters' (1986), and Servello and Kirkpatrick's (1988) ether extract analyses of chestnut oak and white oak acorn meats. This resulted in a fat content of 7.9%. Metabolizable energy was calculated by following the procedure outlined on pp. 70-71. The result was 3.755 kcal ME/g. Fresh sweet acorn meats contain 51.3% water (Wainio and Forbes 1944; Goodrum et al. 1971; Burns and Viers 1973). Thus, these nuts have 1.829 kcal ME/g on a wet weight basis and the annual sweet acorn crop could have provided humans with 76,747,000 kcal ME.

Summary cost data for sweet acorn meat (wet weight) on Havens

Season	Hours/Kg Fresh	Hours/ 1000 Kcal ME Fresh	Hours/Kg Stored	Hours/ 1000 Kcal ME Stored
Fall	5.44	2.97	5.74	3.14

Acorn-gathering experiments by Petruso and Wickens (1984) revealed that 0.31 hours are required to gather sufficient acorns to produce 1 kg of sweet acorn meat. Experiments simulating the prehistoric shelling of sweet acorns with hammerstones and stone slabs have revealed that 5.1 hours are required to produce 1 kg of nut meat (Petruso and Wickens 1984). When a search and transportation cost of 0.03 hours/kg was added to the collection and processing costs, the total cost of producing 1 kg of sweet acorn meat was 5.44 hours. Because there are 1,832 kcal ME in each kg of sweet acorn meat, the cost was transformed into 2.97 hours/1000 kcal ME.

Based on Reidhead's (1981) labor estimates to sun-dry plant foods, I adopted a storage preparation cost of 0.1 hours/kg for sweet acorns and all other nut crops in this model. An additional 0.2 hours/kg was added to cover the cost of storage vessel construction. The resulting 0.3 hours/kg storage cost was adopted for all subsequent nut resources in this study. The stored cost of sweet acorns would have been 5.74 hours/kg or 3.06 hours/1000 kcal ME. A seasonal storage loss of 10% due to rodents, insects, and spoilage was subtracted from the available harvest in each subsequent season. This storage loss was adopted for all plant resources in this study.

Summary harvest data for bitter acorns (wet weight) on Havens

Season	No. Trees	Edible Biomass/ Tree (kg)	% Available	Edible Yield (kg)	Kcal ME/Kg	Kcal ME Available
Fall	97,164	2.01	10.0	19,579	2,948	57,719,000

I estimated that there were 97,164 trees producing bitter acorns on Woodland period Havens. Northern red, scarlet, and black oaks generally produce "bumper" crops at five-year intervals, with two years of failure and two years of moderate crops between the bumper crops (Downs and McQuilkin 1944; Beck and Olsen 1977). During moderate yield years, black, northern red, and scarlet oaks that are 25.4-76.2 cm dbh produce an average of 3.1 kg/tree (Downs 1949). I adopted this estimate for bitter acorn production on Woodland-period Havens. This resulted in a 301,208 kg bitter acorn crop during a moderate yield year. Bitter acorns experience approximately the same percentage of crop loss (90%) due to insects, wildlife, and immaturity as sweet acorns (Downs and McQuilkin 1944; Keene 1981). With 65% of the total crop edible, 19,579 kg would have been available for human consumption.

Dry bitter acorn meat contains approximately 91.4% neutral detergent solubles (Servello et al. 1987). I estimated the percentage of fat in bitter acorn meat by averaging the results of Lund and Sandstrom's (1943), Wainio and Forbes' (1944), National Academy of Science (1972), and Servello's (1985) ether extract analyses of black oak and northern red oak acorn meats. This resulted in a 22.6% fat estimate. Metabolizable energy was calculated by following the procedure outlined on pp.

70-71, the result was 4.785 kcal ME/g. Fresh bitter acorn meats contain 38.4% water (Wainio and Forbes 1944; Burns and Viers 1973). Thus on a wet weight basis these nuts have 2.948 kcal ME/g. and the annual bitter acorn crop could have provided humans with 57,719,000 kcal ME.

Summary cost data for bitter acorn meat (wet weight) on Havens

Season	Hours/Kg Fresh	Hours/ 1000 Kcal ME Fresh	Hours/Kg Stored	Hours/ 1000 kcal ME Stored
Fall	1.46	0.50	1.76	0.60

Bitter acorns are less costly to collect than sweet acorns. Not only are they larger, but they do not sprout early, enabling the gatherer to delay harvest until the entire crop is on the ground (Reidhead 1981). Petruso and Wickens (1984) found they could collect sufficient acorns to produce 1 kg of acorn meat in 0.12 hours. I adopted this gathering rate for the Havens foragers. Reidhead (1981) and Petruso and Wickens (1984) shelled and pulverized 1 kg of bitter acorn meat with stone implements in 1.13 and 1.19 hours, respectively. The average of these 2 rates (1.16 hours/kg) was used in this study. Historically, Indians removed the bitter taste of red, scarlet, and black oak acorns by leaching out the tannic acid (Swanton 1946). This was accomplished by either boiling the acorn meats with wood ashes or placing the pulverized meats in cane sieves and running cold water over them (Swanton 1946). Reidhead (1981) simulated the latter leaching practice, and found that 0.15 hours were required to leach 1 kg of acorns. Summing up procurement and processing costs and a 0.03 hours/kg search and transportation cost resulted in a total cost of 1.46 hours/kg. Because there are 2,948 kcal ME in each kg of bitter acorn meat, the cost was translated to 0.50 hours/1000 kcal ME. A storage cost of 0.3 hours/kg produced a 0.60 hours/1000 kcal ME cost for stored bitter acorns.

Blueberries/Huckleberries

Summary harvest data for blueberries/huckleberries (wet weight) on Havens

Season	No. Shrubs	Edible Biomass/ Shrub (kg)	% Available	Edible Yield (kg)	Kcal ME/Kg	Kcal ME Available
Summer	20,213,320	0.41	5.0	416,900	665	277,239,000

Blueberry (*Vaccinium* spp.) and huckleberry (*Gaylussacia* spp.) plants were shrub layer dominants in old-growth oak chestnut forest in the central and southern Appalachians (Braun 1950; Keever 1953; Strahler 1972). Keever's (1953) study of virgin oak-chestnut forest in Macon County, North Carolina revealed 6,920 huckleberry and blueberry plants/ha. Based on this estimate, there would have been 20,213,320 huckleberry and blueberry plants on Woodland-period Havens.

After an extensive review of the blueberry literature, I was unable to find any reference to wild blueberry and huckleberry yields. The average yield of commercial highbush and lowbush varieties of blueberries is between 2.2 and 5.5 ℓ/mature plant (Stiles and Abdalla 1966; Stiles and Bailey 1966). Personal observations of huckleberry and blueberry plant yields led me to conservatively adopt a 0.5 ℓ/plant estimate for Woodland-period Havens. According to Charles Odell (pers. comm.), horticultural extension specialist at VPI and SU, there are approximately 825 g in 1 ℓ of wild blueberries and huckleberries. Thus the huckleberry and blueberry plants on Havens would have produced 8,338,000 kg of fruit each year. Due to the short length of time that this crop is available and numerous animal consumers, I assumed that only 5% of the total crop (416,900 kg) would have been available to the Havens foragers.

I was unable to find any nutrient composition data on huckleberries. Therefore, the following estimates are based solely on the common highbush blueberry (*Vaccinium corymbosum*), tree deerberry (*Vaccinium stamineum*), and farkleberry (*Vaccinium arboreum*). Dry wild blueberries contain 64.1% neutral detergent solubles (Short and Epps 1977). I estimated the percentage of fat in blueberries/huckleberries by averaging the results of Wainio and Forbes' (1944), Spinner and Bishop's (1950), and Bonner's (1971) ether extract analyses. The result was a 5.1% fat estimate. Metabolizable energy was calculated following the procedure described on pp. 70-71. The result was 2.819 kcal ME /g on a dry weight basis. Fresh wild blueberries contain 84.3% water (Wainio and Forbes 1944) and huckleberries contain 68.5% water (Burns and Viers 1973). I adopted the average of these two estimates, 76.4% water. Thus, fresh blueberries and huckleberries would have had 0.665 kcal ME /g. The potential annual harvest could, therefore, have furnished 277,239,000 kcal ME .

Summary cost data for blueberries/huckleberries (wet weight) on Havens

Season	Hours/Kg Fresh	Hours/ 1000 Kcal ME Fresh	Hours/Kg Stored	Hours/ 1000 kcal ME Stored
Summer	0.48	0.72	0.70	1.05

The mean collection rate of Dewey Griffey (pers. comm.), Lawton Brooks (pers. comm.), and Stanley Hicks (pers. comm.) was 0.45 hours/kg, I adopted this rate for the Havens foragers and added a search and transportation cost of 0.03 hours/kg. Thus the total cost for fresh blueberries/huckleberries would have been 0.48 hours/kg or 0.72 hours/1000 kcal ME. Native peoples of eastern North America generally sun-dried blueberries and huckleberries prior to storage (Keene 1981). Reidhead's (1981) observations of plant food drying among the Otavalo of Ecuador indicated that 0.02 hours/kg are necessary to sun-dry fruits and berries for storage. I adopted this rate and added a storage vessel production cost of 0.2 hours/kg. The resulting cost for stored blueberries and huckleberries would have been 0.70 hours/kg or 1.05 hours/1000 kcal ME.

Chestnuts

Summary harvest data for chestnuts (wet weight) on Havens

Season	No. Trees	Edible Biomass/ Tree (kg)	% Available	Edible Yield (kg)	Kcal ME/Kg	Kcal ME Available
Fall	216,411	5.42	10.0	117,252	1,905	223,365,000

I estimated that there were 216,411 mature chestnut trees on Woodland period Havens. The virtual eradication of the American chestnut by the chestnut blight occurred before the mast yield of this species was determined. To estimate the mast production of the American chestnut, I obtained yield-related data from (1) publications on commercial chestnut (*Castanea* spp.) orchards, (2) individuals who harvest chestnuts from American chestnut orchards in Michigan and Wisconsin, (3) an examination of the bur crop of a large original survivor in Virginia of the chestnut blight, (4) interviews with people who collected chestnuts in the Appalachians prior to the blight, and (5) an interview with an individual who harvests chestnuts from American chestnut trees that presently grow in beech-maple forest in Michigan.

Because yield data were obtained from a variety of sources, I did not estimate American chestnut production by calculating the mean yield of the five sources. Instead, the context of each data source was used to narrow the range of values from which a yield estimate could be selected.

The yield data from sources 1,2, and 4 were typically expressed in bushels. To convert bushels to kilograms, I developed a conversion factor based on the weight to volume ratio of American chestnuts. This ratio was established by filling a 500 ml graduated cylinder with chestnuts (seed and shell) obtained from the VPI and SU Plant Pathology Physiology and Weed Science Department. The nuts were then removed and weighed. This procedure was repeated 5 times. The result was an 18.36 kg/bu estimate ($s^2 = 0.48$). This value is not substantially different from Toumey and Korstan's (1942) 20.4-22.7 kg/bu estimate.

1. Commercial orchard data

Commercial chestnut orchards were first planted in the United States during the late 19th century (Davis 1912). These early orchards typically contained European chestnuts (*Castanea sativa*) saplings grafted to American chestnut rootstock. At the Sober Farm in Pennsylvania, 12-year old grafted trees annually averaged 6.0 kg of nuts/tree (Davis 1912). Taylor and Gould (1914) reported the nut yield of a single tree--the Boone Chestnut, an American chestnut--Japanese chestnut, (*Castanea crenata*) cross--for a 17-year interval. This tree produced 0.5 kg at 2 years, 2.7 kg at 5 years, 14.1 kg at 10 years, 36.3 kg at 15 years, and 63.5 kg at 17 years. More recently, an orchard of 27-year old Chinese chestnuts (*Castanea mollissima*) in Cordele, Georgia produced 1.87 kg nuts/tree (Payne 1978). An experimental planting of Chinese chestnut trees in Byron, Georgia, yielded 5.2 kg nuts/tree at 10 years (Payne 1978). The preceding information indicated that young chestnut trees can potentially produce substantial mast crops. However, with low competition for light and nutrients, the mast crops of orchard-grown trees would be expected to be markedly higher than forest trees of the same age. I viewed the yields of these commercial trees as upper mast production limits for comparable American chestnut trees in a forested environment.

2. Midwest orchard data

Although the western limit of the American chestnut's native range is extreme southeastern Michigan (Thompson 1969; Brewer 1982), early settlers planted chestnuts throughout the midwest. Today, in Michigan alone, there are 224 documented locations of American chestnut trees (Brewer 1982). I interviewed several individuals from Michigan and Wisconsin who regularly harvest chestnuts from some of these trees and their progeny.

George Unger (pers. comm.) harvested chestnuts from a 50-tree, 120-year old American chestnut orchard in Grand Haven, Michigan for over 70 years. Between 1920 and 1940, Unger's (pers. comm.) average annual harvest was 1700 kg (34 kg/tree). Unger (pers. comm.) estimated that an additional 570 kg were consumed by wildlife. Thus the total mast yield/tree would have been 45 kg.

The Wexford Soil and Water Conservation District collects nuts from a grove of seven large American chestnut trees in Benzie County, Michigan. These open-grown trees are approximately 130 years old and have an average dbh of 92.3 cm and an average height of 19.2 m (Rick Deuell, soil conservationist, pers. comm.). Rick Deuell (pers. comm.) stated that in 1987, 136 kg of chestnuts were harvested from these trees, representing an estimated 50% of the total mast crop. Thus, annual mast production would have been 39 kg/tree.

In Galesville, Wisconsin, Phil Lunde (pers. comm.) collects chestnuts from a shelterbelt composed of 40 American chestnut trees. These trees have an average dbh of 91 cm and an average height of 21 m and are believed to be older than 100 years (Phil Lunde, pers. comm.). Lunde (pers. comm.) annually collects 3 kg/tree and estimated that at least 50% of the total crop is consumed by wildlife. Lunde (pers. comm.) also collects chestnuts from the progeny of the shelterbelt trees. These trees have an average dbh of 22.9 cm and furnish Lunde (pers. comm.) with 4 kg of nuts/tree.

In Benzonia, Michigan, two open-grown American chestnut trees with an average dbh of 40.6 cm have an annual mast yield of 9 kg/tree (Arthur Hart, pers. comm.). Two smaller open-grown American chestnut trees in Manistee County, Michigan ($\overline{X}$ dbh = 16.5 cm, $\overline{X}$ ht = 6.1 m) produced 11.3 kg/tree in 1987 (Rick Deuell, pers. comm.).

The annual mast yield of large (> 90 cm dbh), mature open-grown, American chestnut trees in Michigan and Wisconsin ranged from 6 to 45.4 kg/tree while trees between 16.5 and 40.6 cm dbh produced 8-11.3 kg/tree. Though the sample size was small, the low yield of the mature Lunde trees appeared to be an outlier. Because these trees grow in a shelterbelt, mast production would be expected to be lower than orchard trees which would probably have larger crowns. In addition, spring freezes often damage chestnut flowers and reduce the mast crop of the Lunde trees (Phil Lunde, pers. comm.). Late spring freezes that damage the Michigan chestnut trees are rare (Hart, pers. comm.; Deuell, pers. comm.; Unger, pers. comm.). In the central and southern Appalachians, American chestnut trees bloom in mid-June when there is no danger of frost. Therefore, the 39-45.4 kg/tree yield of the large mature Michigan chestnuts should more accurately represent the potential production of comparable open-grown trees in the Appalachians.

3. Amherst Chestnut data

The largest original survivor of the chestnut blight in its native range is the Amherst Chestnut. Located in Amherst County, Virginia, this 150-year old, open-grown tree has a 106.7 cm dbh and height of 20.1m. This tree is infected with the blight, but approximately 70% of the crown remains blight-free each year (Griffin et al. 1983). The Amherst Chestnut does not produce nuts because there are no mature chestnut trees nearby to fertilize this tree. However, the Amherst Chestnut does produce burs. The number of burs is believed to be an accurate indicator of potential nut yield (Gary Griffin, chestnut specialist, pers. comm.). There are three nuts in a typical chestnut bur. According to Griffin (pers. comm.), approximately 10% of burs have only two nuts. Thus, I adopted a 2.9 nut/bur estimate for the Amherst Chestnut.

In November, 1987, burs were concentrated in 270m^2 beneath the Amherst Chestnut. A 30m^2 plot with a representative bur distribution was selected, and the burs within were counted. This plot contained 1200 burs. Thus I estimated that this tree produced 10,800 burs in 1987. Based on the 2.9 nuts/bur estimate, there would have been 31,320 nuts.

To estimate the weight of this crop, American chestnuts obtained from the VPI and SU Plant Pathology Department were weighed. The mean wet nut weight (with shell) was 3.83 g (n=35). This figure corresponds with Touney and Korstian's (1942) 2.80-4.54 g estimate and Jayne's (1984) 2.6-6.0 g ("common weight" =3.5 g) estimate. Based on 3.83 g/nut, the Amherst Chestnut would have produced 120 kg of chestnuts in 1987. I believe a mast crop of this magnitude represents the upper production limit of an open-grown American chestnut.

4. Appalachian elder data

Five individuals who harvested chestnuts prior to the blight in Madison, Cherokee, Wautauga, and Graham Counties of western North Carolina were interviewed to estimate the yield of a "typical," mature, forest-grown American chestnut. They provided estimates that led to a mean yield of 21.8 kg/tree (σ^2 = 6.9). These individuals stated that, unlike oaks and hickories, chestnut crops were relatively stable. Noel Moore gathered chestnuts in the mountains of north Georgia and stated that "almost every year was a good year for chestnuts" (Rice et al. 1980).

Although I asked for the yield of a *typical* forest-grown American chestnut, these individuals probably based their estimates solely on trees that they harvested. Thus I believe the 21.8 kg/tree estimate represents the average yield of chestnut trees that were superior mast producers.

5. Recent forest-grown chestnut data

There are several tracts of beech-maple forest in Michigan that contain large, mature American chestnut trees (Larry Brewer, botanist, pers. comm.). These trees originated from nuts that were produced in local chestnut orchards and dispersed by wildlife. John Williams (pers. comm.) has been harvesting chestnuts from one of these stands in Manistee County, Michigan for the past 13 years. Williams (pers. comm.) observed annual fluctuations and provided mast estimates for low and high yield years by dbh class. Williams (pers. comm.) estimated mast yields of 1.1-2.7 kg/year, for 30 cm dbh trees, 6.1-11.4 kg/year, for 61 cm dbh trees, and 9.1-18.1 kg/tree for 90 cm dbh trees.

I believe Williams' (pers. comm.) estimates best represent the mast production of mature forest-grown Appalachian chestnut trees. The trees from which he collects have crowns that are similar in size and structure to chestnut trees in pre-blight Appalachian forests. Unlike the Appalachian elders, Williams (pers. comm.) harvests chestnuts from every tree in a given tract, so his estimates are probably not biased toward superior mast-producers. Consequently, I conservatively estimated that an average mast-producing chestnut would have annually yielded 7.0 kg/tree. Thus, the 216,411 chestnuts on Woodland Period Havens would have produced 1,514,877 kg of nuts annually. Approximately 22.6% of the wet weight of a chestnut is from shell (Diamond et al. in prep.). The edible biomass of the chestnut crop would have been 1,172,515 kg.

Only a portion of the chestnut crop would have been available to humans. Martin et al. (1951) noted that prior to the invasion of *Endothia parasitica* the chestnut was one of the most important wildlife food plants in the eastern United States. Numerous wildlife species consumed large quantities of chestnuts, including white-tailed deer, eastern wild turkey, ruffed grouse, gray squirrel, eastern cottontail, and eastern chipmunk (*Tamias striatus*) (Martin et al. 1951; Rice et al. 1980). In addition, insects such as the chestnut weevil (*Curculio spp.*) also fed on chestnuts (Payne 1978). The extent of chestnut consumption by animals and insects has not been quantified. I estimated that 10% of the total crop, 117,252 kg, was available to the Havens foragers.

Dry chestnut meat contains 74.8% neutral detergent solubles and 12.2% fat (Diamond et al. in prep.). Metabolizable energy was calculated by following the procedure outline on pp. 70-71. The result was 3.602 kcal ME/g, dry weight. Fresh chestnut meat contains 47.1% water and thus furnishes 1.905 kcal ME/g on a wet weight basis (Diamond et al.). Thus, 223,365,000 kcal ME would have been available to the Havens foragers.

Summary cost data for chestnut meat (wet weight) on Havens

Season	Hours/Kg Fresh	Hours/ 1000 Kcal ME Fresh	Hours/Kg Stored	Hours/ 1000 kcal ME Stored
Fall	0.48	0.25	0.78	0.41

Cost estimates of chestnut gathering were obtained from interviews with older people (n=7) of the Appalachians. The mean collection cost for 1 bushel was 1.7 hours. This estimate was converted to 0.09 hours/kg based on the previously established 18.36 kg/bushel. Approximately 22.6% of the weight of a chestnut is from shell (Diamond et al. in prep.) Taking this into account, 0.13 hours would have been required to collect enough chestnuts to secure 1 kg of nut meat. In the 19th and 20th century, Appalachian people hulled chestnuts with knives (Griffey, pers. comm.; Raper, pers. comm.; Hicks, pers. comm.). The mean hulling estimate obtained from the aforementioned individuals was 0.19 hours/kg of nut meat. I assumed that flint knives were used by the Havens foragers to hull chestnuts. It is probable that these implements were less efficient than metal knives. Therefore, I increased the hulling cost by 75% to 0.33 hours/kg. With the addition of a 0.03 hour/kg search and transportation cost, the total cost to procure and process chestnuts was 0.48 hours/kg or 0.25 hours/1000 kcal ME. A storage cost of 0.3 hours/kg produced a stored cost of 0.41 hours/1000 kcal ME (0.78 hours/kg).

Hickory Nuts

Summary harvest data for hickory nut seeds (wet weight) on Havens

Season	No. Trees	Edible Biomass/ (kg)	% Available	Edible Yield Tree (kg)	Kcal ME/Kg	Kcal ME Available (kg)
Fall	31,652	0.93	10.0	2,944	4,520	13,307,000

I estimated that there were 31,652 mature hickories on Woodland-period Havens. The only long-term study on the yields of hickories is Nixon et al.'s (1980) work in southeastern Ohio. Between 1972 and 1977, Nixon et al. (1980) estimated the yield of pignut (*Carya glabra*), shagbark (*C. ovata*), and mockernut (*C. tomentosa*) hickories, species that would have dominated the hickory component of the Woodland period forest on Havens. The pignut hickories were 19.3-48.8 cm dbh ($\bar{x}=35.5$ cm dbh) and 44-155 years old ($\bar{x}=92$ years old). The shagbark hickories were 20.6-45.7 cm dbh ($\bar{x}=30.0$ cm dbh) and 42-131 years old ($\bar{x}=77$ years old). The mockernut hickories were 19.1-43.9 cm dbh ($\bar{x}=31.0$ cm dbh) and 44-113 years old ($\bar{x}=69$ years old).

Like oaks, the annual yield of hickories varies considerably (Nixon et al. 1980; Sork 1983). During Nixon et al.'s (1980) 6-year study, there were 2 high, 2 moderate, and 2 low seed production years that were coincident for all species. I used data from one of the moderate production years (1975) to develop a hickory yield estimate for this study. In 1975, pignut hickories produced 360 filled seeds/tree. According to Nelson (1961), pignut hickory seeds average 2.27 g. Based on this estimate, 0.82 kg were produced per tree. In good years, pignut hickories produced 1.0 kg/tree in good years and in poor years, 0.12 kg/tree (Nixon et al. 1980). In 1975, shagbark hickories produced 105 filled seeds/tree. According to Nelson's (1961) 4.54 g/seed estimate, there would have been 0.48 kg/tree. In good years, mockernut hickories produced

1.66 kg/tree and in poor years, 0 kg/tree (Nixon et al. 1980). In 1975, mockernut hickories averaged 295 filled seeds/tree (Nixon et al. 1980). Following Nelson's (1959) 5.04 g/seed estimate, there would have been 1.49 kg/tree. Mockernut hickories produced 1.56 kg/year in good years and 0.17 kg/tree in poor years.

Since my reconstruction of the Havens forest does not contain a species level breakdown of the hickory component, I averaged the 1975 yields for the three species to obtain a hickory seed production estimate. The result was 0.93 kg/tree. Therefore, 29,436 kg of filled seeds would have been produced on Havens during a moderate yield year. Numerous wildlife species and the hickory nut curculio (*Conotrachelus affinis*) would have consumed a substantial portion of the annual yield. I estimated that 10% of the total crop (2,944 kg) would have been available to the Havens foragers.

Dry hickory nut meat contains approximately 81% neutral detergent solubles and 65.5% fat (Short and Epps 1977). Metabolizable energy was calculated following the procedure described on pp. 70-71. The result was 6,507 kcal ME/g. Fresh hickory nut meat contains 30.5% water (Burns and Viers 1973). Thus, these nuts have 4.520 kcal ME/g on a wet weight basis. The annual hickory nut crop would have provided the Havens foragers with 13,307,000 kcal ME.

Summary cost data for hickory nut seeds (wet weight) on Havens

Season	Hours/Kg Fresh	Hours/ 1000 kcal ME Fresh	Hours/Kg Stored	Hours/ 1000 kcal ME Stored
Fall	2.91	0.64	3.21	0.71

Timed collections of shagbark hickory, mockernut hickory, and bitternut hickory nuts have revealed that nuts producing 1.0 kg of nut meats can be collected and hulled in 0.71 hours (Talalay et al. 1984). However, these collections were made from field grown trees in open pastures. These trees would likely have produced exceptionally high nut densities. Moreover, the grass pasture would have provided a higher quality gathering substrate than forest litter. Therefore, I reduced the collection and hulling rate by 40% to 0.99 hours/kg.

Bartram (1791) has provided a detailed account of the preparation of hickory nuts by the Creek Indians in Georgia. Large quanitities of whole nuts were pounded into small pieces (Bartram 1791). Although not specified, Reidhead (1981) believed that wooden mortars and pestles were used. The shattered nuts were placed in boiling water that was then poured through "fine strainers" (Bartram 1791). The nut meat that floated to the top was collected and the oily water (hickory milk) was consumed as a beverage. Reidhead (1981) based a simulation experiment on this account. Using a wooden mortar and pestle, Reidhead (1981) crushed enough whole nuts to produce 1 kg of meat and oil in 1.47 hours. Boiling and straining the crushed nuts and skimming the oil required an additional 0.4 hours/kg, bringing the total processing cost to 1.87 hours/kg. The addition of collection costs and a 0.05 hour/kg search and transportation cost resulted in a total cost of 2.91 hours/kg (0.64 hours/1000 kcal ME). To store 1 kg of hickory nuts would have cost 0.3 hours. This resulted in a stored cost of 0.71 hours/1000 kcal ME.

Table 4. Characteristics of food-producing trees and shrubs on Woodland-period Havens -- summary data.

Taxon	Yield/ Plant (kg)	% Refuse	Edible Biomass/Plant (kg)	% Available	Edible Yield (kg)	Kcal ME/ Kg	Kcal ME Available[4]
Blueberry/Huckleberry	0.41	0.0	0.41	5.0	416,900	665	277,239,000
Chestnut	7.00	22.6	5.42	10.0	117,252	1,905	223,365,000
Hickories[1]	2.27	41.0	0.93	10.0	2,944	4,520	13,307,000
Sweet Oaks[2]	2.70	35.0	1.97	10.0	41,961	1,829	76,747,000
Bitter Oaks[3]	3.00	35.0	2.01	10.0	19,579	2,948	57,719,000

[1] Pignut hickory, mockernut hickory, and shagbark hickory.

[2] Chestnut oak and white oak.

[3] Northern red oak, scarlet oak, and black oak.

[4] Estimates based on moderate yield years.

Tubers

Although the herbaceous layer of old-growth oak-chestnut forest is generally low in diversity and biomass, several species of edible tubers are present including, Solomon's seal (*Polygonum biflorum*), false Solomon's seal (*Smilacena racemosa*), Indian cucumber (*Medeola virginiana*), greenbrier (*Smilax* spp.), and Jack-in-the-pulpit (*Arisaema triphylum*). However, given the habitat requirements and distributional patterns of these species, only Jack-in-the-pulpit and false Solomon's seal would have been available in sufficient quantities to permit intensive harvesting (Thorne and Cooperider 1960; Justice and Bell 1968).

Jack-in-the-pulpit

Summary harvest data for Jack-in-the-pulpit corms (wet weight) on Havens

Season	No. Plants	Wet Weight (g)	% Available	Edible Yield (kg)	Kcal ME/ kg	Kcal ME Available
Spring and Summer	47,424	17.4	15.0	124	934	116,000

Jack-in-the-pulpit is found in low woods that are at least moderately moist. Today this species is primarily restricted to the forest immediately adjacent to Mason's Creek at the base of Ft. Lewis Mountain. I assumed that this distribution was present during the Woodland period. Thus, Jack-in-the-pulpit habitat would have been restricted to approximately 32 ha. Keene (1981) indicated that where

Jack-in-the-pulpit is moderately abundant, there are 1,482 plants/ha. Based on this estimate, 47,424 Jack-in-the-pulpits were present on Woodland period Havens.

My observations of Jack-in-the-pulpit colonies have indicated that approximately 50% of the plants are large enough to harvest. I estimated that 30% of these plants could be annually removed on a sustained yield basis. Thus 7,114 plants would have been annually available to the Havens foragers. These plants would have only been visible during the spring and summer.

Weights from 30 Jack-in-the-pulpit corms collected in late spring furnished a mean wet weight of 17.4 gm. Adoption of this mean weight resulted in a 124 kg resource. Dry corms contained 84.8% neutral detergent solubles and 0.7% fat. Metabolizable energy was calculated following the procedure described on pp. 70-71. The result was 3.422 kcal ME/kg, dry weight. Fresh jack-in-the-pulpit corms contained 72.7% water. Thus fresh corms had 0.934 kcal ME/g. Jack-in-the-pulpits would, therefore, have represented a 116,000 kcal ME resource.

False Solomon's Seal

Summary cost data for Jack-in-the-pulpit corms (wet weight)

Season	Hours/Kg Fresh	Hours/ 1000 Kcal ME Fresh	Hours/Kg Stored	Hours/ 1000 Kcal ME Stored
Spring and Summer	0.83	0.89	1.05	1.12

Dewey Griffey (pers. comm.), a professional plant collector for over 40 years, stated that he could dig 100 Jack-in-the-pulpits/hour with a mattock. Due to the greater efficiency of a steel-bladed mattock over a wooden digging stick or stone hoe, I adopted a harvest rate of 80 corms/hour (0.71 hours/kg). Search and transportation time would have been minimal due to the plant's concentration along Mason's Creek. I added an additional 0.02 hours/kg for search and transportation, which resulted in a total procurement cost of 0.73 hours/kg.

Calcium oxalate crystals make raw Jack-in-the-pulpit corms unpalatable. However, thorough drying modifies the crystal and, according to Gibbons (1966), removes the unpleasant taste and produces a delicious food. I estimated that the amount of time required to clean and dry 1 kg would have been 0.1 hours. This increased the total cost to 0.89 hours/1000 kcal ME (0.83 hours/kg). A storage preparation cost of 0.02 hours/kg plus a 0.2 hours/kg storage vessel construction cost resulted in a stored cost of 1.05 hours/kg or 1.12 hours/1000 kcal ME.

Summary harvest data for false Solomon's seal rhizomes (wet weight) on Havens

Season	No. Plants	Dry Weight (g))	% Available	Edible Yield (kg)	Kcal ME/ kg	Kcal ME/ Available
Spring and Summer	420,000	9.0	22.5	19,076	800	15,261,000

In virgin oak-chestnut forest stands in Macon County, North Carolina, Keever (1953) recorded a false Solomon's seal density of 3,225/ha. This estimate was used in this study, resulting in a 9,420,000 plant population. My observations led me to conclude that 75% of false Solomon's seals have a rhizome that is large enough to harvest. I assumed that 30% of these plants could have been harvested annually on a sustained basis. Thus 2,120,000 plants could have been annually collected by the Havens foragers.

False Solomon's seal rhizomes weighed 9.0 g (n = 15). Based on this weight, there would have been a potential harvest of 19,076 kg. Dry false Solomon's seal rhizomes contained 76.8% neutral detergent solubles and 0.1% fat. Metabolizable energy was calculated following the procedure described on pp. 70-71. The result was 3.052 kcal

ME/g. Fresh false Solomon's seal rhizomes contained 73.8% water. Thus fresh rhizomes furnished humans with 0.800 kcal ME/g. The false Solomon's seal harvest could, therefore, have provided 15,261,000 kcal ME.

Summary cost data for false Solomon's seal rhizomes (wet weight) on Havens

Season	Hours/Kg Fresh	Hours/ 1000 Kcal ME Fresh	Hours/Kg Stored	Hours/ 1000 Kcal ME Stored
Spring and Summer	0.51	0.64	0.73	0.91

Dewey Griffey (pers. comm.) stated that he could dig 500 false Solomon's seal rhizomes/hour. In order to compensate for Griffey's technological advantage, I decreased his harvest rate by 20% to 400 rhizomes/hr (0.28 hours/kg). According to Kavasch (1979), the disagreeable taste of the false Solomon's seal rhizome can be removed by soaking the rhizomes in water that contains wood ashes for several hours. The rhizomes must then be boiled for 0.5 hours to remove the lye (Kavasch 1979). I estimated that this process would have required 0.2 hours/kg. When a search and transportation cost of 0.03 hours/kg was included, the total false Solomon's seal cost would have been 0.51 hours/kg (0.64 hours/1000 kcal ME). A total storage cost of 0.22 hours/kg resulted in a stored cost of 0.91 hours/1000 kcal ME.

Table 5. Characteristics of edible tubers from author's analyses of samples obtained from the Havens area.

Species	Mean Wet Weight (g)	Mean Dry Weight (g)	Plants/ha	% Available	Edible Yield (kg)	Kcal ME/ kg	Kcal ME Available
False Solomon's Seal	9.0	2.4	3,225	22.5	19,076	800	15,261,000
Jack-in-the-Pulpit	17.4	4.8	1,482[1]	15.0	124	934	116,000

[1] Restricted to 32 ha.

Table 6. Cost estimates for procuring and processing fresh plant resources and procuring and processing stored plant resources on Havens during the Early and Middle Woodland period.

Resource	Part	Hours/Kg Fresh[1]	Hours/1000 Kcal ME Fresh	Hours/Kg Stored[2]	Hours/1000 Kcal ME Stored
Blueberry/Huckleberry	Whole Fruit	0.48	0.72	0.70	1.05
Chestnut	Nut Meat	0.48	0.25	0.78	0.41
False Solomon's Seal	Rhizome	0.51	0.64	0.73	0.91
Hickories[3]	Nut meat	2.91	0.43	3.21	0.48
Jack-in-the-Pulpit	Corm	0.83	0.89	1.05	1.12
Sweet Oaks[4]	Seed	5.44	2.97	5.74	3.14
Bitter Oaks[5]	Seed	1.46	0.50	1.76	0.60

[1] Based on wet weight.
[2] Based on wet weight.
[3] Pignut hickory, mockernut hickory, and shagbark hickory.
[4] Chestnut oak and white oak.
[5] Northern red oak, scarlet oak, and black oak.

Animal Resource Estimates

Black Bear

Summary harvest data for black bear (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	70.67	70.0	49.470	6	297	3,704	1,100,000
Winter	71.55	66.0	47.220	5	236	2,819	665,000
Spring	52.67	61.0	32.130	6	193	1,343	259,000
Summer	61.97	66.0	40.900	6	245	2,806	687,000

Historical accounts of black bear in western Virginia indicate great abundance. The Spottswood expedition of 1716 killed bear daily, often 3 per day (Handley and Patton 1947). The 1671 Abraham Wood expedition reported observing and killing many bears in the western portion of the state (Handley and Patton 1947).

Stickley (1957) stated that large stands of mature, hard-mast producing trees maintain the highest bear densities in the Appalachians. Given the accounts of historical abundance and bear habitat requirements, I assumed that Woodland-period Havens would have supported a relatively high bear density.

Bear densities in Shenandoah National Park were reported to be between 1.0/km^2 and 1.5/km^2 (Carney 1985). In the Great Smoky Mountains National Park, bear densites of 1.7 to 11.8/km^2 have been recorded (Carlock et al. 1983). All of these densities are considered high. Since the habitat of Shenandoah National Park is similar to Havens, but with generally richer soils and greater biomass, I adopted a breeding density of 0.8 bear/km^2. Therefore, Early and Middle Woodland period Havens would have supported a breeding population of 23 bears.

Black bear litters range between 1 and 4 cubs, with 2-3 most common (Trippensee 1948). Carney (1985) reported a mean litter size of 2.0 for Shenandoah National Park. Stickley (1957) reported a mean litter size of 2.27 in Virginia. I used Carney's (1985) estimate because it was obtained by direct observation. Although female bears occassionally become sexually mature at 2 years, 3 years is more typical (Carney 1985). Mature females produce litters every other year (Carney 1985).

Given these population parameters and a 100:100 sex ratio (Carney 1985), I assumed that 4 female bears would have annually produced 8 cubs on Early and Middle Woodland period Havens. Adult mortality is extremely low in unexploited black bear populations. Unfortunately, there are no true unhunted populations in western Virginia from which to derive mortality estimates (males frequently leave Shenandoah National Park and often are killed by humans) (Carney 1985). However, mortality data on the female component of the Shenadoah National Park population are indicative of the mortality in unexploited black bear populations as females rarely leave the park (Carney 1985). This mortality estimate, approximately 8%/year (Carney 1985), was used in this study. I also assumed that there were no seasonal differences in mortality. Following these guidelines and Carney's (1985) 30% annual juvenile mortality estimate, there would have been 23 black bears on Havens at the beginning of winter. In spring, the population would have increased to 30. By early summer, the population would have dropped to 29 and in early fall there would have been 28 bears on Havens.

Carpenter (1973) has reported that 20% of the black bear population in Virginia can be annually harvested without reducing the population the next year. I adopted this estimate for all 4 seasons. Thus, 6 bears (5 adults or subadults and 1 cub) were harvestable in all seasons but winter, when 5 bears (5 adults or subadults) could have been harvested.

Carney (1985) indicated that 26% of the Shenandoah National Park black bear population was composed of subadults. Based on this estimate and reported weight differences between adults and subadults in the Shenandoah National Park (Garner 1986), males weighed 98 kg and females 63.2 kg in fall. Cubs weighed approximately 21 kg at this time (Stickley 1957). Based on White's (1953) 70% edible meat estimate, 297 kg of bear meat would have been available for humans. The mean winter weights were 85.8 kg for males and 57.3 kg for females. The total harvestable biomass would have been 358 kg. In winter, the percentage of edible meat is approximately 66% of total biomass (236 kg) (based on White 1953). The mean spring weight of black bears was 73.5 kg for males and 51.3 kg for females (Garner 1986). In Virginia, cubs weigh approximately 4 kg in mid-spring (Stickley 1957). Based on this information and a 61% edible meat estimate, 193 kg would have been available for human consumption. The summer weights of males and females increased to 85.9 kg and 58.1 kg (Garner 1986). In mid-summer, cubs weighed approximately 11.8 kg (Stickley 1957). The edible biomass for this season would have been 245 kg (66% edible meat estimate).

During the fall, caloric value (3,704 kcal ME/kg; all caloric densities of animal meat are on a wet weight basis) and net biomass (297) were assumed to be at their peaks. The potential harvest would have provided 1,100,000 kcal ME. Winter bear meat contained 2,819 kcal ME/kg and would have provided the Havens foragers with a 665,000 kcal ME resource. The caloric value of bear meat dropped to 1,343 kcal ME/kg in spring (Reidhead 1981), making 259,000 kcal ME available. In the summer, the potential harvest contained 687,000 kcal ME (2,806 kcal ME/kg x 245 kg). Caloric estimates were developed following the procedure described on pp. 73-74.

Summary cost data for black bear meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	62.85	--	1.27	--	0.34	--
Winter	41.95	61.39	0.89	1.31	0.32	0.46
Spring	79.35	--	2.46	--	1.83	--
Summer	53.90	--	1.32	--	0.47	--

There are few descriptions of aboriginal bear hunting in eastern North America. Accounts of winter bear hunts among the Creek, Alabama, and Natchez all state that once den trees were located, bears were driven out with fire. (Swanton 1946). During the spring, the Natchez searched the forest for claw marks on tree bark. If fresh marks were observed, hunters would imitate the cry of a bear cub to bring an adult within shooting range (Swanton 1946).

Based on these accounts, I assumed that the Havens foragers would have stalked bears in spring, summer, and fall. In winter, they would have searched for den sites. I also assumed that an atlatl-thrown spear was used to kill these animals.

The bear hunting cost estimate initially required that I determine the number of hours involved in fashioning an atlatl and spear. Larry Dean Olsen (pers. comm.) has made functional atlatls and spears with stone implements for over 20 years. He stated that a finished and durable atlatl required 6 hours to complete. Four distinct steps were necessary to make the spear's longshaft: (1) straighten and cure shaft (0.3 hours), (2) trim shaft (0.3 hours), (3) wrap nocked end (0.08 hours), (4) add feathers (0.5 hours). The total cost of longshaft construction would, therefore, have been 1.18 hours. The foreshaft required 1.8 hours to make: 0.5 hours to shape and flake a point, 0.5 hours to trim and cure the shaft, and 0.8 hours to dry, pound, and wrap sinew around the point and foreshaft (Olsen, pers. comm.) Olsen (pers. comm.) maintained that an atlatl and longshaft could easily survive 1 year's use while foreshafts are easily damaged when a shot is missed.

I assumed that to hunt bear, an individual would need 1 atlatl, 1 longshaft, and 2 foreshafts/bear each year. Based on the age and sex composition of the Havens band, there would have likely been 5 active hunters. To outfit this group for bear hunting, would have required 35.9 hours + 3.6 hours/bear.

To develop estimates of bear hunting cost, I interviewed James Krause, a wildlife biologist and black bear authority working at Shenandoah National Park. Krause's (pers. comm.) cost estimates were based on the assumptions that the Havens foragers had a substantial body of knowledge on black bear movements and seasonal habitat preferences. He also assumed the foragers were superior trackers. Krause (pers. comm.) believed that the extensive availability of hard mast in fall and the lack of alternate high preference food items would make locating a bear moderately difficult. He estimated that 40-45 hours would be required to come within 30 m of a bear. Based on this estimate, I adopted a fall search cost of 42.5 hours/bear. Krause (pers. comm) believed that high den tree densities in old-growth forest and the probable concentration of bear dens in specific locales would make winter the most efficient season to hunt bear. He estimated that 20-25 hours would be required to find a denned bear. Based on this estimate, I adopted a 22.5 hours/bear search time for the Havens foragers. The low activity level of black bears in spring led Krause (pers. comm) to estimate a 60 hours/bear search time. Due to the high activity level of bears during summer and their focus on berry patches, Krause (pers. comm.) believed that 25-35 hours would be required to come within 30 m of a bear. I adopted a 30 hours/bear search cost for the Havens foragers in the summer.

I added a 3 hour/bear tracking cost to account for the time necessary to track and dispatch a wounded bear. The time involved in hauling a bear carcass back to the base camp would have largely depended on the weight of the bear and the hauling distance. Based on interviews with bowhunters, I assumed that 1 person could have hauled a bear < 60 kg at a rate of 1.55 km/hour. Bears > 60 kg would have required 2 individuals. I used the distance between the geographic center of Havens and the base camp (4.83 km) as the mean distance that a bear carcass must be hauled. Thus 7.5 hours would have been required to transport a bear < 60 kg from the kill site to the Havens base camp while 15 hours would have been required for a bear > 60 kg. Since the Havens bear population was evenly divided between bears < 60 kg and bears > 60 kg, I adopted a transportation cost of 11.25 hours/bear. Larry Dean Olsen (pers. comm.) maintained that approximately 1 hour is required to skin, quarter, and rough-process a bear with stone tools. This estimate was adopted for the Havens foragers.

The total cost to procure and process 1 bear was calculated in the following manner. The atlatl and longshaft production cost was divided by the number of bear that could be obtained in a given season. This value (6.0 hours in fall, spring, and summer; 7.2 hours in winter) was added to the foreshaft production, search and procurement, tracking, transportation, and processing costs. This procedure resulted in total cost estimates of 62.85 hours/bear (1.27 hours/kg) in fall, 41.95 hours/bear (0.89 hours/kg) in winter, 79.35 hours/bear (2.46 hours/kg) in spring, and 53.9 hours/bears (1.32 hours/kg) in summer. These costs were converted to 0.34 hours/1000 kcal ME in fall, 0.32 hours/1000 kcal ME in winter, 1.83 hours/1000 kcal ME in spring, and 0.47 hours/1000 kcal ME in summer.

To prepare bear meat for storage, the flesh must be cut into thin strips and placed on wood drying racks in the sun or over a fire to dry (Olsen pers. comm.). According to Olsen (pers. comm.), this process (including rack construction) would take 10 hours/bear or 0.22 hours/kg for winter bear meat. With the addition of a 0.2 hours/kg storage vessel production cost, the cost of stored winter bear meat would have been 1.31 hours/kg or 0.46 hours/1000 kcal ME.

Box Turtle

Summary harvest data for box turtle (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Spring	0.75	16.7	0.125	8,763	1,095	1,110	1,215,000
Summer	0.75	16.7	0.125	8,763	1,095	1,110	1,215,000

Box turtle (*Terrapene carolina carolina*) densities of 17-22/ha near Knoxville, Tennessee, and 10/ha in Laurel, Maryland have been recorded (Ernst and Barbour 1972). I used the average of these two estimates, 15/ha in this study. This gave Woodland-period Havens a population of 43,815 box turtles. Reidhead (1981) estimated that 20% of a box turtle population can be consisistently removed annually. This would have made 8,763 turtles annually available to humans on Early and Middle Woodland-period Havens.

It is believed that box turtles yield 0.125 kg of useable meat per individual (Reidhead 1981). Therefore, the edible meat weight of the Havens box turtle population would have been 1,095 kg. Edible box turtle meat contains 1,110 kcal ME/kg througout the year (Reidhead 1981). Hence, box turtles would have provided 1,215,000 kcal ME each season. However, the seasonal activity pattern of box turtles make them almost exclusively available during the spring and summer.

Summary cost data for box turtle meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Spring	0.52	0.58	4.13	4.63	3.72	4.17
Summer	1.04	--	8.30	--	7.48	--

Box turtles can be most efficiently collected in spring, the season of of peak activity. I estimated that 2 turtles/hour could have been obtained during spring. This estimate included the time involved in the search, collection, and transportation of this resource. In summer, decreased availability increased the cost to 1.0 turtles/hour. Thus in the spring, 4.0 hours were required to procure 1 kg of useable turtle meat and in the summer 8.0 hours were required. In the early 18th century, Seminoles processed turtles by simply cutting off the plastron. The turtle was then roasted in its own shell (Swanson 1946). Based on this account, I estimated that 1 minute was required for plastron removal. The addition of the processing cost resulted in a total cost of 3.72 hours/1000 kcal ME (4.13 hours/kg) in spring. The summer cost of turtle meat would have been 7.48 hours/1000 kcal ME (8.30 hours/kg).

To store box turtle meat, the carcass should be pounded flat and placed in the sun or over a fire to dry (Olsen, pers. comm.). I assumed that this process would require 0.3 hours/kg. The addition of a 0.2 hours/kg storage vessel production cost resulted in a stored spring box turtle cost of 4.17 hours/1000 kcal ME (4.63 hours/kg).

Eastern Cottontail

Summary harvest data for eastern cottontail (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	1.25	60.0	0.750	657	493	2,258	1,113,000
Winter	1.25	60.0	0.750	657	493	2,258	1,113,000
Spring	1.16	57.0	0.661	358	236	1,350	319,000
Summer	1.16	57.0	0.661	358	236	1,350	319,000

The preferred habitats of eastern cottontail are early forest successional stages, dense brush, weed patches, swamps, and open woods (Trippensee 1948; Althoff 1983; Baker 1983). Lorimer (1976) revealed that southern Appalachian climax forests were likely all-aged with approximately 14% of the total land area in early successional stages (primarily due to windthrows). I adopted this percentage for Woodland-period Havens. However, the mass movement of rock and soils in the aftermath of severe rainstorms was probably the dominant mode of forest disturbance in the Ridge and Valley Province of Virginia (Hack and Goodlett 1960). Because 86% of Havens would not have been prime eastern cottontail habitat, I assumed that a relatively low density population was present. Eastern cottontail densities of 2/ha are considered high while 0.8/ha is considered moderate (Trippensee 1948). I adopted a mean annual density of 0.4/ha. Cottontail densities have been reported to be approximately 27% higher in the fall and winter than in the spring and summer (Smith 1975). Thus a mean annual density of 0.4/ha resulted in a fall-winter density of 0.45/ha and a spring-summer density of 0.35/ha. The fall-winter population would have been as 1,314 and the spring-summer population would have been 1,022.

Eastern cottontail populations can sustain annual harvests of approximately 50% (Chapman et al. 1982). This rate was adopted for the fall-winter population, allowing the removal of 657 cottontails. Since the population was believed to be more vulnerable in spring and summer, the potential harvest was reduced to 35% (358) of the spring-summer population.

Weights of eastern cottontails range from 0.8 kg to 1.8 kg (Chapman et al. 1980; Baker 1983). Matula (1983) found that central Pennsylvania males average 1.15 kg while females averge 1.26 kg. These estimates were used in this study. The weight of males does not appear to fluctuate seasonally (Chapman et al. 1977). However, the weight of females increases in fall, holds steady in winter, decreases in spring, and remains stable during the summer (Chapman et al. 1977). Since the exact nature of these fluctuations was not specified, I assumed that female cottontails were 15% heavier during the fall and winter than in the spring and summer. Therefore, female cottontails with a mean annual weight of 1.25 kg weighed 1.35 kg during the fall and winter and 1.17 kg in the spring and summer. Eastern cottontails have a 100:100 sex ratio (Chapman et al. 1982). Based on the aforementioned parameters, cottontails would have provided a harvestable biomass of 821 kg in the fall and winter and 415 kg in the spring and summer. The useable meat of cottontails is approximately 60% of total body weight during fall and winter (Watt and Merrill 1963). The resulting edible biomass would have been 493 kg. The edible meat estimate declines to 57% in spring and summer. The edible biomass would have been 236 kg.

According to Watt and Merrill (1963), the flesh of "wild rabbit" contains 1,350 kcal ME/kg. This estimate was used for the seasons of low weight (spring and summer). Hence, the spring or summer harvest could have furnished 319,000 kcal ME. An increase in subcutaneous fat elevated the energy value of fall-winter meat to 2,258 kcal ME/kg. The fall-winter harvest would have supplied the human foragers of

Havens with 1,113,000 kcal ME of metabolizable energy. Caloric estimates were developed following the procedure described on pp. 73-74.

Summary cost data for eastern cottontail meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	2.43	2.78	3.24	3.71	1.43	1.64
Winter	2.43	--	3.24	--	1.43	--
Spring	3.57	--	5.40	--	3.97	--
Summer	3.57	--	5.40	--	3.97	--

Accounts of methods used by the native people of the eastern United States to hunt eastern cottontails are limited to a description by Elvas during DeSoto's 1540-42 expedition of the southeast. Elvas stated that cottontails were snared "by means of stout springs which lift the feet off the ground and a noose of strong cord fastened to which is a joint of cane which runs to the neck of the rabbit, so that it cannot gnaw the cord" (Swanton 1946).

I assumed that similar snares were used by Early and Middle Woodland people on Havens. Larry Dean Olsen (pers. comm.) stated that the indigenous people of North America used 2-ply cord made from the fibers of such plants as milkweed (*Asclepias* spp.), hemp (*Apocynum camabinum*), and nettle (Urticaceae) to construct snares. Each snare required approximately 3 m of cord (Larry Dean Olsen pers. comm.). Olsen (pers. comm.) typically spends 0.5 hours making 3 m of cord and 0.085 hours fashioning a loop. An additional 0.25 hours are needed to set each snare. He sets 4 to 6 snares on a rabbit trail.

I assumed that the Havens foragers set 12 snares at a given location. In the southern Appalachians, fall and winter are considered the best seasons to trap cottontails (Dewey Griffey pers. comm., Stanley Hicks pers. comm.). This has also been reported from wildlife research in Illinois and Virginia (Bailey 1969; Payne et al. 1987). Thus I assumed that that spring-summer trapping success would have been 50% less than fall-winter trapping success. On an "average" day, Larry Dean Olsen (pers. comm.) caught 1 rabbit in 12 snares (0.083/trap-day) in Idaho during winter. Payne et al. (1987) caught 0.066 cottontails/trap-day with unbaited wooden box traps in Surry County, Virginia during fall. I adopted the average of these 2 estimates (0.075 cottontails/trap-day) for the Havens foragers in fall and winter. The spring-summer estimate was therefore, 0.038 cottontails/trap-day.

Larry Dean Olsen (pers. comm.) stated that the fiber cord of a snare is generally damaged beyond repair after 1 capture. He added that the same trapping site could produce rabbits for approximately 3 weeks. Based on 0.075 cottontails/trap-day, 19 cottontails would have been caught during a 3-week period in fall and winter. The loss of 1 snare/trapped cottontail led to construction costs for 19 traps (15.87 hours) and set-up costs for 31 snares (7.75 hours). I assumed that an additional 1 hour/day was spent checking the snares and transporting captured rabbits back to camp. Approximately 0.08 hours are required to skin and eviscerate a rabbit with stone tools (Olsen, pers. comm.). Thus the total processing cost during the 3-week period would have been 1.5 hours. To capture and process a single cottontail would have required 2.43 hours (15.87 hrs + 7.75 hrs + 21.0 hrs + 1.5 hrs/19 cottontails). This can be expressed as 1.32 hours/1000 kcal ME in fall and winter. Decreased trap-success and lighter cottontails with less body fat combined to raise the cost to 3.57 hours/cottontail and 3.97 hours/1000 kcal ME in spring and summer.

To store small mammals such as cottontails, Olsen (pers. comm.) stated that a stick should be inserted in a skinned and eviscerated carcass to hold the body cavity open and the carcass placed in the sun or over a fire to dry. When dry, the animal should be pounded until the bones are crushed and then left in the sun an additional day to allow the bone marrow to dry. I assumed that this process would require 0.2 hours/cottontail (0.27 hours/kg). With the addition of a 0.2 hours/kg storage vessel production cost, the cost of stored fall-winter cottontail would have been 1.64 hours/1000 kcal ME (3.71 hours/kg).

Eastern Wild Turkey

Summary harvest data for wild turkeys (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	5.81	76.0	4.416	169	746	2,736	2,041,000
Winter	5.81	76.0	4.416	109	481	2,736	1,316,000
Spring	5.50	75.0	4.125	31	136	2,306	314,000
Summer	2.79	73.0	2.037	226	460	1,583	728,000

The U.S. Fish and Wildlife Service habitat suitability index model for the eastern wild turkey (*Meleagris gallopavo*) cited optimum habitat criteria as mature hard-mast-producing forest with 124 or more trees greater than 38.1 cm dbh/ha, overstory trees averaging 30.5 cm in diameter, and canopy cover greater than 50% (Schroeder 1985). Woodland-period Havens would have met all of these requirements. I, therefore, assumed that a high density turkey population was present.

Trippensee (1948) stated that superior turkey habitat can maintain 10 to 16.5 turkeys/km^2. Shelford (1963) estimated that prehistoric densities were 8/km^2. Based on these general, annual densities, I estimated seasonal densities. I adopted a spring density of 7 turkeys/km^2 (205 turkeys) for Early and Middle Woodland-period

Havens. The summer density of a stable turkey population is typically 175% higher than the spring density, due to the addition of poults in late spring (Mosby 1967). Thus the summer population would have contained 564 turkeys. Poult mortality reduces the population 9% by early fall (Mosby 1967). This would have resulted in an early fall population of 513 turkeys. Approximately 60% of the early fall population die during fall and winter (Mosby 1967). I assumed that 25% (77 turkeys) of the mortality occurs in fall and 75% (231 turkeys) in winter. Thus, at the beginning of winter, there would have been 436 turkeys.

Mosby (1967) maintained that 33% of the early fall population can be annually removed without depleting the breeding stock. Thus, 169 turkeys could be harvested in the fall. Increased mortality prevents exploitation at this level during winter. A harvest of 25% (109) was adopted. Breeding and low density make turkey populations most vulnerable during spring. Because turkeys are polygamous, removing 20% (21) of the males and 10% (10) of the females was deemed acceptable. Turkey populations are highest in summer and should be able to sustain greater hunting pressure than in fall. Therefore, a 40% (226) harvest was permitted.

Wild turkey populations have a 50:50 sex ratio and are composed of 36% adults and 64% juveniles (Mosby 1967). The average fall-winter body weight of males is 5.9 kg for juveniles and 9.1 kg for adults. For females, the average fall-winter body weight is 4.2 kg for juveniles and 5.2 kg for adults. According to Mosby and Handley's (1943) 76% edible meat estimate, 746 kg could have been obtained on Havens in the fall and 481 kg could have been obtained in the winter. Males experience an 18% weight loss between March and September while the weight of females declines 7% during this period (Lewis 1967). I assumed the rate of this weight loss is linear. Spring male turkeys (including juveniles) would have averaged 6.4 kg and spring females would have averaged 4.6 kg (Lewis 1967). Males and females would have provided 101 kg and 35 kg of edible meat (75% edible meat estimate), respectively. By the end of summer, adult turkeys are at their lowest weights and would have weighed 5.1 kg (Lewis 1967). The mean summer weight for poults was 1.5 kg (Mosby and Handley 1943). With a 73% edible meat estimate, the 81 available adults and the 145 available poults would have provided the Havens foragers with 460 kg of meat.

Based on Reidhead's (1981) estimate of 1,583 kcal ME/kg for summer turkey meat, fall-winter meat contained 2,736 kcal ME/kg. Therefore, 2,041,000 kcal ME would have been available in the fall and 1,316,000 kcal ME would have been available in the winter. In spring, the energy value dropped to 2,306 kcal ME/kg. The turkey resource would have declined to 314,000 kcal ME. In the summer, the harvestable turkeys could have provided the Havens foragers with 728,000 kcal ME. Caloric estimates were developed following the procedure described on pp. 73-74.

Summary cost data for wild turkey meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	11.10	12.50	2.52	2.88	0.92	1.05
Winter	16.40	--	3.72	--	1.36	--
Spring	57.70	--	15.39	--	6.67	--
Summer	32.30	--	15.86	--	10.02	--

During the 17th and 18th century, the native people of eastern North America used a wide variety of techniques to hunt wild turkey, including drives, decoys, snares and pole-pens (Schorger 1966). Although drives and decoys may have been effectively used in conjunction with bow and arrows, I assumed the lesser accuracy and range of the atlatl-thrown spear would have markedly diminished the effectiveness of these techniques. The use of pole-pens and snares to trap wild turkeys would have been feasible with Early and Middle Woodland technology. Pole-pens were widely used by native people in eastern North America, including the Delaware of Grand River, Ontario, the Cherokee of western North Carolina, and the Powhatan of coastal Virginia (Dodge 1945). Remains of pole-pens have also been recovered from Woodland sites along the lower Mississippi River (Larson 1979). Old Jessie Moses, a Delaware born in 1864, provided the following description of a pole-pen:

> "In the old days turkeys were caught in a trap made of poles driven into the ground with other poles fastened across the top and sides. It formed an enclosure 3 feet high and 6 or more feet square. The top was disguised with a sprinkling of dry leaves. One end had a low opening beneath the poles into which a trench led, excavated for a distance of about a rod, and sloping sufficiently to allow the birds to enter the pen beneath the lowest pole above the opening. The trench was made like a ramp. Leaves were spread bountifully in the runway and inside the pen. A small sprinkling of corn was put out leading from the woods to the ramp into the trap, and plenty of corn was put among the leaves inside the trap. The turkeys would come along feeding with their heads down and feed right into the trap. When they were through eating they would put their heads up and were imprisoned because they did not know enough to put them down again and find their way out at the place they entered. Inevitably, in scratching for the corn among the leaves inside the pen, a deep litter of leaves would be back around the palings and walls and cover the entrance (Dodge 1945)."

Based on the widespread and long-term use of the pole-pen, I assumed it was the dominant turkey procurement method of Early and Middle Woodland people in western Virginia.

The effectiveness of the pole-pen was thoroughly documented in the 18th and 19th century. During this period, pole-pens virtually identical to the Delaware pole-pen enjoyed widespread popularity. In fact, numerous accounts suggest that during the 19th century this was the dominant Euroamerican method for hunting turkeys (Schorger 1966). These accounts revealed that up to 18 turkeys were trapped at one time, though a catch of 6 or 7 was deemed average (Schorger 1966). Audubon (1831) recorded 76 captures from a single pole-pen during 2 winter months (approximately 1.27 turkeys/trap-day) in Ohio. Not only were pole-pens used by early Americans, but they have also been employed by wildlife biologists. Wheeler (1948) noted that of 3 turkey trapping devices, the pole-pen was most effective. Between 1942 and 1946, Wheeler (1948) used pole-pens to trap turkeys from July to March in Alabama. A typical catch was 1-3 turkeys with a maximum of 7 (Wheeler 1948). Pole pens were most successful from October 1 to December 31. They were moderately successful between January 1 and March 31 and least successful during summer (Wheeler 1944a, 1944b, 1945a, 1945b, 1946a, 1946b).

I assumed that with Early and Middle Woodland-period technology, the Havens foragers would have been able to construct a pole-pen in 12 hours. Audubon's (1831) 1.27 turkeys/trap-day was probably an unusually high trapping success rate. I conservatively adopted a trapping success rate of 0.3 turkeys/trap-day. This rate was adopted for fall, the most productive turkey trapping season (Wheeler 1948; Stanley Hicks pers. comm.; Dewey Griffey pers. comm.). Based on Wheeler's (1944a, 1944b, 1945a, 1945b, 1946a, 1946c) trap-success record, I reduced turkeys/trap-day to 0.2 in winter, 0.1 in summer, and 0.05 in spring. Thus a single pole-pen could have produced 27 turkeys in fall, 18 turkeys in winter, 5 turkeys in spring, and 9 turkeys in summer. I adopted a daily trap-check cost of 3 hours/day (includes rebaiting). According to Larry Dean Olsen (pers. comm.), 0.5 hours are required to process a turkey with stone tools. Thus the total cost, including trap construction (12 hours), trap-check (274 hours/season), and processing (0.5 hours/turkey) would have resulted in seasonal costs of 11.1 hours/turkey in fall, 16.4 hours/turkey in winter, 57.7 hours/turkey in spring, and 32.3 hours/turkey in summer. These values can be expressed as 0.92 hours/1000 kcal ME in fall, 1.36 hours/1000 kcal ME in winter, 6.67 hours/1000 kcal ME in spring, and 10.02 hours/1000 kcal ME in summer.

To process turkey for storage would require deboning the carcass and drying pieces of meat in the sun or over a fire. I assumed that such a procedure would have required 0.6 hours/turkey (0.16 hours/kg). The addition of a 0.2 hours/kg storage vessel production cost resulted in a a stored fall turkey cost of 1.05 hours/1000 kcal ME (2.88 hours/kg).

Elk

Summary harvest data for elk (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	208.50	65.0	135.525	6	813	2,792	2,270,000
Winter	211.67	64.0	135.469	3	406	2,547	1,034,000
Spring	238.00	61.0	145.180	2	290	1,258	365,000
Summer	212.17	62.0	131.560	6	815	2,351	1,916,000

Paleontological and archaeological sites and historic accounts have revealed that elk populations resided in western Virginia from the late Pleistocene until the early 18th century. Yet by 1855, elk were eliminated from Virginia (Handley and Patton 1947). The elk's early extermination from Virginia and the rest of Eastern United States makes an understanding of habitat preferences difficult. Fortunately, the reintroduction of elk in western Virginia in 1917 has provided some indication of the relationship between these animals and upland Appalachian environments.

Wood (1943) revealed that in the summer, mixed oak and hardwood communities on mountain crests were extensivley utilized by elk. Areas of local concentration were on burn sites and near ponds. During the winter, elk frequented chestnut oak stands on the slopes of mountains, particularly those with southern exposures (Wood 1943). The most heavily utilized habitats, however, were high mountain fields and abandonded farmland. These locales were utilized throughout the year with peak activity during winter and spring (Wood 1943). From this description of habitat use, it appears that elk in western Virginia would have been most abundant in a mosaic of woodland and grassy openings. This conception is supported by the habitat preferences of elk in the western United States which are dependent on both open meadows and mature timber (Baker 1983). With only 14% of Woodland-period Havens in early successional stages, it seemed reasonable to assume a low elk density.

It has been estimated that prior to European settlement there were 1.5 elk/km^2 in eastern North America (Seton 1929). Recent elk densities in Michigan range from 1.7/km^2 to 11.5/km^2 (Baker 1983). Based on this information, I conservatively adopted a spring breeding density of 0.7/km^2. This gave Havens an early spring population of 20 elk. Although elk have a 100:100 sex ratio at birth, the stress of the rutting season, rutting combat, and the greater energy needs of males reduces the percentage of males to 35 in adult populations (Taber et al. 1982). Hence, the Havens breeding population would have been composed of 13 females and 7 males. Approximately 90% of adult females reproduce each year (Peek 1982). Wood (1943) reported that elk calving in western Virginia occurs in June. Since twins are an extremely rare occurrence, the cows on Havens would have produced 12 calves, resulting in a summer population of 32. Elk experience high post-partum mortality. In fact, within one month of birth up to 50% of calves are lost, largely to predation (Taber et al. 1982). I assumed that 25% (3) of the calves born on Havens did not survive their first month. Thus the early summer population was composed of 20 adults and 9 calves. I estimated that approximately 15% of calves that survived their first month died during the summer. Using this estimate reduced the elk population to 28 by fall. Elk mortality is highest during the winter (Taber et al. 1982). I assumed that 8% (2) of the mean summer population died during fall and and 20% (6) died during winter. The resulting early winter population was 26.

Trippensee (1948) suggested that 20-25% of an elk population can be annually harvested on a sustainable yield basis. I adopted a 20% fall harvest, allowing the Havens foragers a potential take of 6 elk. Food shortages increase the vulnerability of elk populations in the winter. Thus the winter harvest was reduced to 10% (3) of the mean winter population. Elk density is at its lowest in the spring. Yet the removal of 2 elk should not decrease the population's reproductive capabilities. Following Trippensee (1948), a 20% (6) summer harvest was adopted.

Elk are heaviest in fall (Murie 1951). Based on Murie's (1951) data, a mean fall weight of 302 kg for males, 235 kg for females, and 122 kg for calves was used. The potential fall harvest was composed of 1 male, 3 females, and 2 calves. Hence, the harvestable biomass was 1,251 kg. Following Keene's (1981) 65% edible meat estimate, 813 kg could have been consumed. Murie (1951) reported that mean winter weights are 291 kg for males, 226 kg for females, and 118 kg for calves. I assumed that the potential harvest of 3 elk consisted of 1 male, 1 female, and 1 calf. With an edible meat estimate of 64%, 406 kg of meat would have been available for human consumption. I estimated that the mean spring weight of males and females was 266 kg and 210 kg, respectively. A harvest of 2 elk would have provided 290 kg of edible meat (61% edible meat estimate). During the summer, elk recover their winter weight losses (Murie 1951). I used mean summer weights of 280 kg for males, 218 kg for females, and 59 kg for calves and an edible meat weight of 62% (Murie 1951). Thus the 6 available summer elk, 3 females, 2 males, and 1 calf, weighed 1,273 kg and provided 815 kg of meat.

Fall elk meat contained 2,792 kcal ME/kg. The fall harvest would, therefore, have provided 2,270,000 kcal ME. Winter elk meat contained 2,547 kcal ME/kg and would have furnished the Havens foragers with 1,034,000 kcal ME. Spring elk meat has 1,258 kcal ME/kg (Reidhead 1981) and would have provided 365,000 kcal ME. In the summer, the energy value of this resource would have risen to 1,916,000 (815 kg x 2,351 kcal ME/kg). Caloric estimates were developed following the procedure described on pp. 73-74.

Summary cost data for elk meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	70.10	117.10	0.52	0.86	0.19	0.31
Winter	76.10	--	0.56	--	0.22	--
Spring	74.60	--	0.51	--	0.41	--
Summer	62.60	--	0.48	--	0.20	--

The native people of eastern North America employed a variety of techniques to hunt elk, including snares, drives, stalking with spears, stalking with bows and arrows, and pitfall traps (McCabe 1982). Historic and archaeological evidence (spear points embedded in elk bone) suggest that during the Early and Middle Woodland period, stalking with an atlatl-thrown spear was the dominant method for hunting elk (Driver 1969; Wing and Brown 1979).

The cost of outfitting the Havens foragers with atlatls and spears (35.9 hours + 3.6 hours/elk) has been established (pp. 105-106). The eradication of elk from eastern North America has eliminated the data and informants necessary to make direct estimates of search and procurement time. However, reasonable prehistoric cost estimates of white-tailed deer hunting have been obtained (pp. 142-145). The similarities between the species, the prehistoric use of similar hunting techniques, and the lack of better information led me to base elk search and procurement cost on the white-tailed deer estimates. The 14.6 hour/deer search and procurement cost was adjusted to 30 hours/elk due to the substantially lower density of elk. This estimate was used for all seasons (see p. 145). The 2.5 hour/deer tracking estimate was increased to 4 hours/elk. I assumed that the elk's large size would increase its ability to withstand the damage of a spear point. An increase in survival time would have raised the number of hours needed to track a wounded elk. The transportation cost of an elk carcass would have varied with seasonal weight differences. The distance between the geographic center of Havens and the foragers' base camp is 4.83 km. I assumed that this was the mean distance between an elk kill and the base camp. With the 60 kg/person hauling limit and a travelling speed of 1.55 hours/km, transportation of 1 elk from the kill site to the base camp would have required 22.5 hours in fall and winter and 15.0 hours in spring and summer. According to Olsen (pers. comm.), 4 hours are required to skin, quarter, and process 1 elk with stone tools.

The total cost to procure and process 1 elk was calculated in the following manner. The atlatl and longshaft production cost was divided by the number of elk that could be obtained in a given season. This value (6 hours in fall, 12 hours in winter, 18 hours in spring, and 6 hours in summer) was added to the foreshaft production, search and procurement, transportation, and processing costs. This procedure resulted in total cost estimates of 70.1 hours/elk (0.19 hours/1000 kcal ME) in fall, 76.1 hours/elk (0.22 hours/1000 kcal ME) in winter, 74.6 hours/elk (0.41 hours/1000 kcal ME) in spring, and 62.6 hours/elk (0.20 hours/1000 kcal ME) in summer.

To prepare elk meat for storage, the meat must be cut into thin strips and placed on wood drying racks in the sun or over a fire to dry (Olsen pers. comm.). According to Olsen (pers. comm.), this process (including rack construction) would take 20 hours/elk (0.13 hours/kg). The addition of a 0.2 hours/kg storage vessel production cost resulted in a stored fall elk cost of 0.31 hours/1000 kcal ME (0.86 hours/kg).

Gray Squirrel

Summary harvest data for gray squirrels (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	0.41	68.0	0.279	12,619	3,521	1,295	4,560,000
Winter	0.50	70.0	0.350	8,062	2,821	1,375	3,879,000
Spring	0.45	69.0	0.310	8,062	2,499	1,368	3,419,000
Summer	0.44	67.0	0.295	12,619	3,723	1,127	4,196,000

Old growth oak-chestnut forest was optimal gray squirrel habitat (Trippensee 1948, Baker 1959, Mosby 1969). With the mature nut-bearing hardwood forest reduced, the gray squirrel population has declined substantially in the Appalachians within the last 100 years. In fact, at the turn of the century, several conservationists feared the gray squirrel might become extinct (Baker 1959). Although the situation has subsequently improved, it is extremely difficult to estimate aboriginal squirrel density from recent data. Early writers have chronicled events indicating tremendous gray squirrel abundance in the eastern United States. Seton noted that in 19th century Kentucky, 12 hunters killed approximately 10,000 squirrels in a week (Baker 1959). In 1749, the state of Massachusetts paid out bounties for 640,000 squirrels killed that year (Baker 1959). In 1842, a 4-week gray squirrel migration in Wisconsin contained over 500,000,000 animals (Baker 1959). Trippensee (1948) stated that early Ohio hunters shot up to 160 squirrels/day in areas that yielded an average of 1 squirrel/day in 1940. Given these indications of past gray squirrel abundance, and the inferior quality of most current gray squirrel habitat, modern densities do not generally reflect gray squirrel densities prior to European settlement.

In a study of an unexploited gray squirrel population in a mature, but non-virgin, stand of pine, oak, hickory, and poplar in the North Carolina Piedmont, the density annually fluctuated between 0.6 and 3.1 squirrels/ha (Barkalow et al. 1970). Trippensee (1948) stated that when cover is abundant, a density of 5 squirrels/ha has been recorded. In Mosby's (1969) long-term study in 150-200 year old oak woodlots in Montgomery County, Virginia, squirrel density ranged from 10 to 17/ha. Because this habitat resembled the arboreal reconstruction of Havens and Mosby's (1969) figures corresponded well with early accounts of squirrel densities, I adopted a mean annual density of 10 squirrels/ha.

Barkalow et al. (1970) indicated that the summer-fall densities of an unexploited squirrel population in the North Carolina piedmont were 8% higher than spring-winter densities. Based on these estimates and a mean annual density of 10/ha, the gray squirrel population of Early and Middle Woodland period Havens was 31,547 in the summer and fall and 26,873 in the winter and spring. Both Mosby (1969) and Trippensee (1948) asserted that 40% of gray squirrel populations can be annually removed in the fall without danger of depletion. Since summer and fall densities were considered equal, I adopted a 40% harvest for both summer and fall. The number of squirrels that could have been harvested in either of these two seasons was 12,619. Winter-spring harvest was adjusted to 30% to account for the greater vulnerabilty of squirrels during this time of year. The potential harvest for winter and spring was 8,062.

Montgomery et al. (1975) reported that gray squirrel weights in western Virginia old-growth woodlots are lowest in fall ($\overline{x}=$ 0.41 kg) due to the high percentage (54%) of subadults and juveniles. Squirrel weights peak in winter ($\overline{x}=0.50$ kg) and decline in spring ($\overline{x}=0.45$ kg) and summer ($\overline{x}=0.44$ kg). These data were used for the seasonal weights in this study. The adult component of the population was 46% in fall, 33% in winter, 55% in spring, and 50% in summer (Montgomery et al. 1975). An analysis of Montgonmery et al.'s (1975) weight data indicated that the weight of adult squirrels was lowest in summer, increased 5.4% in fall, increased 5.4% in winter, and declined 4.2% in spring. The preceding information was used to calculate fluctuations in percentage of edible meat and seasonal caloric values of this resource. Based on this information, the net winter biomass on Havens was 4,031 kg. Following Keene's (1981) 70% edible meat estimate, 2,821 kg of usable meat were available to Early and Middle Woodland foragers. During spring, the edible biomass would have declined to 2,499 kg (69% edible meat estimate). The summer edible meat estimate was 67% and the potential harvest would have provided the Havens foragers with 3,723 kg of meat. In fall, the edible biomass would have declined slightly to 3,521 kg (68% edible meat estimate).

Fall squirrel meat contained 1,295 kcal ME/kg. Hence, 4,456,000 kcal ME were available to humans foraging on Havens. Spring squirrel meat had 1,368 kcal ME/kg (Leung et al. 1972). Thus, the spring squirrel harvest would have contained 3,419,000 kcal ME. The energy content of squirrel meat declined to 1,127 kcal ME/kg in summer. This would have reduced the resource to 4,196,000 kcal ME. The energy value of squirrel meat increased to 1,375 kcal ME/kg in the winter. Therefore, the winter harvest would have furnished 3,879,000 kcal ME. Caloric estimates were developed following the procedure described on pp. 73-74.

Summary cost data for gray squirrel meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	0.69	--	2.43	--	1.88	--
Winter	0.69	--	2.62	--	1.91	--
Spring	0.91	1.17	2.35	3.27	1.72	2.39
Summer	0.91	--	2.90	--	2.57	--

The indigenous people of the Southeast used several methods to hunt squirrels. The Cherokee used with great accuracy blowguns made from river cane (Martha Wachacha pers. comm., see Appendix p. 194). Numerous southeastern tribes used snares and traps (Swanton 1946). Since cane is uncommon in the central Ridge and Valley Province of Virginia, I assumed that trapping was the dominant mode of squirrel acquisition.

Martha Wachacha (pers. comm.), Stanley Hicks (pers. comm.), and Larry Dean Olsen (1973) have all maintained that deadfalls are the most effective homemade trapping device for squirrels. Native American deadfalls consisted of a large stone or log set on a stick trigger (Olsen 1973). Olsen (pers. comm.) stated that 0.1 hours are required to make 1 trigger. The set-up time would have been dependent on the availablity of suitable stones or logs. In mountainous North Carolina, Stanley Hicks (pers. comm.) has set 1 deadfall/0.5 hours. This rate was adopted for the Havens foragers. I assumed that squirrels were baited with nut meats and/or animal fat.

The only quantitative data on squirrel trapping I was able to uncover were those of Nixon et al. (1967) using walnut-baited box traps in Ohio. In late summer and early fall, Nixon et al. (1967) averaged 0.026 squirrels/trap-day in mixed-mesophytic forest that contained 1.2 squirrels/ha. I assumed that trapping success is largely a function of squirrel density. Therefore, a squirrel density of 10/ha on Early and Middle Woodland-period Havens led me to adopt a trapping success rate 8-times that of Nixon et al. (1967) for summer and fall. I reduced the trapping success rate by 25% to 0.156 squirrels/trap-day in winter and spring, due to low density.

I assumed that the traplines of the Havens foragers would have contained 30 deadfalls. Thus the construction and set-up time would have been 18 hours/trapline. Stanley Hicks (pers. comm.) daily trapline check required 0.15 hours/trap while Dewey Griffey's (pers. comm.) trapline check required 0.1 hours. I adopted the average of these 2 estimates, 0.13 hours/trap (3.9 hours/trapline). Olsen (pers. comm.) has stated that 0.3 hours are required to skin and eviscerate 1 squirrel with stone tools. Based on the aforementioned trapping rates, 1 trapline would have produced 569 squirrels in summer and fall and 427 squirrels in winter and spring. The total cost to produce and process these harvests would have been 391 hours (18 hours + (3.9 hours x 91.25 days) + 569 squirrels x 0.03 hours) in summer and fall and 387 hours (18 hours + (3.9 hours x 91.25 days) + 427 squirrels x 0.03 hours) in winter and spring. These cost estimates were converted to 1.88 hours/1000 kcal ME in fall, 1.91 hours/1000 kcal ME in winter, 2.57 hours/1000 kcal ME in summer, and 1.72 hours/1000 kcal ME in spring.

To store small mammals such as squirrels, Olsen (pers. comm.) stated that a stick should initially be inserted in a skinned and eviscerated carcass to hold the body cavity open and the carcass placed in the sun or over a fire to dry. When dry, the animal should be pounded until the bones are crushed and then left in the sun to allow the bone marrow to dry. I assumed that this process would require 0.2 hours/squirrel (0.72 hours/kg). When a 0.2 hours/kg storage vessel production cost was added the total cost for stored spring squirrel was 2.39 hours/1000 kcal ME (3.27 hours/kg).

Opossum and Raccoon

Opossum food base

Summary harvest data for opossum (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	2.70	70.0	1.890	173	327	3,725	1,218,000
Winter	2.45	67.0	1.642	15	25	2,928	73,000
Spring	2.10	62.0	1.302	114	148	1,343	199,000
Summer	1.30	63.0	0.819	340	278	1,638	455,000

Although opossum can exist in a wide variety of habitats, mature timber near riparian zones is optimal (Reynolds 1945; Holmes and Sanderson 1965; Baker 1983). Since Havens does not have extensive water resources, the Early and Middle Woodland period opossum density would not have been exceptionally high. The old-growth oak-chestnut forest would likely have supported an intermediate density population. Density estimates range from 1 to 115 opossum/km^2 (Holmes and Sanderson 1965; Baker 1983). Moderate opossum densities are between 3 and 12/km^2 (Reidhead 1981; Baker 1983). I used these estimates as a guide and adpoted 5/km^2 as the density of the winter breeding population (146 opossum). Sonenshine and Stout's (1974) 6-year study in the Piedmont of Virginia contained seasonal population estimates. These data were used to develop the seasonal population fluctuations on Early and Middle Woodland period-Havens.

Opossum populations are at their lowest in mid-winter, prior to the winter breeding season. Stout and Sonenshine (1974) have indicated that in typical years, spring opossum density is 162% higher than the winter density. Thus Havens would have had a spring opossum density of 13/km^2 (380) during spring. Becasue opossum often have 2 litters, populations continue to increase in the summer. Sonenshine and Stout's (1974) data revealed that there is a 90% population increase in the summer. This would have resulted in a summer population of 722 opossum. Increased mortality during fall reduces the population by approximately 40% (Sonenshine and Stout 1974). Therefore, the fall population would have contained 433 opossum.

During a 5-year period, Yeager (1937) was able to achieve a sustained harvest of 2.33 times the breeding population. I adopted this harvest during the summer when the opossum population was least vulnerable. The resulting potential summer harvest on Early and Middle Woodland-period Havens would have been 340. Increased mortality during fall suggested that this harvest should be significantly reduced. A harvest of 40% (173) was used. Opossum populations are most vulnerable during winter. Yet I believed that sustained removal of 10% (15) of the population could be achieved. Since opossum populations are relatively low in spring and breeding is occurring, a 30% (114) harvest was allowed.

Reidhead (1981) maintained that the average fall weight of opossums is 2.7 kg (including juveniles). The resulting harvestable biomass would have been 467 kg (173 x 2.7) and the edible biomass (70%) would have been 327 kg (White 1953). During winter, opossum weights decline 15% (Reidhead 1981) and the edible meat estimate drops to 67%. The resulting mean winter weight of 2.45 kg would have produced an edible biomass of 25 kg. An additional weight loss of 15% is incurred during winter (Reidhead 1981). This resulted in a mean weight of 2.1 kg. Thus, the 114 harvestable opossum that could be killed in spring would have provided 148 kg of meat (62%

edible meat estimate). I was unable to find weight estimates for juvenile opossum in their first summer. I assumed they averaged 1.0 kg. The mean weight I used for adults was 2.3 kg. Since adults only comprised 20% of the summer population, the mean summer weight was 1.3 kg. Given a 63% edible meat estimate, the 340 available opossum would have provided 278 kg of meat.

During the fall, edible opossum meat contained 3,725 kcal ME/kg, and would have produced an energy source of 1,218,000 kcal ME. In winter, the energy value of this resource declined to 73,000 kcal ME (25 kg x 2,928 kcal ME/kg). Edible spring meat contained 1,343 kcal ME/kg (Reidhead 1981) and would have furnished 199,000 kcal ME. Largely due to the high percentage of juveniles, the caloric value of summer opossum meat is a relatively low 1,638 kcal ME/kg. Thus the summer harvest would have furnished 455,000 kcal ME. Caloric estimates were developed following the procedure described on pp. 73-74.

Raccoon Food Base

Summary harvest data for raccoon (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	3.39	63.0	2.136	182	389	4,734	1,842,000
Winter	2.82	58.0	1.637	91	149	3,431	511,000
Spring	3.10	48.0	1.488	18	27	1,343	36,000
Summer	4.90	65.0	3.185	26	83	5,423	450,000

Optimal raccoon habitat contains numerous large cavity trees and rock crevices, heavy mast crops, and abundant water resources (Sonenshine and Winslow 1972; Rabinowitz 1981; Olsen 1983). Although the Woodland-period forest of Havens would amply satisfy the first two criteria, water resources would likely have been limited.

Therefore, I assumed that Havens supported a moderate density raccoon population. This position was supported by Olsen (1983) who stated that raccoon densities are highest in bottomland hardwoods, intermediate in upland forests, and lowest in pine stands.

Reported densities range from 2/km^2 to 66/km^2 (Rabinowitz 1981). Densities that are considered low are less than or equal to 5/km^2 (Kaufman 1982). A density of 6/km^2 has been reported for Cades Cove, Great Smoky Mountains National Park (Rabinowitz 1981). Since this density was moderate and the mature Appalachian hardwood forest of Cades Cove is compostionally similar to the climax forest on Woodland-period Havens, it was used as the spring breeding density in this study. Estimating the density for the remaining seasons required knowledge of the raccoon's reproductive capacities. The sex ratio of this species is 100:100 and mean litter size ranges from 1.9 to 5 (Rabinowitz 1981; Olsen 1983). The overall mean for litter size in 16 studies is 3.4 (Rabinowitz 1981). Based on this information, the Havens breeding population of 175 raccoon would have annually produced 296 kits. Females generally give birth in late June, yet kits do not emerge from their dens until the end of August (Rabinowitz 1981). Therefore, the summer population was kept at the same level as the spring breeding population. Raccoon mortality is low during spring and summer. Olsen (1983) reported that juvenile mortality is approximately 5% between birth and the fall hunting season. Based on this account, the fall population would have contained 456 raccoons (38% adults and 62% juveniles). I was unable to locate any quantitative estimates of fall and winter mortality. However, Olsen (1983) stated that winter mortality is high. A fall mortality of 20% and a winter mortality of 52% were used in this study. These estimates brought the population back to the spring breeding density. Therefore, by winter, the raccoon population declined to 365.

I was unable to find any guidelines for raccoon harvest in the wildlife literature. A potential harvest of 40% (182) of the fall population was adopted. Due to additional stresses during winter, only 25% (91) of the season's population was harvestable. During the spring, raccoon populations are particularly vulnerable with females bearing and nursing young. A spring harvest of 10% (18) was allowed. Although raccoon densities do not effectively increase during the summer (young remain in their dens), the addition of young has decreased the population's vulnerability. Thus a harvest of 15% (26) was adopted.

Adult raccoon weights were highest in the fall with males averaging 6.9 kg and females averaging 4.4 kg. During fall, juveniles weigh approximately 2.0 kg (Rabinowitz 1981). With 70% of adult body weight edible (White 1953) and 50% of juvenile body weight edible, the fall raccoon population would have the potential to provide humans with 389 kg of meat. Adult mean winter weight dropped to 4.7 kg for males and 3.6 kg for females (Rabinowitz 1981), and the percentage of edible meat declined to 64%. I assumed that juvenile weights and percentage of edible meat remained stable. The resulting edible biomass would have been 149 kg. The adult weight decline in raccoons continues through spring with males and females having mean weights of 3.7 kg and 2.5 kg, respectively (Rabinowitz 1981). Weight loss, lower density, and an edible meat estimate of 48% would have reduced the raccoon resource to 27 kg in spring. During the summer, mean adult weights increased to 6.1 kg for males and 3.7 kg for females (Rabinowitz 1981). The resulting edible meat weight would have been 83 kg (65% edible meat estimate).

Fall raccoon meat contained 4,734 kcal ME/kg. The fall harvest would have provided 1,842,000 kcal ME. The energy value of winter meat declined to 3,431 kcal ME/kg. The harvestable raccoons would have furnished 511,000 kcal ME. The spring harvest would have provided 36,000 kcal ME (27 kg x 1,343 kcal ME/kg). Summer raccoon meat contained 5,423 kcal ME/kg and the summer harvest would have secured a 450,000 kcal ME resource. Caloric estimates were developed following the procedure described on pp. 73-74.

Opossum and Raccoon Cost

Summary cost data for opossum and raccoon meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	2.00	3.00	1.01	1.36	0.25	0.33
Winter	4.42	--	1.64	--	0.80	--
Spring	3.55	--	2.68	--	2.00	--
Summer	2.68	--	2.29	--	0.72	--

I have been unable to uncover any primary sources referring to opossum hunting techniques of Native Americans. However, I agreed with both Lawson (1980) and Runquist (1979) that traps and snares were likely employed. Interviews with older people of the the Appalachians have revealed that deadfalls were the most effective homemade device for trapping opossum (Stanley Hicks, pers. comm.; Dewey Griffey, pers. comm.). The home range of opossum is close to water sources. Thus, I assumed that deadfalls would have been set along Mason's Creek at the base of Fort Lewis Mountain, the only substantial perennial water source on Havens.

Firsthand accounts of aboriginal raccoon hunting techniques are sparse. Swanton (1946) described a deadfall used by native people of the southeast in which bait removal prompted a trigger to release logs on a raccoon's back.

Due to similar habitat requirements, I assumed that the Havens foragers would set deadfalls with the intention of trapping both opossum and raccoon. Therefore, I combined the costs for these 2 species into a single variable.

I assumed the Havens foragers would have created traplines that contained 30 deadfall traps. The construction and set-up cost of deadfalls has been established (pp. 127-128: 0.6 hours/deadfall). Thus an 18 hour/trapline start-up cost would have been required. Stanley Hicks' (pers. comm.) 40-deadfall trapline produced 4 opossum and 2 raccoon per day during fall and winter in Wautauga County, North Carolina (9.12 opossum/trap/season and 4.5 raccoon/trap/season. In Madison County, North Carolina, Dewey Griffey's 100 trap trapline yielded 5 opossum and 4 raccoon per day during fall and winter (4.65 opossum/trap/season and 3.65 raccoon/trap/season. Yeager (1937) set 25 steel traps between November 15 and January 1 in Mississippi. During a 5-year period, this trapline averaged 28.4 opossums and 9.0 raccoons (1.14 opossum/trap/season and 0.36 raccoon/trap/season). The average yield of these 3 traplines is 4.97 opossum/trap/season and 2.84 raccoon/trap/season. Rabinowitz (1981) found no seasonal differences in raccoon trapping success. I assumed this would also hold true for opossum. Hence, the trapping rates of 4.97 opossum/trap/season and 2.84 raccoon/trap/season were adopted for each of the 4 seasons. A Havens trapline would, therefore, have yielded 149 opossum and 85 raccoon in a single season.

Stanley Hicks' (pers. comm.) daily trapline check required 0.2 hours/trap while inspection of Dewey Griffey's (pers. comm.) trapline required 0.1 hours/trap. I used the average of these 2 estimates, 0.15 hours/trap. This resulted in a seasonal cost of 411 hours for daily trap-checks of a Havens trapline. Skinning and quartering 1 raccoon or opossum would have required 0.17 hours with stone tools (Olsen, pers. comm.). Therefore, the seasonal harvest from a Havens trapline would have required

40 hours to process. The addition of the processing cost to the trap-check and construction/set-up cost resulted in a total seasonal cost of 469 hours. The fall harvest from a single trapline would have yielded 1,049,000 kcal ME of opossum and 860,000 kcal ME of raccoon. Thus,the fall cost of opossum and raccoon would have been 0.25 hours/1000 kcal ME. The winter cost would have declined to 0.26 hours/1000 kcal ME, largely due to the low number of opossum that could be harvested. The reduced caloric value of spring meat, decreased body weight, and few available raccoon increased the cost to 2.0 hours/1000 kcal ME. The opossum and raccoon harvested from 1 trapline in the summer would have required 0.72 hours/1000 kcal ME.

To store small mammals such as opossum, Olsen (pers. comm.) stated they would be processed as previously described for the squirrel. I assumed that this process would require 0.4 hours/raccoon or opossum (0.15 hours/kg). With the addition of a 0.2 hours/kg storage vessel production cost, stored fall opossum and raccoon would have cost 0.33 hours/1000 kcal ME (1.36 hours/kg).

Passenger Pigeon

Summary harvest data for passenger pigeon (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	0.30	75.0	0.225	10,000	2,250	2,790	6,278,000

Paleontological evidence and historic accounts revealed that the passenger pigeon was present in the Ridge and Valley province of Virginia from at least 30,000 B.P. until 1893 (Eshelman and Grady 1986; Schorger 1973). However, the passenger pigeon was not a permanent resident. During its fall migration south, large flocks would roost for extended periods in the Appalachians (Schorger 1973). Flocks would disperse and forage in the day and return to localized roosts at night (Schorger 1973). Hence, the passenger pigeon was probably only a viable food resource in areas that contained roosts. Whether Havens was used as roost during the Early and Middle Woodland period is not known. However, the possibility is not remote. In 1876 and 1878 *Forest and Stream* published notices of the passenger pigeons' arrival in the vicinity of Blacksburg,Virginia, 24 km south of Havens (Elzey 1876; Elzey 1878). These brief accounts indicated that this was a regular occurrence and that flocks remained in the area from September through October (Elzey 1878). Since it is not currently possible to establish whether passenger pigeons roosted on Havens during the Early and Middle Woodland-period, this resouce had an optional slot in the model.

The passenger pigeon was exterminated before any population estimates of roosts were attempted. Schorger (1973) stated that roosts ranged in size from 2.0 to 31,000 ha. Typical roosts covered 100 to 1,000 ha (Schorger 1973). If Havens was used as a roosting site, I conservatively assumed that 100 ha would have been occupied. Roosts were densely populated. Accounts abound of limbs breaking under the weight of birds and layers of excrement building up to 30 cm beneath roost trees (Schorger 1973). I adopted a density of 500 passenger pigeons/ha. Therefore, the Havens pigeon roost contained 50,000 birds. Passenger pigeon populations were at or near their peak during fall roosting. Yet since these birds only produced 1 egg per year, a 20% harvest was allowed (Schorger 1973).

Adult passenger pigeons weighed 0.26-0.34 kg (Schorger 1973). Using the average of these 2 figures and Keene's (1981) 75% edible meat estimate, the Havens roost produced an edible biomass of 2,250 kg. Caloric estimates for passenger pigeon are unavailable. I used Watt and Merrill's (1963) metabolizable energy estimate of 2,790 kcal ME/kg for rock dove (*Columbia livia*) which produced a 6,278,000 kcal ME energy source.

Summary cost data for passenger pigeon meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	0.20	0.35	0.89	1.53	0.32	0.55

The most frequently employed harvesting technique for roosting passenger pigeons among Native Americans was to knock birds off tree limbs with long poles (Schorger 1973). This method was also used by early Americans. Schorger (1973) stated that a Massachusetts family killed 1,200 birds in 1 night solely using long poles. If this family hunted for 6 hours and contained 6 people, 1 bird was obtained every 0.03 hours. Historic accounts, however, are generally success-oriented. Events that are unsuccessful or unexceptional were not often recorded. Therefore, I increased the hourly cost of acquiring passenger pigeons by 33% (0.01 hours) and added travel time of 1 hour/person. I assumed that 1.5 hours of travel time would have been required to reach the roost and that 1.5 hours would have been required to transport 20 kg of passenger pigeons (67 birds) back to the base camp. Birds were likely strung in bunches to the poles with plant fiber cord. I assumed that 3.8 m of cord would be sufficient to tie 67 birds. Approximately 1.9 hours (0.028 hours/bird) would have been needed to make the cord. Skinning and cleaning a mourning dove (*Zenaidura macroura*) requires 0.083 hours. (David Howerter, pers. comm). The similarities between the 2 species supported the adoption of this estimate for the passenger pigeon. Summing the preceding costs resulted in a total cost of 0.20 hours/bird. With a mean weight of 0.3 kg and an edible meat estimate of 75%, 1000 kcal ME could have been obtained in 0.32 hours.

I assumed that the process required to store passenger pigeon meat would have been similar to the process described for small mammals and estimated that 0.1 hours/bird (0.44 hours/kg) would have been expended. The addition of a 0.2 hours/kg storage vessel production cost resulted in a stored passenger pigeon cost of 0.55 hours/1000 kcal ME (1.53 hours/kg).

White-tailed Deer

Summary harvest data for white-tailed deer (wet weight) on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Fall	44.30	65.0	28.795	41	1,181	2,544	3,004,000
Winter	44.90	65.0	29.185	29	846	2,544	2,152,000
Spring	38.80	62.0	24.056	15	361	1,258	454,000
Summer	37.15	65.0	24.148	52	1,256	1,626	2,042,000

Climax oak-chestnut forest is not optimal white-tailed deer habitat. Deer thrive in vegetationally diverse habitat that includes mast-producing hardwoods, sprout coppice, and forb production (Dasmann 1971). Cushwa et al. (1970) found a high proportion of grass in the diets of deer in spring and summer. Although Early and Middle Woodland-period Havens had excellent mast production, coppice would not have been available and grass and forb production would have been significant on only 14% of the total land area. A high deer density would have required a greater percentage of total land area in early successional stages. Therefore, moderate deer density would be expected. Shelford (1963) estimated aboriginal white-tailed deer density was 4-31/km^2 with an equilibrium density of 15/km^2. Giles (1978) stated that 8/km^2 is "better than average density." I adopted a breeding density of 5.25/km^2, giving Havens a spring breeding population of 153.

In order to estimate the productivity of deer populations, it is necessary to determine the ratio of fawns to adults in the fall rutting season. I adopted a 30:70 ratio. Although it is not uncommon for fawns to bear young, it is not the norm under average conditions (Shrauder 1984). Therefore, 51 females would have produced fawns on prehistoric Havens (based on a 100:100 sex ratio) (Trippensee 1948). In the central and southern Appalachians, an average of 1.5 fawns/mature female (Shrauder 1984) is produced in spring, with peak fawning between late May and early June (Dutton 1987). Based on this information, 77 fawns would have been added to the Havens population in late spring. I assumed that 10% of these animals would die during the first month of life. Thus, the early summer population would have contained 146 adults and 69 fawns. Haynes (1984) reported that annual survival rates of white-tailed deer are approximately 70%. Therefore, I assumed that 30% (44) of the spring breeding population would succumb to non-human generated mortality during the year. I also assumed that 35% of the fawns that survived their first month would die during the remainder of the year. Since deer mortality is highest in winter, I believed that 40% of annual losses would occur in this season. The remaining deaths were evenly distributed among the other seasons. The early fall population would have contained 142 adults and 61 fawns. By the beginning of winter, there would have been 138 adults and 58 fawns. When spring arrived the population would have declined to 108 adults and 45 fawns.

Trippensee (1948) and Shelford (1963) both asserted that humans can crop 20% of a white-tailed deer population without depleting the breeding stock. I adopted this harvest level in fall, allowing the Havens foragers a potential take of 41 deer. Due to increased mortality, a 15% harvest (29) was permitted in winter. Spring populations are particulary vulnerable because of fawning and low numbers. Yet I believed a 10% harvest (15) could be sustained. A 24% summer harvest of the Cades Cove deer herd in the Great Smoky Mountains National Park was recommended in order to maintain a stable population (Burst and Pelton 1978). This harvest was adopted for the Havens population and would have allowed the prehistoric foragers a take of 52 deer.

The following weight estimates were derived from data collected by Dutton (1987) in the western Virginia counties of Wise, Scott, and Giles. In fall and winter, the mean weights were 56 kg for males, 50 kg for females, and 25 kg for fawns. The resulting harvestable biomass was 1,816 kg in fall and 1,302 kg in winter. According to Verme (1965), 65% of total biomass is edible. This estimate was used for fall and winter. Thus, the edible biomass was 1,181 kg in fall and 846 kg in winter. Spring weights were 46 kg for males, 44 kg for females, and 26 kg for fawns. Based on a 62% edible meat estimate (developed following the procedure described on pp. 72-73), 361 kg were available for human consumption. In summer, the weight of males and females was 49 kg and 45 kg. Rue (1979) indicated that fawns weigh approximately 15 kg in mid-summer. Thus the resulting edible biomass would have been 1,256 kg (65% edible meat estimate).

Fall and winter deer meat would have contained 2,544 kcal ME/kg, making the fall harvest a 3,004,000 kcal ME resource and the winter harvest a 2,152,000 kcal ME resource. Spring meat would have contained 1,258 kcal ME/kg (Watt and Merrill 1963). The potential spring harvest would have provided the Havens foragers with 454,000 kcal ME. In summer, deer meat would have contained 1,626 kcal ME/kg and could have provided humans with 2,046,000 kcal ME. Caloric estimates were developed following the procedure described on pp. 73-74.

Summary cost data for white-tailed deer meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Fall	30.10	--	1.05	--	0.42	--
Winter	30.40	44.24	1.04	1.51	0.41	0.59
Spring	31.60	--	1.31	--	1.04	--
Summer	29.60	--	1.23	--	0.76	--

Numerous methods were used to hunt white-tailed deer by the indigenous people of eastern North America, including snares, drives, and stalking with bow and arrow (Swanton 1946). The majority of early historic accounts indicate that stalking was the dominant deer-hunting technique. In most accounts of deer-stalking, a single hunter wears either a preserved deer head or deer hide that includes the head (Swanton 1946). This disguise, coupled with keen tracking and stalking ability allowed the hunter to get within the range that a bow and arrow would be effective. This is illustrated by Cate's description of a Santee Indian stalking deer with a deerskin disguise in eastern North Carolina during the early eighteenth century (Swanton 1946).

> In these habiliments an Indian will go as near a deer as he pleases, the exact motions and behavior of a deer being so well counterfeited by them, that several times it hath been known for two hunters to come up with a stalking head together, and unknown to each other, so that they have killed an Indian,...for which reason they allow not that sort of practice where the nation is populous.

Not only did Indians imitate the physical features and movements of deer, they also imitated deer sounds. In the mid-18th century, Dupratz stated that in spring the Natchez imitated a bleating fawn by sucking the palm of their hand, a practice "which very often makes the deer come toward the hunter" (Swanton 1946). This technique was also observed among the Yuchi of Tennessee and the Choctaw of Mississippi (Swanton 1946). I have assumed that deer-stalking was the primary deer-hunting technique on Havens during the Early and Middle Woodland period.

Archaeological evidence indicates that the atlatl-thrown spear was the dominant weapon used to kill deer during stalks in this period. I assumed that to hunt white-tailed deer, an individual would need 1 atlatl, 1 longshaft and 2 foreshafts/deer each year (see pp. 105-106). Based on the age and sex composition of the Havens band, there would have likely been 5 active hunters. To outfit this group for white-tailed deer hunting, would have required 35.9 hours + 3.6 hours/deer (see pp. 105-106).

Interviews with 3 experienced bowhunters, all of whom are in the wildlife profession, revealed that 7-18 hours ($\bar{x} = 11.7$ hours) were required to kill 1 white-tailed deer during the fall in the Ridge and Valley Province of Virginia. These estimates represent the time engaged in actual hunting and did not include the time involved in selecting hunting locations, tracking hit deer, and transporting the carcass. Each of these individuals hunt from tree stands in areas frequented by white-tailed deer. I believed that it was reasonable to use this information to develop hourly estimates of prehistoric deer hunting because in both situations:

1. A single hunter was involved.
2. A location where deer frequented was selected.
3. The hunters were concealed.

Although Early and Middle Woodland hunters had greater mobility than modern hunters in tree stands, this advantage was probably more than compensated for by the greater accuracy and range of the compound bow when compared with the atlatl. I assumed that adding 25% to the mean modern bowhunter estimate would compensate for the technological limitations of the atlatl. Therefore, 14.6 hours of actual hunting time would have been required to kill 1 deer. All of the bowhunters that were interviewed stated that search time was neglible when familiar with an area. I assumed that Early and Middle Woodland people had a wealth of knowledge regarding the likely location of deer on Havens and, therefore, did not add any scouting costs. The bowhunter interviews revealed that tracking a shot deer was often unnecessary. However, there were occassions when up to 6 hours were required to find a deer that had been hit. The substantially lower force of an atlatl would probably have increased a deer's survival time. This would have increased the time necessary for tracking. Although Early and Middle Woodland hunters were probably better trackers than the interviewed bowhunters, I assumed that a 2.5 hour/deer tracking cost would be appropriate. The bowhunter interviews indicated that approximately 1.55 hours/km were required to haul a deer across rugged terrain. I used the distance between the geographic center of Havens and the base camp (4.83 km) as the mean distance that a deer carcass must be hauled. Thus an average of 7.5 hours would have been required to transport a deer from the kill site to the Havens base camp.

The interviewed bowhunters maintained that the number of hours required to shoot a deer in spring, summer, and winter would not be significantly different from their fall estimates. They remarked that although the deer population is low in the spring, the shift to early successional areas would allow hunters to key in on animals that survive the winter. In summer, the advantages provided by a high deer population were believed to be eliminated by a lack of concentrated foraging locales.

Larry Dean Olsen (pers. comm.) maintained that 1 hour is required to skin, quarter, and rough process a deer with stone tools. This estimate was adopted for the Havens foragers.

The total cost to procure and process 1 white-tailed deer was calculated in the following manner. The atlatl and longshaft production cost was divided by the number of white-tailed deer that could be obtained in a given season. This value (0.9 hours in fall, 1.2 hours in winter, 2.4 hours in spring, and 0.7 hours in summer) was added to the foreshaft production, search and procurement, transportation, and processing costs. This procedure resulted in total cost estimates of 30.1 hours/deer (0.42 hours/1000 kcal ME) in fall, 30.4 hours/deer (0.41 hours/1000 kcal ME) in winter, 31.6 hours/deer (1.05 hours/1000 kcal ME) in spring, and 29.9 hours/deer (0.76 hours/1000 kcal ME) in summer.

To prepare deer meat for storage, the meat must be cut into thin strips and placed on wood drying racks in the sun or over a fire to dry (Olsen pers. comm.). According to Olsen (pers. comm.), this process (including rack construction) would take 8 hours/deer (0.27 hours/kg). The addition of a 0.2 hours/kg storage vessel production cost resulted in a stored winter deer meat cost of 0.59 hours/1000 kcal ME (1.51 hours/kg).

Woodchuck

Summary harvest data for woodchuck on Havens

Season	Weight/ Animal (kg)	% Edible	Edible Biomass/ Animal (kg)	Animals Available	Edible Yield	Kcal ME/ kg	Harvestable Kcal ME
Spring	3.10	61.0	1.89	58	110	1,258	148,000
Summer	2.89	67.0	1.94	280	543	2,990	1,624,000

Woodchuck inhabit old-growth oak stands, though heavy-canopied climax forest is sub-optimal habitat (DeGraaf 1981; Baker 1983). Rather, these animals prefer edges of forest, open cultivated land, pastures, meadows, and brushy areas (DeGraaf 1981). As was previously mentioned, Woodland period Havens likely had 14% of the total land area in early successional stages. Hence, there would have certainly been some prime woodchuck habitat. However, since the bulk of Havens would have been marginal habitat, a relatively low density was deemed appropriate. The reported densities of woodchuck vary from 7/km^2 to a high of 213/km^2 (Twichell 1939; Grizzel 1955; Baker 1983). I adopted a spring density of 10/km^2, giving Havens a breeding population of 292 woodchucks. Snyder and Christian (1960) reported that woodchuck have a mean reproductive rate (proportion of young to total female adults) of 2.8 and a 100:100 sex ratio. Since young of the year do not emerge from their dens until June, the 409 new recruits were not added to the population until summer. Therefore, the summer population contained 701 woodchucks. Population estimates were not necessary for fall and winter as woodchucks were not believed to be a viable food resource during hibernation.

I have been unable to locate any reference to the percentage of woodchucks that can be harvested consistently. I conservatively adopted a potential spring harvest of 20% (58) and a potential summer harvest of 40% (280).

Mean spring weights for woodchucks were 2.4 kg for yearlings and 3.4 kg for adults (Snyder et al. 1961). I assumed that 30% of the spring population was composed of yearlings. Based on a 61% edible meat estimate, 110 kg were available for human consumption. Mean summer weights for juveniles, yearlings, and adults were 2.0 kg, 3.4 kg, and 4.4 kg (Snyder et al. 1961). The summer population was composed of 58% juveniles, 12% yearlings, and 30% adults. The resulting edible meat from the harvestable population was 566 kg (70% edible meat estimate).

I was unable to uncover any information on the caloric content of woodchuck meat. Therefore, I used Reidhead's (1981) spring estimates for raccoon and opossum meat (1,343 kcal ME/kg) for spring woodchuck. The caloric value of summer woodchuck meat would have been 2,990 kcal ME/kg. The spring harvest would have furnished 148,000 kcal ME and the summer harvest would have furnished 1,624,000 kcal ME. Caloric estimates were developed following the procedure described on pp. 73-74.

Summary cost data for woodchuck meat (wet weight) on Havens

Season	Hrs/ Animal (Fresh)	Hrs/ Animal (Stored)	Hrs/kg (Fresh)	Hrs/kg (Stored)	Hrs/ 1000 kcal ME (Fresh)	Hrs/ 1000 kcal ME (Stored)
Spring	2.15	--	1.14	--	0.91	--
Summer	2.15	2.95	1.11	1.47	0.37	0.49

Although woodchuck remains are common in Woodland sites in western Virginia (Rose 1986), I have been unable to find any accounts of aboriginal woodchuck hunting in eastern North America. However, the native people of western North America and 19th and 20th century Appalachian "mountaineers" used snares to trap woodchuck. Hence, assumed that snares were used by the Havens foragers during the Early and Middle Woodland period. I have identified 2 types of snares used to trap woodchuck: ground snares and lift-pole snares.

Ground snares were composed of plant fiber cord and wood and required 0.83 hours to construct and set (see p. 112). During the 1920's, Stanley Hicks (pers. comm.) used similar ground snares to trap woodchuck in the spring and summer. He set 6 snares/day at the entrance of woodchuck burrows. One hour/day was required to examine the snares. Stanley Hicks (pers. comm.) trapped an average of 2 woodchucks/day. Based on this information, I assumed that ground snares used by Havens foragers would have produced 6 woodchuck during a 4-day period. Thus the cost (construction, set-up, and procurement) to obtain 1 woodchuck would have been 1.5 hours ((0.83 hours x 6) + 4 x 1 hour = 9 hours/6 woodchuck). Processing 1 woodchuck with stone tools would have required an additional 0.17 hours (Larry Dean Olsen 1973).

A lift-pole snare consists of a weighted pole with a plant fiber loop at one end that is balanced in the crotch of a limb that is planted in ground. There is a stick trigger at the opposite end of the pole that holds the loop and pole down (Olsen 1973). Olsen (pers. comm.) stated that 1.0 hours are required to make 6.6 m of plant fiber cord for this device. An additional 0.5 hours is needed to fashion the pole, trigger, and crotch stick. The set-up time is approximately 0.125 hours. Olsen (pers. comm.) stated that a trapper must wait at the snare site as a woodchuck can easily chew through a plant fiber loop. The average waiting time is 0.5 hours/woodchuck.

Several woodchuck burrows are often found close together. I assumed that 3 woodchucks could be caught in a single trapping expedition. One hour would have been required to bring these animals back to the base camp. According to Larry Dean Olsen (pers. comm.), the time to skin and quarter a woodchuck with stone tools is approximately 0.17 hours. Thus the total cost to procure and process 1 woodchuck would have been 2.625 hours (1.125 construction and set-up cost + 0.5 hours waiting cost + 0.33 hours transportation cost + 0.17 hours processing cost).

I averaged the cost/woodchuck of the lift-pole snare and the ground snare to obtain a cost estimate for the Havens foragers. This value was 2.15 hours/woodchuck. In addition, I assumed that trapping success in spring and summer would have been equal. In spring the cost per 1000 kcal ME would have been 0.91 hours. The higher caloric content of summer woodchuck meat would have reduced the cost to 0.37 hours/1000 kcal ME.

Woodchucks were processed for storage in the same manner described for squirrels (p. 128). I assumed that this process required 0.4 hours/woodchuck (0.16 hours/kg). With the addition of a 0.2 hours/kg storage vessel production cost, the cost of stored summer woodchuck would have been 0.49 hours/1000 kcal ME (1.47 hours/kg).

Table 7. Harvest characteristics of animal resources on Havens during the Early and Middle Woodland period.

Species	Weight/ Animal (kg)[1]	% Edible	Edible Biomass Animal (kg)	Animals Available	Edible Yield	Kcal ME kg (kg)	Harvestable Kcal ME
Black Bear							
Fall	70.67	70.0	49.470	6	297	3,704	1,100,000
Winter	71.55	66.0	47.220	5	236	2,819	665,000
Spring	52.67	61.0	32.130	6	193	1,343	259,000
Summer	61.97	66.0	40.900	6	245	2,806	687,000
Box Turtle							
Spring	0.75	16.7	0.125	8,763	1,095	1,110	1,1,215,000
Summer	0.75	16.7	0.125	8,763	1,095	1,110	1,1,215,000
Eastern Cottontail							
Fall	1.25	60.0	0.750	657	493	2,258	1,113,000
Winter	1.25	60.0	0.750	657	493	2,258	1,113,000
Spring	1.16	57.0	0.661	358	236	1,350	319,000
Summer	1.16	57.0	0.661	358	236	1,350	319,000
Wild Turkey							
Fall	5.81	76.0	4.416	169	746	2,736	2,041,000
Winter	5.81	76.0	4.416	109	481	2,736	1,316,000
Spring	5.50	75.0	4.125	31	136	2,306	314,000
Summer	2.79	73.0	2.037	226	460	1,583	728,000
Elk							
Fall	208.50	65.0	135.525	6	813	2,792	2,270,000
Winter	211.67	64.0	135.469	3	406	2,547	1,034,000
Spring	238.00	61.0	145.180	2	290	1,258	365,000
Summer	212.17	62.0	131.560	6	815	2,351	1,916,000
Gray Squirrel							
Fall	0.41	68.0	0.279	12,619	3,521	1,295	4,560,000
Winter	0.50	70.0	0.350	8,062	2,821	1,375	3,879,000
Spring	0.45	69.0	0.310	8,062	2,499	1,368	3,419,000
Summer	0.44	67.0	0.295	12,619	3,723	1,127	4,196,000
Opossum							
Fall	2.70	70.0	1.890	173	327	3,725	1,218,000
Winter	2.45	67.0	1.642	15	25	2,928	73,000
Spring	2.10	62.0	1.302	114	148	1,343	199,000
Summer	1.30	65.0	0.819	340	278	1,638	455,000
Passenger Pigeon[2]							
Fall	0.30	75.0	0.225	10,000	2,250	2,790	6,275,000
Raccoon							
Fall	3.39	63.0	2.136	182	369	4,734	1,842,000
Winter	2.82	58.0	1.637	91	149	3,431	511,000
Spring	3.10	48.0	1.488	18	27	1,343	36,000
Summer	4.90	65.0	3.185	26	83	5,423	450,000
White-tailed Deer							
Fall	44.30	65.0	28.795	41	1,181	2,544	3,004,000
Winter	44.90	65.0	29.185	29	846	2,544	2,152,000
Spring	38.80	62.0	24.056	15	361	1,258	454,000
Summer	37.15	65.0	24.148	52	1,256	1,626	2,042,000
Woodchuck							
Spring	3.10	61.0	1.89	58	110	1,258	148,000
Summer	2.89	67.0	1.94	280	543	2,990	1,624,000

[1] Mean weight based on the age and sex composition of the population.

[2] Optional resource.

Table 8. Cost estimates for procuring and processing fresh animal resources and procuring, processing, and storing, stored animal resources on Havens during the Early and Middle Woodland period.

Species	Hrs/ Animal Fresh	Hrs/ Animal Stored[1]	Hrs/kg Fresh	Hrs/kg Stored	Hrs/1000 kcal ME Fresh	Hrs/1000 kcal ME Stored
Black Bear						
Fall	62.85	--	1.27	--	0.34	--
Winter	41.95	61.39	0.89	1.31	0.32	0.46
Spring	79.35	--	2.46	--	1.83	--
Summer	53.90	--	1.32	--	0.47	--
Box Turtle						
Spring	0.52	0.58	4.13	4.63	3.72	4.17
Summer	1.04	--	8.30	--	7.48	--
Eastern Cottontail						
Fall	2.43	2.78	3.24	3.71	1.43	1.64
Winter	2.43	--	3.24	--	1.55	--
Spring	3.57	--	5.40	--	3.97	--
Summer	3.57	--	5.40	--	3.97	--
Wild Turkey						
Fall	11.10	12.50	2.52	2.88	0.92	1.05
Winter	16.40	--	3.72	--	1.36	--
Spring	57.70	--	15.39	--	6.67	--
Summer	32.30	--	15.86	--	10.02	--
Elk						
Fall	70.10	117.10	0.52	0.86	0.19	0.31
Winter	76.10	--	0.56	--	0.22	--
Spring	74.60	--	0.51	--	0.41	--
Summer	62.60	--	0.48	--	0.20	--
Gray Squirrel						
Fall	0.69	--	2.43	--	1.88	--
Winter	0.69	--	2.62	--	1.91	--
Spring	0.91	1.17	2.35	3.27	1.72	2.39
Summer	0.91	--	2.90	--	2.57	--

Table 8 cont. Cost estimates for procuring and processing fresh animal resources and procuring, processing stored animal resources on Haven during the Early and Middle Woodland period.

Species	Hrs/ Animal Fresh	Hrs/ Animal Stored[1]	Hrs/kg Fresh	Hrs/kg Stored	Hrs/1000 kcal ME Fresh	Hrs/1000 kcal ME Stored
Opossum/Raccoon						
Fall	2.00	3.00	1.01	1.36	0.25	0.33
Winter	4.42	–	1.64	–	0.80	–
Spring	3.55	–	2.68	–	2.00	–
Summer	2.68	–	2.29	–	0.72	–
Passenger Pigeon[2]						
Fall	0.20	0.35	0.89	1.53	0.32	0.55
White-tailed Deer						
Fall	30.10	–	1.05	–	0.42	–
Winter	30.40	44.2	1.04	1.51	0.41	0.59
Spring	31.60	–	1.32	–	1.05	–
Summer	29.60	–	1.23	–	0.76	–
Woodchuck						
Spring	2.15	–	1.14	–	0.91	–
Summer	2.15	2.95	1.11	1.47	0.37	0.49

[1] Stored costs were only estimated for the season where cost was lowest.
[2] Optional resource.

Energy Requirement Estimate

Weiss' (1973) life table MT 15-20 indicated that a 25-person hunter-gatherer band has 2 individuals of undetermined sex between the ages of 0 and 2, 7 individuals of undetermined sex 2 to 10 years old, 3 males and 3 females 10-20 years, 5 males and 4 females 20-50 years, and 1 individual of undetermined sex over 50 (Weiss 1973; Keene 1981). This sex and age structure has been adopted for the Havens band and is represented in Table 9.

The metabolizable energy requirements of this band were based on the National Research Council's recommended daily dietary allowances (in Wing and Brown 1979). The 2 youngest children required approximately 900 kcal ME/day and children 2 to 10 years required an average of 1600 kcal ME daily. Males between the ages of 10 and 20 required 3,000 kcal ME/day while females in this age class needed 2,400 kcal ME daily. Adult males between 20 and 50 years required an average of 2,700 kcal ME/day. Adult women in this age group required 2,000 kcal ME daily. The individual who is over 50-years old was assumed to require 2,100 kcal ME/day (Wing and Brown 1979). Based on this information, the Havens band required 52,800 kcal ME /day in each season except winter. The additional energy requirements in winter would increase the energy demand of the band to 56,800 kcal ME/day. Since this model is annual, but analyzed in 4 seasons, the required total daily kcal ME estimate for the band was multiplied by 91.25 days for each season. The result was an energy requirement of 4,818,000 kcal ME for all 3 seasons but winter. The winter energy requirement would have been 5,183,000 kcal ME for the band.

Table 9. Life table for an Early to Middle Woodland population of 25 with a sex ratio of 100:100. Age classes extrapolated from Weiss' table MT 15-50 (1973:119).

Age	%	Number	Male	Female	Undetermined[1]
0-2	9.1	2			2
2-10	29.6	7			7
10-20	23.9	6	3	3	
20-50	35.0	9	5	4	
50+	2.6	1			1

[1] Gender was not determined for uppermost and lowermost age classes.

Results

Interpretation

The annual diet selection model was composed of 4 seasonal models. The models were solved consecutively beginning with fall and ending with summer. The fall model was run first because fall was the season of greatest resource abundance and lowest resource cost.

The results of the seasonal models are represented in Tables 10-13. All food items were assigned to 1 of 4 resource classes: primary, secondary, tertiary, and marginal. Resources selected by the model were labelled primary resources. Because there is potential for error in cost estimates, I also categorized food items as primary resources if they required a cost reduction of 10% or less before being selected by the model. Food items that required a cost reduction of 11-25% before they would be selected were termed secondary resources. These resources were considered the most likely alternatives to the primary resources. Resources that required a cost reduction of 26-50% before being selected by the model were deemed tertiary resources. Although I believe the importance of these resources was low, they may have become valuable under certain environmental conditions (e.g., mast failures, fires). Food items that required a cost reduction greater than 50% to be selected by the model, were categorized as marginal resources. These items would probably have been only procured or used incidentally.

The last 2 columns of Tables 10-13 depict the degree that resource costs can vary before affecting the regimen of resources selected by the model. Column 5, Cost Range (- %), contained the percentage decrease in cost that is needed before a resource is selected by the model. Column 6, Cost Range (+ %), contains the percentage increase in cost that is acceptable before altering the regimen of resources selected by the model.

Fall Results

The fall model predicted the acquisition of elk, opossum and raccoon, and chestnuts (Table 10). All available elk (6 animals) were harvested, satisfying 47% of the forager's seasonal energy requirement. When resource costs are identical, as with opossum and raccoon and chestnuts, the linear programming algorithm selects the resource that appears first in the objective function. Rather than accept this arbitrary selection, I assumed that items of equal cost would have been acquired at the same rate. Therefore, the foragers remaining energy demand would have been equally satisfied by opossum (101 animals) and raccoon (56 animals) and chestnuts (669 kg). Secondary resources were passenger pigeon, if available. The tertiary resources were fresh and stored black bear, white-tailed deer, stored woodchuck, and bitter acorns.

The results of the model are robust. A cost decrease greater than 50% is required of 11 of the 17 untapped resources before they are selected by the model. Passenger pigeon was the most sensitive unutilized resource. A 22% cost decrease would permit this resource to enter the optimal diet regimen and would diminish the use of both chestnuts and opossum and raccoon.

Approximately 1,068 hours (0.47 hours/person daily) were required to satisfy the Havens foragers′ fall energy needs. If there were 100,000 more kcal ME of elk, the seasonal food acquisition cost would have declined by 6 hours. A 100,000 kcal ME decline in demand would have reduced cost by 25 hours. Because the 9 children less than 10 years old probably did not contribute significantly to food acquisition efforts, the 16 remaining band members would have spent 0.73 hours/ person foraging daily. Although these labor estimates may seem low, Reidhead (1981) predicted seasonal labor estimates for prehistoric people in Indiana as low as 0.7 hours/person daily. In the marginal environment of the Kalahari, the Kung spend 1.7 to 2.7 hours/person/day foraging (Lee 1968).

Table 10. Predicted fall food use on Havens of an Early and Middle Woodland band.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
Elk	2,270,000	Primary	0.19	--	32
Opossum and Raccoon	1,274,000	Primary	0.25	--	4
Chestnut	1,274,000	Primary	0.25	--	4
Passenger Pigeon[3]	--	Secondary	0.32	22	--
Black Bear	--	Tertiary	0.34	26	--
White-Tailed Deer	--	Tertiary	0.42	40	--
Bitter Acorns	--	Tertiary	0.48	50	--
Hickory Nuts	--	Marginal	0.64	61	--
Wild Turkey	--	Marginal	0.92	73	--
Eastern Cottontail	--	Marginal	1.43	83	--
Gray Squirrel	--	Marginal	1.88	87	--
Sweet Acorns	--	Marginal	2.97	92	--
Stored					
Black Bear	--	Tertiary	0.46	46	--
Woodchuck	--	Tertiary	0.49	49	--
White-Tailed Deer	--	Marginal	0.59	58	--
False Solomon's Seal	--	Marginal	0.91	73	--
Blueberries/Huckleberries	--	Marginal	1.05	76	--
Jack-In-The-Pulpit	--	Marginal	1.12	78	--
Gray Squirrel	--	Marginal	2.39	90	--
Box Turtle	--	Marginal	4.17	94	--

[1] Cost Range (- %) - Minimum percentage decrease in resource cost before a resource would be selected by the model.

[2] Cost Range (+ %) - Maximum percentage increase in resouce cost that would not alter the regimen of resources selected by the model.

[3] Optional resource.

Winter Results

The winter model predicted the acquisition of black bear, stored opossum and raccoon, stored chestnuts and white-tailed deer (Table 11). The 5 available black bear were harvested, furnishing 13% of the band's winter energy requirement. Stored opossum (135) and raccoon (75)

resource satisfied 33% of the band's seasonal energy needs and was also exhausted. Although this resource was selected in winter, its stored form indicated that it was procured in fall. Due to identical costs, stored chestnuts (747 kg) and white-tailed deer (24 animals) contributed equally (27%) to the band's winter energy requirement. Secondary resources in winter were stored woodchuck, and, if available, stored passenger pigeon. Tertiary resources were stored bitter acorns, stored hickory nuts, and opossum and raccoon.

Approximately 65% of the unutilized food resources were marginal and thus, would have required a cost reduction greater than 50% before being selected by the model. The most sensitive unutilized resource was stored woodchuck. A 16% cost reduction would have permitted woodchuck to become a primary resource.

The satisfaction of winter energy needs required 1,930 hours of labor. An additional 100,000 kcal ME of bear would have reduced the winter cost by 9 hours while a 100,000 kcal ME decrease in demand would have reduced cost by 41 hours. The labor expended for stored chestnuts and stored opossum and raccoon was actually spent in fall. Consequently, 789 hours were expended in winter and 1,141 hours were expended in fall to meet the band's winter energy requirement. Individuals older than 10 years would have foraged 0.54 hours/day in winter and 0.78 hours/day in fall to meet the winter energy demand.

Table 11. Predicted winter food use on Haven of an Early and Middle Woodland band.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
Black Bear	655,000	Primary	0.32	–	3
White-Tailed Deer	1,414,000	Primary	0.41	–	3
Opossum and Raccoon	–	Tertiary	0.80	49	–
Wild Turkey	–	Marginal	1.36	70	–
Eastern Cottontail	–	Marginal	1.43	71	–
Gray Squirrel	–	Marginal	1.91	79	–
Stored					
Opossum and Raccoon	1,700,000	Primary	0.33	–	18
Chestnut	1,414,000	Primary	0.41	–	3
Woodchuck	–	Secondary	0.49	16	–
Passenger Pigeon[1]	–	Secondary	0.55	25	–
Bitter Acorns	–	Tertiary	0.60	32	–
Hickory Nuts	–	Tertiary	0.71	42	–
False Solomon's Seal	–	Marginal	0.91	55	–
Blueberries/Huckleberries	–	Marginal	1.05	61	–
Wild Turkey	–	Marginal	1.05	61	–
Jack-In-The-Pulpit	–	Marginal	1.12	63	–
Eastern Cottontail	–	Marginal	1.64	75	–
Gray Squirrel	–	Marginal	2.39	83	–
Sweet Acorns	–	Marginal	3.14	87	–
Box Turtle	–	Marginal	4.17	90	–

[1] Cost Range (- %) - Minimum percentage decrease in resource cost before a resource would be selected by the model.

[2] Cost Range (+ %) - Maximum percentage increase in resource cost that wouldnot alter the regimen of resources selected by the model.

[3] Optional resource.

Spring Results

Stored chestnuts (2,529 kg) were the only resource selected by the spring model and the only primary resource (Table 12). Secondary resources were stored forms of woodchuck and, if available, passenger pigeon. False Solomon's seal rhizomes, stored hickory nuts, stored bitter acorns, and white-tailed deer were tertiary resources.

Approximately 70% of the unutilized food items would have required a cost reduction greater than 50% before being selected by the model. The most sensitive unutilized resource was stored woodchuck. A 16% cost decrease would have led to its selection by the model.

The band's spring energy requirement demanded 1,975 hours of labor. Because stored chestnuts were the only resource that were selected, all of these hours would have been expended in fall. Individuals greater than 10 years of age would have spent 1.35 hours/day foraging in fall to meet the spring ME damand.

Table 12 Predicted spring food use on Havens of an Early and Middle woodland band.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
False Solomon's Seal	–	Tertiary	0.64	36	–
Jack-In-The-Pulpit	–	Marginal	0.83	51	–
Woodchuck	–	Marginal	0.91	55	–
White-Tailed Deer	–	Marginal	1.05	61	–
Gray Squirrel	–	Marginal	1.72	76	–
Box Turtle	–	Marginal	3.72	89	–
Eastern Cottontail	–	Marginal	3.97	90	–
Wild Turkey	–	Marginal	6.67	94	–
Stored					
Chestnut	4,818,000	Primary	0.41	–	20
Woodchuck	–	Secondary	0.49	16	–
Passenger Pigeon[3]	–	Secondary	0.55	25	–
White-Tailed Deer	–	Tertiary	0.59	31	–
Bitter Acorns	–	Tertiary	0.60	32	–
Hickory Nuts	–	Tertiary	0.71	42	–
False Solomon's Seal	–	Marginal	0.91	55	–
Blueberries/Huckleberries	–	Marginal	1.05	61	–
Wild Turkey	–	Marginal	1.05	61	–
Jack-In-The-Pulpit	–	Marginal	1.12	63	–
Eastern Cottontail	–	Marginal	1.64	75	–

[1] Cost Range (- %) - Maximum percentage decrease in resource cost before a resource would be selected by the model.
[2] Cost Range (+ %) - Maximum percentage increase in resource cost that would not alter the regimen of resources selected by the model.
[3] Optional resource.

Summer Results

The summer model predicted the use of all harvestable woodchucks (280) and 1,677 kg of stored chestnuts (Table 13). These resources contributed 34% and 66%, respectively, to the band's summer energy requirement. The only secondary resource was stored passenger pigeon, if available. False Solomon's seal rhizomes, blueberries/huckleberries, fresh and stored white-tailed deer, stored bitter acorns, and stored hickory nuts were tertiary resources.

More than half the unutilized resources were accorded a marginal status. Stored passenger pigeon was the most sensitive unutilized resource; a 25% cost reduction would have led to its selection by the model. Approximately 1,910 hours were required to meet the band's summer energy requirement. Only 601 hours of labor were actually expended in summer. The remaining cost (1,309 hours) was incurred in fall. Individuals older than 10 years would have foraged 0.41 hours/day in summer and 0.90 hours/day in fall to meet the summer ME demand.

Table 13. Predicted summer food use on Havens of an Early and Middle Woodland band.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
Woodchuck	1,624,000	Primary	0.37	–	11
False Solomon's Seal	–	Tertiary	0.64	36	–
Blueberries/Huckleberries	–	Tertiary	0.70	41	–
White-Tailed Deer	–	Tertiary	0.76	46	–
Jack-In-The-Pulpit	–	Marginal	0.89	54	–
Gray Squirrel	–	Marginal	2.57	84	–
Eastern Cottontail	–	Marginal	3.97	90	–
Box Turtle	–	Marginal	7.48	95	–
Wild Turkey	–	Marginal	10.52	96	–
Stored					
Chestnut	3,194,000	Primary	0.41	–	2
Passenger Pigeon[3]	–	Secondary	0.55	25	–
White-Tailed Deer	–	Tertiary	0.59	31	–
Bitter Acorns	–	Tertiary	0.60	32	–
Hickory Nuts	–	Tertiary	0.71	42	–
Wild Turkey	–	Marginal	1.05	61	–
Eastern Cottontail	–	Marginal	1.64	75	–
Gray Squirrel	–	Marginal	2.39	83	–
Sweet Acorns	–	Marginal	3.14	87	–

[1] Cost Range (- %) - Minimum percentage decrease in resource cost before a resource would be selected by the model.

[2] Cost Range (+ %) - Maximum percentage increase in resource cost that would not alter the regimen of resources selected by the model.

[3] Optional resource.

Annual Foraging Strategy

Because the seasonal models did not contain riverine and valley resources, the results do not accurately describe an annual foraging strategy. Rather, they indicate the role of upland and mountain food resources in Early and Middle Woodland subsistence. The output of the seasonal models strongly suggest that fall was the optimal season for the exploitation of upland and mountain resources. Approximately 81% of the band's annual energy requirement was met in this season while winter and summer contributed 11% and 8%, respectively. Although the inclusion of riverine and valley food resources may have reduced the fall contribution to the band's annual energy budget, the total fall labor requirement 3.76 hours/person over 10 years daily) revealed that a substantial reliance on fall food items was possible.

Upland and mountain areas were important foraging locales in fall, primarily because of one abundant and low cost resource -- chestnuts. Of the metabolizable energy secured in fall, 67% was from chestnuts. Thus, it seems likely that Early and Middle Woodland people would have foraged in the upland and mountain areas during fall principally for chestnuts, with most of the harvest stored for use in other seasons. The presence of low-cost elk was probably an additional attraction. Although opossum and raccoon furnished 19% of the fall energy demand, these animals were probably more abundant and less costly in river and large creek floodplains. Therefore, these species may not have been as important as the model results suggest.

During winter, riverine and valley resources were less abundant and more costly than in other seasons (Keene 1981; Reidhead 1981). Thus, I believe the winter model's selection of black bear and white-tailed deer is probably an accurate reflection of the focus of winter foraging.

The seasonal models predicted that no food resources would have been procured in upland and mountain areas in the spring. However, this is the season where the cost of such riverine resources as fish were low (Reidhead 1981; Keene 1981). I believe that these resources would have been procured to supplement stored chestnuts.

The only resource that the models predicted would be obtained in summer was woodchuck. Woodchuck were likely more abundant in the lowlands. Therefore, I believe they would have been specifically sought in these areas, not in uplands or mountains, during the summer.

The analysis of the results indicated that Early and Middle Woodland people would have focused their food procurement activities in the uplands and mountains in the fall, with fall resources stored for use in other seasons. In winter, the intensity of foraging activity would have declined, but the focus would have remained in the uplands and mountains. During spring and summer, foraging would have been directed at valley and riverine resources.

Discussion

Model Results and the Archeological Record

Mountain Woodland sites with assemblages of faunal and floral remains are scarce in western Virginia; those available have preservation, collection, and analysis biases (McDonald 1986). Therefore, I decided that verifying the model with available archeological data was not feasible. However, I felt some comparison of the model's output with the archaeological record was necessary to add support and context for the work and to allow reasonably simple efforts at refutation of the results.

Archaeologists have maintained that fall was the dominant season of upland and mountain food exploitation from the Early Archaic period through the Woodland period in western Virginia. (Gardner 1977; Custer 1980; Brashler 1984). This assertion is supported by the results of the model. The amount of ME obtained during fall was 4-times greater than the 3 other seasons combined.

The regimen of resources that archaeologists have contended Early Woodland foragers exploited in upland and mountain ecosystems differs from the model's output. Among archaeologists, there has been general agreement that hickory nuts, acorns, and white-tailed deer were the major upland and mountain food resources. (Spencer and Jennings 1977; Custer 1980; Geier 1983). This project suggested that chestnuts, opossum, raccoon, and elk were the primary upland and mountain food resources. These differences required a closer examination of both the archaeological record and the model.

The omission of chestnuts from archaeologist's mountain food resource regimen was particularly striking. Although this project provides the first quantitative estimate of chestnut mast production, the chestnut component of the Appalachian forest has long been recognized as a major source of hard mast. Chestnuts were not only abundant, but also an efficiently processed and energy-rich resource, as this project has demonstrated. Thus, southeastern tribes such as the Cherokee, not suprisingly, considered chestnuts to be the "most valuable nut food" (Goodwin 1977).

I believe the low food value that archaeologists have placed on chestnuts is a reflection of biased archaeological data, not the foraging practices of prehistoric people. Chestnut remains have yet to be uncovered in western Virginia archaeological sites. In fact, throughout the Appalachians, Chestnut remains are a rare archaeological find (Yarnell and Black 1985). Hickory nut remains, on the other hand, are plentiful, and acorn remains are also common (Yarnell and Black 1985). Part of the explanation of the different preservation of these nut types may lie in the preservation process itself.

Nut remains uncovered at most archaeological sites in the southeast have been carbonized shell fragments (Petruso and Wickens 1984; Ison 1987). Thin, fragile chestnut shells were more susceptible to rapid decay following carbonization than the thicker and more robust hickory nut shells (Ison 1987). Further, hickory nut shells may have been used as a cooking fuel because of their ability to produce "an excellent small, hot, virtually smokeless fire" (Smith 1985). Thus, not only did hickory nut shells have higher preservation qualities than chestnuts, they also had a greater chance of being transformed into a state that was optimal for preservation.

Dry rockshelters are one of the few Appalachian locations that provide conditions for preservation of uncarbonized nut remains (Ison 1987). Unfortunately, the proportion of each nut type uncovered during most excavation of dry rockshelters were not recorded (Ison 1987). However, preliminary findings from the Cold Oak Rockshelter in southeastern Kentucky reveal a high proportion of Late Archaic chestnut remains (Ison 1987).

Acorn remains have also been more prevalent at western Virginia archaeological sites than chestnut remains. Acorn shells are thicker than chestnut shells, though the difference between them is substantially less than between hickory and chestnut shells. This slight advantage of thickness may have provided acorn shells with a higher preservation potential than chestnut shells. However, a more probable important factor contributing to biased archaeological data, is misidentification. Ison (1987) has stated that archaeologists may often have misconstrued chestnut shell fragments as acorn shell fragments. This should not be surprising since few archaeologists have examined intact American chestnut shells.

Therefore, although the archaeological record and this project are not in accord on the food value of chestnuts during the Early and Middle Woodland period, it seems clear that archaeologists themselves do not have sufficient data to determine the relative food value of nut types. I believe that future excavations of ethnobotanical remains from dry rockshelters, re-analysis of "acorn" shell fragments, and use of energy analyses of foodstuffs may diminish the gap between the findings of this project and the archaeological record.

Another discrepancy between the model results and archaeological data can be found in relative estimates of white-tailed deer utilization. White-tailed deer bones dominate the faunal assemblages from Archaic and Woodland sites in western Virginia (Benthall 1971; MacCord 1976; Barber and Barody 1977; Buchanan 1980; Egloff and Reed 1980; MacCord 1981). Although this project classified white-tailed deer as a primary resource during the winter, it only provided 15.8 % of animal-derived ME during an "average" year. The abundant white-tailed deer remains in western Virginia archaeological sites and the merely moderate food value this project estimated from deer suggest that this resource may have had other benefits or uses.

Ethnographic accounts reveal that deer hides were preferred for clothing (Swanton 1946; Goodwin 1977). Although elk and bear hides were larger, their thickness made them unsuitable for everyday wear in the Appalachians (Keene 1981; McCabe 1982). Gramly (1977) estimated that the Huron of Ontario required an average of 3.5 deer hides/person each year to satisfy minimum clothing needs. Thus, approximately 88 deer hides would have met the annual clothing requirement for the Havens foragers. With acquisition of food energy as the sole goal, the model predicted the Havens foragers would have killed 24 deer. By not taking into account the non-food value of white-tailed deer, the model likely underestimated the utilization of white-tailed deer. While 88 deer were necessary for the band, a maximum of 52 deer could have been obtained from Havens annually without depleting the breeding stock. To obtain the 88 deer and meet the clothing needs of the Havens foragers, the foraging territory would have had to expand to 5000 ha, a 72% increase. This analysis indicates, therefore, that in upland Appalachian ecosystems, human density was limited not by food needs, but by clothing requirements.

Anthropological research has produced support for this finding. The territoriality of the Netsilik Eskimo and the natives of of northeastern North America and the Upper Mississippi River Valley is believed to have been the product of the demand for deer hide clothing (Hickerson 1965; Gramly 1977).

A comparison between the thermoregulatory morphology of humans and other mammals reveals the basis for clothing's critical role. All mammals that live in temperate climates, except humans, have a pelage or a layer of subcutaneous blubber. These structures provide natural insulation, reducing thermal dissipation from radiation, evaporation, convection (wind effects), metabolism, and conduction. Without a pelage or blubber layer to conserve energy, humans must acquire insulation from external sources.

Finally, remains of opossum and raccoon have been uncovered in smaller quantities than the model has predicted. Providing 33% of animal-derived ME, opossum and raccoon appeared in the model results as the dominant faunal resource. However, of the 18 archaeological sites in western Virginia with published data on faunal assemblages, raccoon remains have been found at 11 sites and opossum remains at only 2 sites. The remains of these species were not abundant at any site. I believe the difference between opossum and raccoon use estimates was at least partially due to the underestimate of deer use. Utilization of deer at the rates necessary to meet the minimum clothing requirement would have substantially reduced opossum and raccoon use.

There is also the possibility that opossum and raccoon remains may have been underrepresented in archaeological faunal assemblages. The predominance of deer bones may have been partially due to their being larger and more dense, and therefore more likely to be preserved than the fragile opossum and raccoon bones.

Moreover, domestic dogs, woodland rodents, and wild carnivores may have completely consumed opossum and raccoon bones.

Discrepancies between archaeological data and model results are minimal for estimates of elk utilization. Elk remains have been found in 50% of western Virginia faunal assemblages. Although the model predicted that elk would have provided 25.4% of animal-derived ME, only 6 elk would have been acquired annually. Thus, an abundance of elk remains would not be expected. In addition, elk were probably too large to carry back to camp whole. Rose (1986) indicated that elk carcasses would have been dismembered at kill sites, with only useable portions brought to camps.

Results of Model Run Without Storage Capabilities

The emergence of pottery-making skills during the Early Woodland period in western Virginia (Gardner 1984) allowed food to be securely stored at a relatively low cost. By predicting that 57% of the Havens foragers' annual ME demand was satisfied by stored food, the seasonal models suggest this technological advance had considerable impact on diet composition. To investigate this hypothesis more thoroughly, I ran the model without stored food items (model B).

The results of this run differed markedly from the run that did include stored food. When stored food was unavailable, diet richness (the number of different items consumed regardless of their proportional contribution) increased by 50% with wild turkey, eastern cottontail, and false Solomon's seal rhizome added to the diet.

To consider "evenness" of food resource use, I used the following equation:

$$B = (\sum_{i=1}^{n} p_i^2)^{-1}$$

where B is diet breadth, p_i is the proportion of food type *i* in the diet, and *n* is the number of items used (Christensen 1980). When stored food items were not available, diet breadth increased from 2.90 to 4.75. Diet richness and breadth increased because the foragers, unable to take advantage of a surplus of an inexpensive resource, had to procure several less-abundant and more-costly resources.

Perhaps the most striking difference between the results of the original model and model B was a change in annual cost. When stored food was unavailable, the number of hours required to satisfy the band's annual ME demand increased from 6883 to 10,817, a 57% increase. Clearly, this would have reduced the number of hours that could be spent on procuring clothing and shelter. Presentation of the actual results of model B will allow a more precise understanding of how the lack of storage technology affected diet composition.

Both models produced the same results for fall (Table 14). The results of model B (Table 15) included two additional resources, wild turkey (109) and eastern cottontail (384) in winter. These items replaced stored chestnut and stored opossum and raccoon. The number of white-tailed deer that were acquired increased from 24 to 29. Gray squirrel was elevated from a marginal to a secondary resource. The cost to meet the seasonal ME demand increased from 1830 hours to 4020 hours, with a 1.49 hours/day increase in the amount of labor required from individuals over 10 years.

False Solomon's seal rhizomes replaced chestnuts as the sole spring resource in the model B results (Table 16). There was a 56% increase in the cost of the spring ME requirement. The resource status of Jack-in-the-pulpit corms rose from marginal to secondary status.

False Solomon's seal replaced both stored chestnuts and fresh woodchuck in model B's summer results (Table 17). Woodchuck retained its primary resource status. Blueberries/huckleberries and Jack-in-the-pulpit corms were elevated to secondary resources. There was a 38% cost increase to meet the seasonal ME requirement.

The major differences in the diet selected by model B was the emergence of false Solomon's seal rhizome as a staple and the substantially diminished use of chestnut.

When stored food was unavailable, false Solomon's seal contribution to the band's annual ME demand increased from 0% to 40.1% while chestnut's contribution dropped from 54.4% to 6.5% (Figs. 1 and 2). Wild turkey and eastern cottontail, resources that were unutilized when stored food was available, furnished 12.4% of the annual ME requirement when there were no stored foods. Other marked differences in the results of model B and the original model were a 44 % decline in opossum and raccoon use and a 26% increase in white-tailed deer use.

The results of the original model and model B may highlight differences between Late Archaic and Early and Middle Woodland food procurement strategies. The only significant technological difference between these periods was the lack of pottery during the Late Archaic. The storage vessels of the Late Archaic were made of steatite. The cost of these containers was probably quite high, because steatite could only be obtained through trade or a journey of over 150 km (Custer 1980; Catlin 1982). The cost of clay pots was substantially lower. Clay was a common resource in the region, and the construction of clay pots required less labor than steatite pots. Thus, the lack of inexpensive storage technology likely minimized dependence on stored food during the Late Archaic. Based on the results of this project, diet richness and breadth would have been higher in the Late Archaic period than during the Early Woodland period. In addition, the importance of a major fall resource (e.g., chestnuts) would have been greatly diminished, with food procurement spread more evenly across the seasons.

Table 14. Predicted fall food use by a prehistoric band on Havens without storage capabilities.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
Elk	2,270,000	Primary	0.19	–	32
Opossum and Raccoon	1,274,000	Primary	0.25	–	4
Chestnut	1,274,000	Primary	0.25	–	4
Passenger Pigeon[3]	–	Secondary	0.32	22	–
Black Bear	–	Tertiary	0.34	26	–
White-Tailed Deer	–	Tertiary	0.42	40	–
Bitter Acorns	–	Tertiary	0.50	50	–
Hickory Nuts	–	Marginal	0.71	65	–
Wild Turkey	–	Marginal	1.05	73	–
Eastern Cottontail	–	Marginal	1.43	83	–
Gray Squirrel	–	Marginal	1.88	87	–
Sweet Acorns	–	Marginal	2.97	92	–

[1] Cost Range (- %) - Minimum percentage decrease in resource cost before a resource would be selected by the model.

[2] Cost Range (+ %) - Maximum percentage increase in resource cost that would not alter the regimen of resources selected by the model.

[3] Optional resource.

Table 15. Predicted winter food use by a prehistoric band on Havens without storage capabilities.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
Black Bear	655,000	Primary	0.32	–	374
White-Tailed Deer	1,711,000	Primary	0.41	–	249
Opossum and Raccoon	383,000	Primary	0.80	–	79
Wild Turkey	1,784,000	Primary	1.05	–	36
Eastern Cottontail	650,000	Primary	1.43	–	1
Gray Squirrel	–	Secondary	1.91	25	–

[1] Cost Range (- %) - Minimum percentage decrease in resource cost before a resource would be selected by the model.

[2] Cost Range (+ %) - Maximum percentage increase resource cost that would not alter the regimen of resources selected by the model.

Table 16. Predicted spring food use by a prehistoric band on Havens without storage capabilities.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
False Solomon's Seal	4,818,000	Primary	0.64	–	42
Jack-In-The-Pulpit	–	Secondary	0.83	23	–
Woodchuck	–	Tertiary	0.91	30	–
Eastern Cottontail	–	Marginal	1.43	55	–
Gray Squirrel	–	Marginal	1.72	63	–
Box Turtle	–	Marginal	3.72	83	–

[1] Cost Range (- %) - Minimum percentage decrease in resource cost before a rresource would be selected by the model.

[2] Cost Range (+ %) - Maximum percentage increase in resource cost that wouldnot alter the regimen of resources selected by the model.

Table 17. Predicted summer food use by a prehistoric band on Havens without storage capabilities.

Resource	Kcal ME Acquired	Resource Status	Hours/ 1000 Kcal ME	Cost Range[1] - %	Cost Range[2] + %
Fresh					
Woodchuck	1,624,000	Primary	0.37	–	73
False Solomon's Seal	3,194,000	Primary	0.64	–	13
Blueberries/Huckleberries	–	Secondary	0.72	11	–
Jack-In-The-Pulpit	–	Secondary	0.83	23	–
Gray Squirrel	–	Marginal	2.57	75	–
Eastern Cottontail	–	Marginal	3.97	84	–
Box Turtle	–	Marginal	7.48	91	–

[1] Cost Range (- %) - Minimum percentage decrease in resource cost before a resource would be selected by the model.

[2] Cost Range (+ %) - Maximum percentage increase in cost that would not alter the regimen of resources selected by the model.

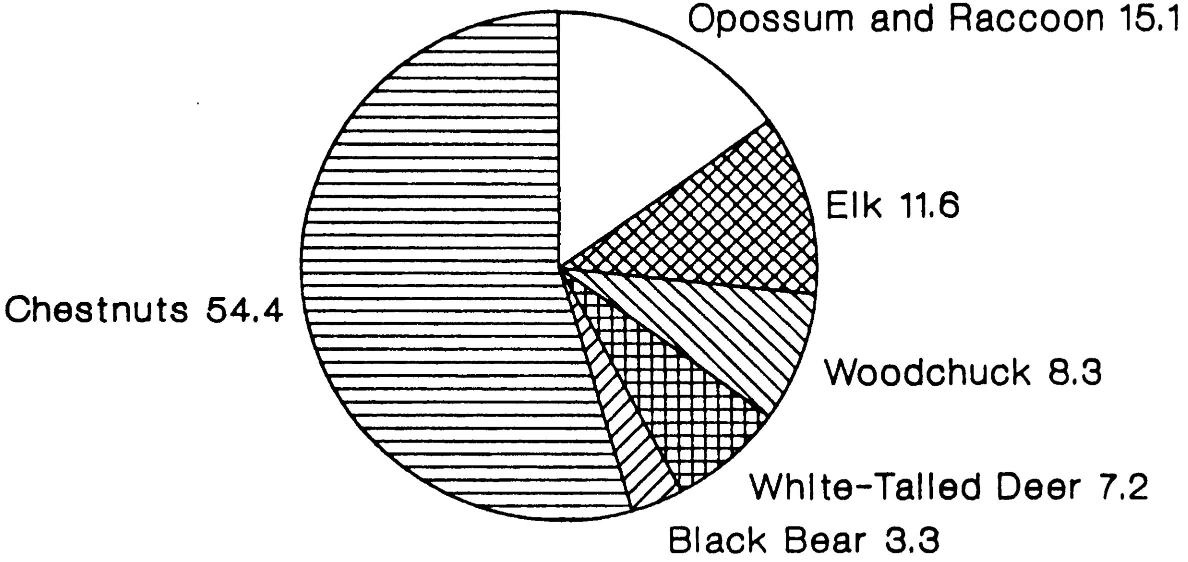

Figure 1. Percentages of food resource contributions to the annual ME demand of the Havens foragers during the Early and Middle woodland period.

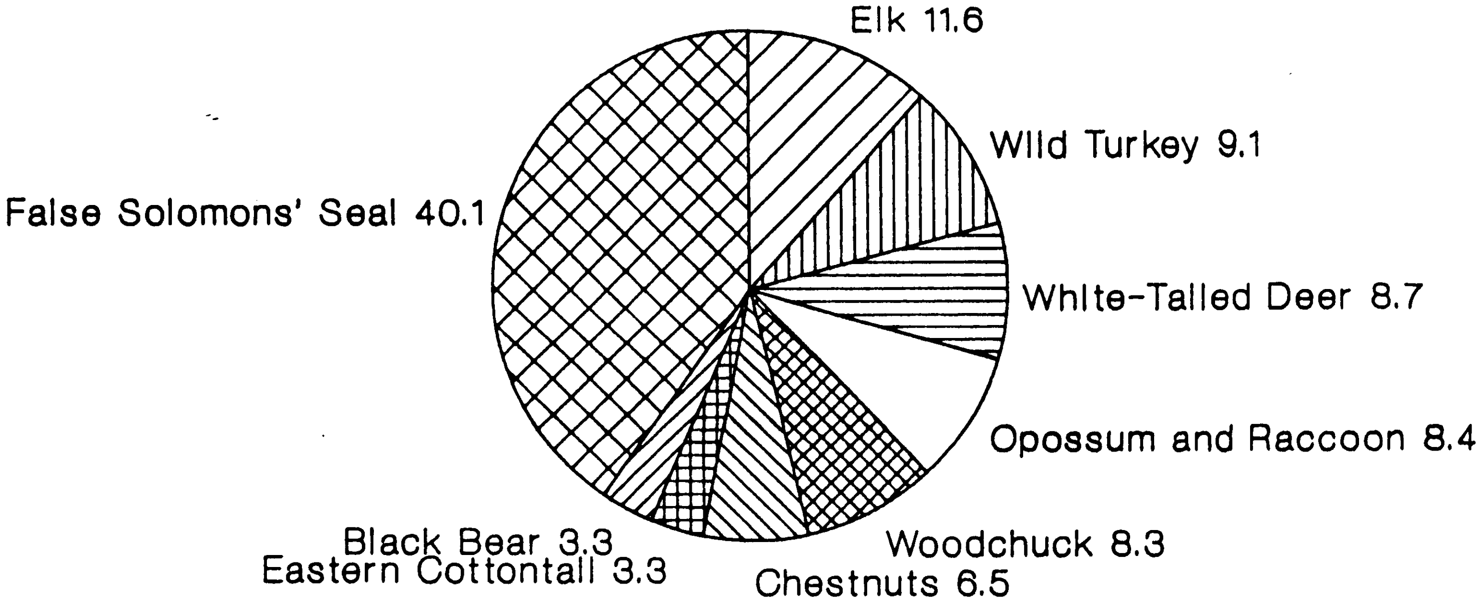

Figure 2. Percentages of food resource contributions to annual ME demand of the Havens foragers when stored food was unavailable.

Overview

The goal of this project was to develop an ecological history of Virginia's Ridge and Valley Province that not only illuminated past ecological relationships, but also provided information that could improve land management decisions. I approached this goal from "wide-angle" as well as "telephoto" perspectives. The wide-angle perspective was provided by the overview of western Virginia's prehistoric vegetation, wildlife, and humans. The telephoto perspective was provided by an investigation of a single ecological relationship (human energy demand--upland food resources) within a limited geographic area and time period. This dual-perspective approach directly addressed one facet of the project's goal--illumination of past ecological relationships--permitting a degree of intimacy and clarity often absent in ecological histories. However, I did not use this approach to tackle specific land management problems. Because past and present conditions are inextricably connected, I believed that an ecological history would naturally generate insight into contemporary natural resource management issues.

Using the wide-angle perspective, I created an ecological history of western Virginia that synthesized research from a wide array of sources and challenged traditional beliefs (e.g., a grassland-dominated Shenandoah Valley). However, the utility of this ecological history for natural resource managers cannot be predicted. Clearly, information such as the compostion of the pre-Euroamerican forest has potential utility. Yet actual utility can only be determined by a study that tests this document's ability to affect the decisions of natural resource managers.

I believe the telephoto perspective gave clarity and structure to an ecological relationship that previously had been obscured by sparse archaeological evidence.

An upland food resource regimen for Early and Middle Woodland people based on an ecological reconstruction and studies of human foraging behavior was developed. Creating this regimen allowed the project to overcome the limitations of the archaeological record and to produce reasonable insight into food resources radically different than those traditionally advanced by archaeologists. In additon, this project indicated that the availabilty of clothing, not food, limited Early Woodland population density. Although these conclusions have not been validated, they can be transformed into testable hypotheses for inductive explorations. Other epistemological bases as tests for the knowledge presented here seem equally or more relevant.

Despite a focus on a 2500-year-old ecological relationship, this component of the project did expose information that may provide solutions to current land management problems. Without chestnuts, the cost of the Havens foragers' diet would have been markedly higher. This finding spurred me to investigate the impact that the demise of the American chestnut had on Appalachian wildlife (Diamond et al. in prep.). Wildlife research has revealed that the variability of acorn mast crops and acorn mast failures, in particular, can limit the density of wildlife populations (Harlow et al. 1975; Rogers 1976). After the chestnut blight, Appalachian forests have been almost exclusively dominated by oaks (Woods and Shanks 1959; Karban 1978; Stephenson 1986). I hypothesized that the present oak-dominated Appalachian forest has substantially higher mast production variability and concommitantly a lower carrying capacity for mast-dependent species than the pre-blight forest. Research validating this hypothesis may encourage timber harvesting regimes that conserve chestnut stump sprouts and increase support for efforts to develop naturally reproducing, blight-resistant chestnuts.

This example illustrates that knowledge of the past becomes relevant to the problems of the present only as links between the two are recognized and that the practical value of an ecological history can reside in its role as a stimulus to questions and new answers.

Literature Cited

Adovasio, J. and R.C. Carlisle. 1986. Pennsylvania pioneers. Nat. Hist. 95:20-27.

Althoff, D.P. 1983. Daytime home range, habitat selection, and microenvironments used by cottontail rabbits in central Pennsylavania. Ph.D. Diss., Pennsylvania State University, University Microfilms International, Ann Arbor, Mich. 167pp.

Aldrich, J.W. 1967. Historical background. Pages 3-16 *in* O.H. Hewitt (ed.), The Wild turkey and its management. Wildlife Society, Wash. D.C. 589 pp.

Alvord, C.W. and L. Bidgood (eds.). 1912. First exploration of the Trans-Alleghany region by the Virginians, 1650-1674. Arthur H. Clark, Cleveland, Ohio. 275 pp.

Anderson, A. 1984. The extinction of moa in southern New Zealand. Pages 728-740 *in* P. Martin and R. Klein (eds.), Quaternary extinctions. University of Arizona Press, Tuscon, Az. 892pp.

Ashe, W.W. 1922. Forest types of the Appalachians and White Mountains. J. Elisha Mitchell Scient. Soc. 37:184-198.

Audubon, J.J. 1831. Ornithological biography, or an account of the habits of the birds of the United States of America. Vol. 1. Judah Dobson, Philadelphia, Pa. 527pp.

Bailey, J.A. 1969. Trap responses of wild cottontails. J. Wildl. Manage. 33: 48-58.

Baker, R.H. 1983. Michigan mammals. Michigan State University Press, East Lansing, Mich. 642 pp.

Barber, M.B. 1980. Prehistoric man beyond the Blue Ridge: a summary. Paper presented at Blue Ridge Symposium, Roanoke College, Feb. 29, 1980. 27pp.

Barber, M.B. and J.L. Barody, 1977. Analysis of vertabrate faunal remains from the Shannon site, Montgomery County, Virginia. Q. Bull. Archeol. Soc. Va. 31:101-113.

Barkalow, F.S., Jr., R.B. Hamilton and R.F. Soots, Jr. 1970. The vital statistics of an unexploited gray squirrel population. J. Wildl. Manage. 34:489-500.

Barrett, S.W. 1980. Indian fires in the pre-settlement forests of western Montana. Pages 35-41 *in* M.A. Stokes and J.H. Dietrich (eds.), The proceedings of the fire history workshop. General Technical Report RM-81, USDA, Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colo., 142 pp.

Barry, R.G. 1983. Late Pleistocene climatology. Pages 390-407 *in* H.E. Wright Jr. (ed.), Late-Quaternary enviroments of the United States. Vol. 1. The late Pleistocene. Univ. of Minnesota Press, Minneapolis, Minn., 407pp.

Bartlett, C.S., Jr. 1980. The Arrington site: an Early to Middle Woodland campsite at Abingdon, Virginia. Q. Bull., Archeol. Soc. Va., 35:35-48.

Bartram, W. 1791. Travels through North and South Carolina, Georgia, East and West Florida, the Cherokee Country, the extensive territories of the Muskogulges or Creek Confederacy, and the country of the Choctaws. Containing an account of the soil and natural productions of those region; together with observations on the manners of the Indians. James and Johnson, London. 520pp.

Beck, D.E. 1977. Twelve-year acorn yield in southern Appalachian oaks. U.S.D.A. For. Ser. Res. Note SE-244, Southeast. For. Exp. Sta., Asheville, N.C. 8pp.

Benthall, J.L. 1969. Archaeological investigation of the Shannon site. Virginia State Library, Richmond Va. 291pp.

Benthall, J.L. 1971. The Litten site: a Late Woodland village complex. Q. Bull. Archeol. Soc. Va. 26:1-34.

Binford, M. W., M. Brenner, T.J. Whitmore, A. Higurera-Gundy, E.S. Deevey, and B. Leyden. 1987. Ecosystems, paleoecology, and human distrubance in subtropical and tropical America. Quat. Sci. 6:115-128.

Blake, E.A. and M.R. Wagner. 1987. Collection and consumption of pandora moth, *Coloradia pandora lindseyi* (Lepidoptera: saturniidae) larvae by Owens Valley and Mono Lake Paiutes. Bull. Am. Soc. Ent., 33:22-27.

Bonner, F.T. 1971. Chemical contents of southern hardwood fruits and seeds. USDA For. Serv. Res. Note SO-136, South. For. Exp. Stn., New Orleans, La. 3pp.

Botkin, S. 1980. Effects of human exploitation on shellfish populations at Malibu Creek, California. Pages 121-137 *in* T.K. Earle and A.C. Christenson (eds.), Modeling change in prehistoric subsistence economies. Academic Press, New York, N.Y. 261pp.

Boyd, S.M. Shostak, and M. Conner. 1988. The Paleolithic prescription. Harper and Row, New York, N.Y. 489 pp.

Boyer, W.P. 1982. Archaeological survey and site prediction: towards an understanding of prehistoric settlement in western Virginia. M.A. Thesis. Catholic University, Wash., D.C. 167pp.

Brashler, J. 1984. Exploitation of diffuse resources: Archaic settlement in mountainous West Virginia. Pages 5-24 *in* C.G. Geier, M.B. Barber, and G.A. Tolley (eds.), Upland archaeology in the east: symposium 2. U.S. Forest Service, Southern Region, Cultural Resources Report no.5, Atlanta, Ga. 283pp.

Brewer, L.G. 1982. The present status and future prospect for the American chestnut in Michigan. Mich. Bot. 21:117-128.

Briceland, A.V. 1987. Westward from Virginia: the exploration of the Virginia-Carolina frontier 1650-1710. University Press of Virginia, Charlottesville, Va. 227pp.

Buchanan, W.T. 1980. The Hall site, Montgomery County, Virginia. Q. Bull., Archeol. Soc. Va. 35:72-99.

Burns, T. A. and C. E. Viers, Jr. 1973. Caloric and moisture content of selected fruits and mast. J. Wildl. Manage. 37:585-587.

Burst, T.L. and M.R. Pelton. 1978. Some population parameters of the Cades Cove deer herd, Great Smoky Mountains National Park. Proc. Ann. Conf. Southeastern Game and Fish Comm. 32:339-347.

Caldwell, J.R. 1958. Trend and tradition in the prehistory of the eastern United States. American Anthropological Association Memoir 88, Springfield, Ill. 142pp.

Carbone, V.A. 1976. Environment and prehistory in the Shenandoah Valley. Ph.D. Diss., Catholic Univ., Wash., D.C. University Microfilms, Ann Arbor, Mich. 211pp.

Carbone, V.A. 1982. Environment and society in Archaic and Woodland times. Pages 39-52 *in* R.Moeller (ed.), Practicing environmental archaeology: methods and interpretations. Occasional Papers of the American Indian Archaeological Insitute No. 3, Washington, Conn. 173pp.

Carlock, D.M., R.H. Conley, J.M. Collins, P.E. Hale, K.G. Johnson, A.S. Johnson, M.R. Pelton. 1983. The tri-state black bear study. Tennessee Resources Agency Tech. Rep. 83-9, Knoxville, Tenn. 286pp.

Carney, D.W. 1985. Population dynamics and denning ecology of black bears in Shenandoah National Park, Virginia. M.S. Thesis, VPI and SU, Blacksburg, Va. 84 pp.

Carpenter, Max. 1973. The black bear in Virginia. Virginia Commission of Game and Inland Fisheries, Richmond, Va. 22pp.

Catlin, M., J.F. Custer, and R.M.Stewart. 1982. Late Archaic culture change in Virginia: a reconsideraton of exchange, population, growth, and migrations. Q. Bull., Archeol. Soc. Va., 37:123-140

Chapman, J.A., A.L. Harman, and D.E. Samuel. 1977. Reproductive and physiological cycles in the cottontail complex in western Maryland and nearby West Virginia. Wildl. Monogr. 56. 73pp.

Chapman, J.A., J.G. Hockman, and M.M. Ojeda. 1980. *Sylvilagus floridanus*, Mammalian species no. 136, Am. Soc. Mammal., 8pp.

Chapman, J.A., Hockman, J.G. and W.R. Edwards. 1982. Cottontails: *Syvilagus flordianus* and allies. Pages 83-123 *in* J.A. Chapman and G.A. Feldhammer (eds.), Wild mammals of North America: Biology, management and economics. John Hopkins University Press, Baltimore, Md. 1,147pp.

Chapman, J., P.A. Delcourt, P.A. Cridlebaugh, A.B. Shea, and H.R. Delcourt. 1982. Man-land interaction: 10,000 years of American Indian impact on native ecosystems in the lower Little Tennessee River Valley, eastern Tennessee. Southeastern Archeol. 1:115-121.

Christensen, A.L. 1980. Change in the human niche in response to population growth. Pages 31-72 *in* T.K. Earle and A.L. Christensen (eds.), Modeling change in prehistoric subsistence economies. Academic Press, New York, N.Y. 261 pp.

Charnov, E.L. 1976. Optimal foraging and the marginal value theorem. Theor. Pop. Bio. 9:129-136.

Clapham, W.B., Jr. 1973. Natural ecosystems. Macmillan Co., New York, N.Y.

Clarke, D.L. 1972. Models and paradigms in contemporary archaeology. Pages 1-61 *in* D.L. Clarke (ed.), Models in Archaeology. Metheun and Co. Ltd., London, Great Britain. 1055pp.

Connors, J.A. 1986. Quaternary geomorphic processes in Virginia. Pages 1-22 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia--a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Craig, A.J. 1969. Vegetational history of the Shenandoah Valley, Virginia. Pages 283-296 *in* United States Contributions to Quaternary Research, Special Paper 123. Geological Society of America, Boulder, Colorado.

Cushwa, C.T., R.L. Downing, R.F. Harlow, and D.F. Urbston. 1970. The importance of woody twig ends to deer in the Southeast. USDA Forest Serv. Res. Note SE-140, Southeastern Forest Exp. Station, Asheville N.C. 6pp.

Custer, J.F. 1980. Settlement-subsistence systems in Augusta County, Virginia. Q. Bull., Archeol. Soc. Va., 35:1-27.

Custer, J.F. 1984. A controlled comparison of Late Woodland settlement patterns in the Appalachian Highlands. Pages 75-101 *in* C.G. Geier, M.B. Barber, and G.A. Tolley (eds.), Upland archaeology in the east: symposium 2. U.S. Forest Service, Southern Region, Cultural Resources Report no.5, Atlanta, GA. 283 pp.

Dasmann, W.R. 1971. If deer are to survive. Wildlife Management Institute, Wash., D.C. 128pp.

Davis, M.B. 1976. Pleistocene biogeography of temperate deciduous forests. Geoscience and Man, 13:13-26.

Davis, M.B. 1983. Holocene vegetational history of the eastern United States. Pages 166-181 *in* H.E. Wright Jr. (ed.), Late- Quaternary environments of the United States. Vol. 2. The Holocene. University of Minnesota Press, Minneapolis, Minn. 277pp.

Davis, N.F. 1912. Chestnut culture. Pages 83-98 *in* The Pennsylvanian chestnut blight proceedings, Harrisburg, Pa, February 20th and 21st, 1912, C.E. Auginbaugh, Harrisburg, Pa. 254 pp.

Day, G.M. 1953. The Indian as an ecological factor in the northeastern forest. Ecol. 34:329-346.

Degraaf, R.M., G.M. Witman, and D.D. Rudis. 1981. Forest habitat for mammals of the northeast. U.S. Forest Service, Wash. D.C. 182pp.

Delcourt, H.R. 1979. Late-Quaternary vegetational history of the eastern highland rim and adjacent Cumberland Plateau of Tennessee. Ecol. Mon. 49:255-280.

Delcourt, H.R. and P.A. Delcourt. 1985. Quaternary palynology and vegetational history of the southeastern United States. Pages 1-37 *in* V.M. Bryant and R.G. Holloway (eds.), Pollen records of Late-Quaternary North American sediments. American Association of Stratigraphic Palynologists Foundation, Austin, Tex. 426pp.

Delcourt, H. and P.A. Delcourt. 1986. Late Quaternary vegetational change in the central Atlantic states. Pages 23-35 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia--a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Delcourt, P.A. and H.R. Delcourt. 1981. Vegetation maps for eastern North America: 40,000 yrs. B.P. to the present. Pages 123-165 *in* R.C. Romans (ed.), Geobotany II. Plenum Press, New York, N.Y. 263pp.

Delcourt, P.A. and H.R. Delcourt. 1983. Late-Quaternary vegetational dynamics and community stability reconsidered. Quat. Res. 13:111-132.

Delcourt, P.A. and H.R. Delcourt. 1984. Late-Quaternary paleoclimates and biotic responses in eastern North America and the western North Atlantic Ocean. Paleogeog. Paleoclim. Paleoecol. 48:263-284.

Delcourt, P.A., H.R. Delcourt, and J.L. Davidson. 1983. Mapping and calibration of modern pollen-vegetation relationships in the southeastern United States. Rev. Paleobot. Palynol. 39:1-45.

Delcourt, P.A., H.R. Delcourt, P.A. Cridlebaugh, and J. Chapman. 1986. Holocene ethnobotanical and paleoecological record of human impact on vegetation in the Little Tennessee River Valley, Tennessee. Quat. Res. 25:330-349.

Delcourt, H.R., P.A. Delcourt, and T. Webb. 1983. Dynamic plant ecology: the spectrum of vegetational change in space and time. Quat. Sci. Rev. 1:153-175.

Diamond, S.J., R.H. Giles, Jr., R.L. Kirkpatrick and, G. Griffin. 1989. The impact of the chestnut blight on Appalachian wildlife. (In prep.).

Dixon, K.A. 1977. Applications of archaeological resources: broadening the basis of significance. Pages 277-290 *in* M.B. Schiffer and G.J. Gummerman (eds.) Conservation archaeology: a guide for cultural resource management studies. Academic Press, New York, N.Y. 495pp.

Downs, A. 1949. Trees and food from acorns *in* Trees: the yearbook of agriculture 1949. U.S. Government Printing Office, Wash., D.C. 944pp.

Downs, A. and W.E. McQuilkin. 1944. Seed production of south Appalachian oaks. J. For. 42:913-920

Driver, H.E. 1969. Indians of North America. University of Chicago Press, Chicago Ill. 425 pp.

Durham, W.H. 1981. Overview: optimal foraging analysis in human ecology. Pages 218-231 *in* B. Winterhalder and E.A. Smith (eds.), Hunter-gatherer foraging strategies: ethnographic and archaeological analyses. University of Chicago Press, Chicago, Ill. 268pp.

Dutton, H.J. 1987. An assessment of the nutritional status and habitat quality of a southwestern Virginia deer herd. M.S. Thesis, VPI and SU, Blacksburg, Va. 168pp.

Earle, T.L. 1980. A model of subsistence change. Pages 1-30 *in* T.L. Earle and A.C. Christenson (eds.), Modeling change in prehistoric subsistence economies. Academic Press, New York, N.Y. 261pp.

Egloff, K. and C. Reed. 1980. Crab Orchard Site: a Late Woodland palisaded village. Q. Bull. Archeol. Soc. Va. 34:130-148.

Elzey, M.G. 1876. Untitled. Forest and Stream 7:122.

Elzey, M.G. 1878. Untitled. Forest and Stream 11:224.

Ernst, C.H. and R.W. Barbour. 1972. Turtles of the United States. Univ. Kentucky Press, Lexington, Ky. 347pp.

Eshelman, R. and F.Grady. 1986. Quaternary vertebrate localities of Virginia and their avian and mammalian fauna. Pages 43-70 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia--a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Farmer, F.A. and H.R. Neilson. 1967. The caloric value of meats and fish of northern Canada. J. Can. Diet Assoc. 28:173-178.

Eshelman, R. and F. Grady. 1986. Quaternary vertebrate localities of Virginia and their avian mammalian fauna. Pages 43-70 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia--a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Feit, H. 1973. The ethnoecology of the Waswanipi Cree: or how hunters can manage their resources. Pages 115-125 *in* B. Cox (ed.), Cultural ecology. McClelland and Stewart, Toronto.

Fitch, J.E. 1969. Fossil records of certain schooling fishes of the California current system. Calif. Coop. Oceanic Fish. Invest. Rep. 13: 71-80. Marine Research Committee, California Department of Fish and Game, Terminal Island, Calif.

Food and Agriculture Organization of the United Nations. 1974. Handbook on human nutritional requirements. FAO Nutritional Studies 28. Rome, Italy. 113 pp.

Foote, W.H. 1850. Sketches of Virginia, historical and biographical. Lippincott, Philadelphia, Pa.

Foster, H.D. and W.W. Ashe. 1908. Chestnut oak in the southern Appalachians. USDA, Forest Service Circ. 135. Wash., D.C. 23pp.

Gardner, W.M. 1977. Flint Run Paleo-Indian Complex and its implications for eastern North American prehistory. Pages 257-263 *in* W.S. Newman and B. Salwen (eds.), Amerinds and their paleoenviroments in northeastern North America. N.Y. Academy of Sciences Annals. Vol. 288. New York, N.Y. 328pp.

Gardner, W.M. 1981. What goes up must come down: transhumance in the mountainous zones of the Middle Atlantic. Pages 2-42 *in* C.R. Geier, M.B. Barber, and G.A. Tolley, Upland Archaeology in the east: a symposium. Cultural Resource Report no. 2, U.S. Forest Service, Southern Region, Atlanta, Ga. 359pp.

Gardner, W.M. 1982. Early and Middle Woodland in the Middle Atlantic: an overview. Pages 53-86 *in* R.Moeller (ed.), Practicing environmental archaeology: methods and interpretations. Occasional Papers of the American Indian Archaeological Insitute no. 3. Washington, Conn. 173pp.

Gardner, W.M. 1984. External cultural influence in the western Middle Atlantic: a neo-diffusionist approach. Pages 117-146 *in* C.G. Geier, M.B. Barber, and G.A. Tolley (eds.), Upland archaeology in the east: symposium 2. U.S. Forest Service, Southern Region, Cultural Resources Report no.5, Atlanta, Ga. 283 pp.

Gardner, W.M. 1986. Lost arrowheads and broken pottery: traces of Indians in the Shenandoah Valley. Thunderbird Publications, Manassas, Va. 98pp.

Garner, N.P. 1986. Seasonal movements, habitat selection, and food habits of black bears (*Ursus americanus*) in Shenandoah National Park, Virginia. M.S. Thesis. VPI and SU, Blacksburg, Va. 103pp.

Geier, C.R. 1981. Preliminary observations on aboriginal settlement on headwater streams of the James River, the Ridge and Valley Province of Virginia. Pages 225-249 *in* C.R. Geier, M.B. Barber, and G.A. Tolley, Upland Archaeology in the east: a symposium. Cultural Resource Report no. 2, U.S. Forest Service, Southern Region, Atlanta, Ga. 359pp.

Geier, C.R. 1981. A Late Woodland burial from the Hidden Valley Rockshelter, Bath County. Q. Bull., Archeol. Soc. Va. 35:113-138.

Geier, C.R. 1983. The continuum of Late Woodland/Protohistoric settlement along a section of the Jackson River in the Ridge and Valley Province of Virginia: an initial formulation. Q. Bull., Archeol. Soc. Va. 38:234-276.

Geier, C.R. 1984. Change in ceramic use and taxonomy along the headwaters of the James River. Pages 45-62 *in* C.G. Geier, M.B. Barber, and G.A. Tolley (eds.), Upland archaeology in the east: symposium 2. U.S. Forest Service, Southern Region, Cultural Resources Report no.5, Atlanta, Ga. 283 pp.

Geier, C.R. and D. Campbell. 1979. Cattle, sheep, and white-tailed deer: man in mountainous western Virginia. Vol. 3. Occasional Papers in Anthropology 6. James Madison University, Harrisonburg, Va. 307pp.

Geier, C.R., Hands, R.T., and M.K. Loftus. 1978. A cultural resource investigation: the Bath County pumped storage facility. Vol. 1. Theoretical approach. James Madison Univ. Occasional Papers in Anthropology 3. Harrisonburg, Va. 157pp.

Gelburd, D.E. and E.I. DeBloois. 1986. The future through the past. J. For. 84:31-32.

Gibbons, E. 1966. Stalking the healthful herbs. David McKay Company, Inc. New York, N.Y. 303pp.

Giles, R.H., Jr. 1978. Wildlife management. W.H. Freeman and Co., San Francisco, Calif. 416pp.

Goering, H.K. and P.J. Van Soest. 1970. Forage fiber and analyses: apparatus, reagents, procedures, and some applications. U.S. Dep. Agric. Handb. 379. 20pp.

Goodrum, P.D., V.H. Reid, and C.E. Boyd. 1971. Acorn yields, characteristics and management criteria of oaks for wildlife. J. Wildl. Manage. 35:520-532.

Goodwin, G.C. 1977. Cherokees in transition: a study of changing culture and environment prior to 1775. Univ. of Chicago, Department of Geography Research Paper no. 181. Chicago, Ill. 207pp.

Graham, R.W. 1979. Paleoclimates and late Pleistocene faunal provinces in North America. Pages 49-69 *in* R.L. Humphries and and D. Stanford (eds.), Pre-Llano cultures of the Americas: paradoxes and possibilities. Washington Anthropological Society, Washington, D.C.

Graham, R.W. 1986. Plant-animal interactions and Pleistocene extinctions. Pages 131-156 *in* D.K. Elliot (ed.), Dynamics of extinction. John Wiley and Sons, New York, N.Y. 294pp.

Graham, R.W. and E.L. Lundelius, Jr. 1984. Coevolutionary disequilibrium and Pleistocene extinctions. Pages 223-249 *in* P.S. Martin and R.G. Klein (eds.), Quaternary extinctions. Univ. of Arizona Press, Tuscon, Az. 892pp.

Gramly, R.M. 1977. Deerskins and hunting territories: competition for a scarce resource of the northeastern woodlands. Amer. Antiq. 42:601-604.

Griffin, G.J., F.V. Hevard, R.W. Wendt, and J.R. Elkins. 1983. Survival of American chestnut trees; evaluation of blight resistance and virulence in *Endothia parasitica*. Phytopath. 73:1084-1091.

Grizzel, R.A., Jr. 1955. A study of the southern woodchuck, *Marmota monax* Amer. Midl. Nat. 257-293.

Guilday, J.E. 1971. The Pleistocene history of the Appalachian mammal fauna. Pages 233-262 *in* P. Holt (ed.), The distributional history of the biota of the southern Appalachians: Part III. Vertebrates. VPI and SU Research Division Monograph 4. Blacksburg, Va. 221pp.

Guilday, J.E. 1984. Pleistocene extinction and environmental change: case study of the Appalachians. Pages 250-258 *in* P.S. Martin and R.G. Klein (eds.), Quaternary extinctions. Univ. of Arizona Press, Tuscon, Az. 892pp.

Guthrie, R.D. 1984. Mosaics, allochemics, and nutrients: an ecological theory of late Pleistocene megafaunal extinctions. Pages 259-298 *in* P.S. Martin and R.G. Klein (eds.), Quaternary extinctions. Univ. of Arizona Press, Tuscon, Az. 892pp.

Hack, J. and J.C. Goodlett. 1960. Geomorphology and forest ecology of a mountain region in the central Appalachians. Professional Paper 347, U.S. Geological Survey. Wash. D.C.

Handley, C.O. and C.P. Patton. 1947. Wild mammals of Virginia. Commonwealth of Virginia, Commission of Game and Inland Fisheries, Richmond, Va. 220pp.

Harlow, R.F, J.B. Whelan, H.S. Crawford, and J.E. Skeen. 1975. Deer foods during years of oak mast abundance and scarcity. J. Wildl. Manage. 39:330-336.

Harvill, A.M., Jr. 1970. Spring flora of Virginia. Mclain Printing Co.,, Parsons, W.V. 240pp

Hastorf, C.A. 1980. Changing resource use in subsistence agricultural groups of the prehistoric Mimbres River Valley, New Mexico. Pages 79-120 *in* T.K. Earle and A.L. Christenson (eds.), Modeling change in prehistoric subsistence economies. Academic Press, New York, N.Y. 261pp.

Haynes, D.W. 1984. Population dynamics and analysis. Pages 203-210 *in* L.K. Halls (ed.), White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pa. 870pp.

Hickerson, H. 1965. The Virginia deer and the intertribal buffer zones in the Upper Missippi River Valley. Pages 46-66 *in* A. Leeds and A.P. Vayda (eds.), Man culture, and animals. American Ethnological Society, Washington, D.C. 311pp.

Holman, J.A. 1986, The known herpetofauna of the late Quaternary of Virginia poses a dilemma. Pages 36-42 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia--a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Holmes, A.C. and G.C. Sanderson. 1965. Population and movements of opossums in east-central Illinois. J. Wildl. Manage. 29:287-295.

Howard, L.D. 1974. The atlatl: function and performance. Amer. Antiq. 39:102-104.

Ison, C.R. 1987. Man-pland relationships during the terminal Archaic along the Cumberland Plateau. Pages 86-99 *in* M.B. Barber (ed.). Upland archeology in the east: a third symposium. Cultural Resources Report no. 87-1, U.S.D.A Forest Service, Southern Region, Atlanta, GA 349 pp.

James, C.F. 1969. The woody flora of Virginia. Ph.D. Diss. University of North Carolina-Chapel Hill. University Microfilms, Ann Arbor Mich. 210pp.

Jaynes, R.A. 1984. Chestnuts, the big and the small of them. North. Nut Grow. Assoc. News. 37:3-4.

Jochim, M.A. 1976. Hunter-gatherer subsistence and settlement: a predictive model. Academic Press, New York, N.Y. 205pp.

Karban, R. 1978. Changes in an oak-chestnut forest since the chestnut blight. Castanea 43:221-228.

Kaufman, J.H. 1982. Raccoon and allies. Pages 567-585 *in* J.A. Chapman and G.A. Feldhammer (eds.), Wild mammals of North America: Biology, management and economics. John Hopkins University Press, Baltimore, Md. 1,147pp.

Kavasch, B. 1979. Native harvests: recipes and botanicals of the American Indian. Vintage Books, New York, N.Y. 202pp.

Keene, A.S. 1981. Prehistoric foraging in a temperate forest: a linear programming model. Academic Press, New York, N.Y. 274pp.

Keene, A.S. 1985. Nutrition and economy: models for the study of prehistoric diet. Pages 155-190 *in* R.I. Gilbert, Jr. and J.H. Mielke (eds.), The analysis of prehistoric diets. Academic Press, New York, N.Y. 436pp.

Keever, C. 1953. Present composition of some stands of the former oak-chestnut forest in the southern Blue Ridge Mountains. Ecol. 34:44-54.

Kercheval, S. 1833. A history of the Valley of Virginia. Samuel H. Davis, Winchester, Va.

King, T.R. and H.E. McClure. 1943. Chemical composition of some American wild feedstuffs. J. Agric. Res. 69:33-46.

Korstian, C.F. and P.W. Stickel. 1927. The natural replacement of blight-killed chestnut in hardwood forests of the Northeast. J. Agric. Res. 34:631-648.

Lee, R.B. 1968. What hunters do for a living, or, how to make out on scarce resources. Pages 30-48 *in* R.B. Lee and I. Devore (eds.), Man the hunter. Aldine Publishing Co., Chicago Ill. 415pp.

Leung, W.W., R.R. Butrum, and F.H. Chang. 1972. Proximate composition, mineral, and vitamin contents of East Asian food *in* Food composition table for use in East Asia. Bethesda, Md., U.S. Dept. Health Education, and Welfare and the Food and Agricultural Organization of the United Nations.

Lewis, H.T. 1977. Maskuta: The ecology of Indian fires in northern Alberta. Western Can. J. Anthro. 7:15-52.

Lewis, H.T. 1980. Hunter-gatherers and problems for fire history. Pages 115-119 *in* M.A. Stokes and J.H. Dietrich (eds.), The proceedings of the fire history workshop. General Technical Report RM-81, USDA, Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colo. 142 pp.

Lewis, J.C. 1967. Physical characteristics and physiology. Pages 45-72 *in* O.H. Hewitt (ed.), The wild turkey and its management. Wildlife Society, Washington, D.C. 589pp.

Livingston, S.D. 1987. Prehistoric biogeography of white-tailed deer in Washington and Oregon. J. Wildl. Manage. 51:649-654.

Lund, A.P. and W.M. Sandstrom. 1943. The proteins of various tree seeds. J. Agric. Res. 66:349-355.

Lundelius, C.L., Jr., R.W. Graham, E. Anderson, J. Guilday, J. Holman, D.W. Steadman, and S.D. Webb. 1983. Terrestrial vertebrate faunas. Pages 311-353 *in* H.E. Wright Jr. (ed.), Late-Quaternary enviroments of the United States. Vol. 1. The Late Pleistocene. Univ. of Minnesota Press, Minneapolis, Minn. 407pp.

MacCord, H.A. 1971. The Lipes site. Q. Bull. Archeol. Soc. Va. 26:53-106.

MacCord, H.A. 1976. The Thomas site, Montgomery County, Virginia. Q. Bull. Archeol. Soc. Va 30:113-135.

MacCord, H.A. 1979. The Flanary site, Scott County, Virginia. Q. Bull., Archeol. Soc. Va. 34:1-32.

MacCord, H.A. 1981. The Sullins site, Washington County, Virginia. Q. Bull., Archeol. Soc. Va. 36:94-121.

MacCord, H.A. 1984. The Trigg site, Radford, Virginia: a resume. Pages 178-179 *in* C.G. Geier, M.B. Barber, and G.A. Tolley (eds.), Upland archaeology in the east: symposium 2. U.S. Forest Service, Southern Region, Cultural Resources Report no.5, Atlanta, Ga. 283 pp.

MacCord, H.A. and W.J. Hranicky. 1979. A basic guide to Virginia prehistoric projectile points. Archeological Society of Virginia, Special Publication 6. Richmond, Va. 48pp.

Maril, R.L. 1986. Cannibals and Condos: Texans and Texas along the Gulf Coast. Texas A & M University Press, College Station, Tex. 113pp.

Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. American wildlife and plants: a guide to wildlife food plants. Dover Publications, N.Y. 500pp.

Martin, P.S. 1984. Prehistoric overkill: the global model. Pages 354-403 *In* P.S. Martin and R.G. Klein (eds.), Quaternary extinctions. Univ. of Arizona Press, Tuscon, Az. 892pp.

Martin, P.S. 1986. Refuting late Pleistocene extinction models. Pages 107-130 in D. Elliott (ed.), Dynamics of extinction. John Wiley and Sons, New York, N.Y. 294pp.

Martin, P.S. and H.E. Wright (eds.) Pleistocene extinctions: the search for a cause. Yale Univ. Press, New Haven, Conn. 453pp.

Martin, W.L., T.L. Sharik, and D.W. Smith. 1982. Phytomass and nutrient levels in the understory of an Appalachian oak forest in southwest Virginia. Bull. Torrey Bot. Club. 109:330-343.

Mason, O.T. 1902. Traps of the American Indian--a study in the psychology of invention. Pages 553-590 *in* Annual Report of the Board of Regents of the Smithsonian Institution. Wash., D.C. 728pp.

Matula, G.J., Jr. 1983. Physiological characteristics of cottontail rabbits from two localities in central Pennsylvania. Ph.D. Diss., Pennsylvania State University. University Microfilms International, Ann Arbor, Mich. 168pp.

Maxwell, H. 1910. The use and abuse of forests by the Virginia Indians. William and Mary Quart. Hist. Mag. 19:73-103.

Maxwell, J.A. and M.B. Davis. 1972. Pollen evidence of Pleistocene and Holocene vegetation on the Alleghany Plateau, Maryland. Quat. Res. 2:506-530.

McCabe, R.E. and T.R. McCabe. 1984. Of slings and arrows: an historical retrospection. Pages 19-72 *in* L.K. Halls (ed.), White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pa. 870pp.

McDonald, J.N. 1986. On the status of Quaternary vertebrate paleontology and zooarchaeology in Virginia. Pages 71-93 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia -- a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Mickelson, D.M., L. Clayton, D.S. Fullerton, and H.W. Borns, Jr. 1983. The Late Wisconsin glacial record of the Laurentide ice sheet in the United States. Pages *in* H.E. Wright Jr. (ed.), Late-Quaternary enviroments of the United States. Vol. 1. The Late Pleistocene. Univ. of Minnesota Press, Minneapolis, Minn. 407pp.

Miller, J.A. 1987. Fighting fungi with fungi. Biosci. 37:248-250

Montgomery, S.D., J.B. Whelan, and H.S. Mosby. 1975. Bioenergetics of a woodlot gray squirrel population. J. Wildl. Manage. 39:709-717.

Mosby, H.S. 1941. The wild turkey in Virginia, life history and management. Ph.D. Univ. of Michigan, Ann Arbor, Mich. 202pp.

Mosby, H.S. 1967. Population dynamics. Pages 113-146 *in* O.H. Hewitt (ed.), The wild turkey and its management. Wildlife Society, Wash., D.C. 589pp.

Mosby, H.S. 1969. The influence of hunting on the population dynamics of a woodlot gray squirrel population. J. Wildl. Manage. 35:59-73.

Mosby, H.S. and C.O. Handley. 1943. The wild turkey in Virginia: its status, life history and management. Virginia Commission of Game and Inland Fisheries. Richmond, Va. 281pp.

Munson, P.J., P.J. Parmalee, and R.A. Yarnell. 1971. Subsistence ecology of Scovill, a terminal Middle Woodland village. Amer. antiq. 36:410-431.

Murie, O.J. 1951. The elk of North America. Stackpole Books, Harrisburg, Pa. 279pp.

Mutch, R.W. 1980. Workshop summary: who cares about fire history? Pages 138-140 *in* M.A. Stokes and J.H. Dietrich (eds.), The proceedings of the fire history workshop. General Technical Report RM-81, USDA, Forest Service, Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colo. 142 pp.

National Academy of Sciences. 1971. Atlas of nutritional data on United States and Canadian feeds. Natl. Acad. Sci. Wash., D.C., 772pp.

Neill, M. 1987. For forager Justin Rashid, the woods are lovely dark and deep-and filled with things he can eat. People 28 (16):125-127.

Nelson, T.C. 1955. Chestnut replacement in the southern highlands. Ecol. 36:352-359.

Nelson, T.C. 1959. Silvical characteristics of mockernut hickory. U.S. Dep. Agric. For. Serv., Southeast. For. Exp. Stn. Pap. 105. 10pp.

Nelson, T.C. 1961*a* Silvical characteristics of shagbark hickory. U.S. Dep. Agric. For. Serv., Southeast. For. Exp. Stn. Pap. 135. 11pp.

Nelson, T.C. 1961*b* Silvical characteristics of pignut hickory. U.S. Dep. Agric. For. Serv., Southeast. For. Exp. Stn. Pap. 137. 10pp.

Nixon, C.M., W.R. Edwards, and L. Eberhardt. 1967. Estimating squirrel abundance from live-trapping data. J. Wildl. Manage. 31:96-101.

Nixon, C.M., M.W. McClain, and R.W. Donohoe. 1975. Effects of hunting and mast crops on a squirrel population. J. Wildl. Manage. 39:1-25.

Nixon, C.M., M.W. McClain, and L.P. Hansen. 1980. Six years of hickory seed yields in southeastern Ohio. J. Wildl. Manage 44:534-539.

O'Connell, J.F. and K. Hawkes. 1981. Alyawara plant use and optimal foraging theory. Pages 99-125 *in* B. Winterhalder and E.A. Smith (eds.), Hunter-gatherer foraging strategies: ethnographic and archaeological analyses. Univ. of Chicago Press, Chicageo Ill. 268pp.

Olsen, G.H. 1983. Population dynamics of raccoon in Massachusetts. Ph.D. Diss., University of Massachusetts. University Microfilms International, Ann Arbor, Mich. 179pp.

Olsen, L.D. 1973. Outdoor survival skills. Brigham Young University Press, Provo, Utah. 254pp

Parmalee, P.W., W.E. Klippel, and A.E. Bogan. 1982. Aboriginal and modern freshwater mussel assemblage (Pelcypoda:Unionidae) from the the Chickamauga Reservoir, Tennessee. Brimleyana 8:75-90.

Patton, M.Q. 1980. Qualitative evaluation methods. Sage Publications, Inc., Beverly Hills, Calif. 381pp.

Payne, J.A. 1978. Chinese chestnut production in the southeastern United States: practice, problems, and possible solutions. Pages 20-24 *in* W.L. MacDonald, F.L. Cech, J. Luchak, and C. Smith (eds.), Proc. Am. Chestnut Symp. West Virginia University Press, Morgantown, W. Va. 122 pp.

Payne, N.F., B.S. McGinnes, and H.S. Mosby. 1987. Capture rates of cottontails, opossums, and other wildlife in unbaited wooden box traps. Va. J. Sci. 38:23-26.

Peek, J.M. 1982. Elk: *Cervus elaphus* Pages 851-861 *in* J.A. Chapman and G.A. Feldhammer (eds.), Wild mammals of North America: Biology, management and economics. John Hopkins University Press, Baltimore, Md. 1,147pp.

Perlmam. S.M. 1983. Optimum diet model and return rate curves: a test on Martha's Vineyard Island. Pages 115-167 *in* G. Bronitsky (ed.), Ecological models in economic prehistory. Arizona State Univ., Anthropological Research Papers No. 29. 290pp.

Petruso, K.M. and J.M. Wickens. 1984. The acorn in aboriginal subsistence in eastern North America: a report on miscellaneous experiments. Pages 360-378 *in* P.J. Munson (ed.), Experiments and observations on aboriginal wild plant food utilization in eastern North America. Indiana Historical Society, Prehistory Research Series Vol. 6 (2), Indianapolis, Indiana. 473pp.

Pielke, R.A. 1981. The distribution of spruce in west-central Virginia before lumbering. Castanea 46:201-216

Potter, P. 1984. From Annapolis to Rockbridge: approaches to presenting archaeology to the public in the uplands of Virginia. Pages 273-283 *in* C.G. Geier, M.B. Barber, and G.A. Tolley (eds.), Upland archaeology in the east: symposium 2. U.S. Forest Service, Southern Region, Cultural Resources Report no.5, Atlanta, Ga. 283 pp.

Rabinowitz, A.R. 1981. The ecology of the raccoon (*Procyon lotor*) in Cades Cove, Great Smoky Mountains National Park. Ph.D. Diss., University of Tennessee. University Microfilms International, Ann Arbor, Mich. 133pp.

Rappaport, R.A. 1967. Pigs for the ancestors: ritual in the ecology of a New Guinea people. Yale Univ. Press, New Haven, Conn. 311pp.

Ray, C.B., B. Cooper, and W. Benninghoff. 1967. Fossil mammals and pollen in a late Pleistocene deposit at Saltville, Virginia. J. Paleo. 41:608-622.

Reed, F.W. 1905. Report on an examination of a forest tract in western North Carolina. U.S. Bureau of Forestry Bull. 60.

Reidhead, V.A. 1981. A linear programming model of prehistoric subsistence optimization: a southeastern Indiana example. Indiana Historical Society, Indianapolis, Ind. 277pp.

Reynolds, H.C. 1945. Some aspects of the life history and ecology of the opossum in central Missouri. J. Mammal. 26:361-379.

Rice, G., A. McCoy, T. Webb, C. Bond, V. Speed, K. Gragg, and D. Green. 1980. Memories of the American chestnut. Pages 397-421 *in* Foxfire 6: shoemaking, gourd banjos and songbows, one hundred toys and games, wooden locks, a water-powered sawmill, and other affairs of just plain living, E. Wigginton (ed.). Anchor Books, Garden City, N.Y. 507pp.

Robison, W.C. 1960. Cultural plant geography of the middle Appalachians. Ph.D. Diss., Boston University. University Microfilms, Inc., Ann Arbor, Mich. 313pp.

Rogers, L.L. 1976. Effects of mast and berry crop failure on survival, growth, and reproductive success of blackbears. Trans. North. Am. Wildl. and Nat. Resour. Conf. 41:431-438.

Rose, R.K. 1986. Late prehistoric and protohistoric large mammal zoogeography of Virginia. Pages 79-88 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia--a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Rue, L.L. 1979. The deer of North America. Crown Publishers, Inc., New York, N.Y. 463pp.

Russell, E.B. 1983. Indian-set fires in the forests of the northeastern United States. Ecol. 64:78-88.

Santley, R.S., and E.R. Turner. 1977. On theory in archaeology: a response to Klein, a panorama of theoretical archaeology. Curr. Anthro. 18:747-748.

Schnur, G.C. 1937. Yield, stand, and volume tables for even-aged upland oak forest. U.S.D.A. Technical Bulletin 560. Wash., D.C. 55pp.

Schorger, A.W. 1966. The wild turkey: its history and domestication. University of Oklahoma Press, Norman, Okla. 625pp.

Schorger, A.W. 1973. The passenger pigeon: its natural history and extinction. University of Oklahoma Press, Norman, Okla. 424pp.

Semken, H.A. 1983. Holocene mammalian biogeoraphy and climatic change in the eastern and central United States. Pages 182-207 *in* H.E. Wright Jr. (ed.), Late-Quaternary environments of the United States. Vol. 2. The Holocene. University of Minnesota Press, Minneapolis, Minn. 277pp.

Servello, F.A. 1985. Regional variation in the nutritional ecology of ruffed grouse. Ph.D. Diss., VPI and SU, Blacksburg, Va. 205pp.

Servello, F.A., R.L. Kirkpatrick, and K.E. Webb, Jr. 1987. Predicting metabolizable energy in the diet of ruffed grouse. J. Wildl. Mange. 51:560-567.

Servello, F.A. and R.L. Kirkpatrick. 1988. Nutritional value of acorns for ruffed grouse. J. Wildl. Manage. In review.

Shaw, J.H. 1985. Introduction to wildlife management. McGraw-Hill Inc., New York, N.Y. 316pp.

Shelford, V. 1963. The ecology of North America. Univ. of Illinois Press, Urbana, Ill. 610pp.

Shepherd, W.E. 1987. The influence of historic land use activities on stability and diversity of a desert wetland, p.23 *in* The influence of land use pattern on landscape function: ecological theory and management implications. Proc. 2nd Ann. Landscape Ecol. Symp., Charlottesville, Va. 27pp.

Short, H.L. and E.A. Epps, Jr. 1977. Composition and digestibility of fruits and seeds from southern forests. U.S. For. Serv. Spec. Rep. 6pp.

Smallwood, P.D. and W.D. Peters. 1986. Grey squirrel food preferences: the effects of tannin and fat concentration. Ecol. 67:168-174.

Shrauder, P.A. 1984. Appalachian mountains. Pages 331-344 *in* L.K. Halls (ed.), White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pa. 870pp.

Shugart, H.H., Jr. and D.C. West. 1977. Development of an Appalachian deciduous forest succession model and its application to assessment of the impact of the chestnut blight. J. Env. Manage. 5:161-179.

Smith, B.D. 1975. Middle Missippian exploitation of animal populations. University of Michigan Museum of Anthropology, Anthropological Papers 57. Ann Arbor, Mich. 212pp.

Smith, C.E., Jr. 1985. Recovery and processing of botanical remains. Pages 97-126 *in* R.I. Gilbert, Jr. and J.H. Mielke (eds.). The analysis of prehistoric diets. Academic Press, Inc. New York, N.Y. 436 pp.

Smith, E.A. 1983. Anthropological applications of optimal foraging theory: a critical review. Curr. Anthro. 24:625-651.

Snyder, R.L. and J.C. Christian. 1960. Reproductive cycle and litter size of the woodchuck. Ecol. 41:647-656.

Snyder, R.L., D.E. Davis, and J.C. Christian. 1961. Seasonal changes in the weights of woodchuck. J. Mammal. 42:297-312.

Sonenshine, D.E. and E.L. Winslow. 1972. Contrasts in distribution of raccoons in two Virginia localities. J. Wildl. Manage. 36:838-847.

Sork, V.L. 1983. Mast fruiting in hickories and availability of nuts. Amer. Midl. Nat. 109:81-88.

Spencer, R.F. and J.D. Jennings. 1977. The Native Americans: ethnology and backgrounds of the North American Indians. Harper and Row Publishers, New York, N.Y. 584 pp.

Spinner, G.P. and J.S. Bishop. 1950. Chemical analyses of some wildlife foods in Connecticut. J.Wildl. Manage. 14:175-180

Stephenson, S.L. 1986. Changes in a former chestnut-dominated forest after a half century of succession. Amer. Midl. Nat. 116:173-179.

Stickley, A.R. 1958. The status and characteristics of the black bear in Virginia. M.S. Thesis. VPI and SU, Blacksburg, Va. 142pp.

Stiles, W.C. and D.A. Abdalla. 1966. Harvesting, processing, and storage. Pages 280-301 *in* P. Eck and N.F. Childers (eds.), Blueberry Culture. Rutgers University Press, New Brunswick, N.J. 378pp.

Stiles, W.C. and J.S. Bailey. 1966. Blueberries in the home garden. Pages 320-328 *in* P. Eck and N.F. Childers (eds.), Blueberry culture. Rutgers University Press, New Brunswick, N.J. 378pp.

Stout, J. and D. E. Sonenshine. 1974. Ecology of an opossum population in Virginia 1963-69. Acta. Theriol. 19:235-245.

Strahler, A.H. 1972. Forests of the Fairfax Line. Annals Assoc. Amer. Geogr. 62:664-684.

Swanton, J.R. 1946. The Indians of the southeastern United States. Bureau of American Ethnology, Bulletin 73. Government Printing Office, Wash., D.C.

Taber, R.D., K. Raedeke, and D.A. McCaughran. 1982. Population characteristics. Pages 279-300 *in* J.W. Thomas and D.E. Toweil (eds.), Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa. 698pp.

Talalay, L., D.R. Keller, and P.J. Munson. 1984. Hickory nuts, walnuts, butternuts, and hazelnuts: observations and experiments relevant to their aboriginal exploitation in eastern North America. Pages 338-359

Taylor, A.W. and H.P Gould. 1914. Promising new fruits. Pages 109-124 *in* Yearbook of the United States Department of Agriculture 1913. Government Printing Office, Wash., D.C. 541 pp.

Thompson, P.W. 1969. A unique American chestnut grove. Mich. Acad. 1:175-178.

Trippensee, R.E. 1948. Wildlife management: upland game and general principles. Vol. 1. McGraw-Hill, New York, N.Y. 479pp.

Turner, R.E. 1984. A synthesis of Paleo-Indian studies for the Appalachian mountain province of Virginia. Pages 205-219 *in* C.G. Geier, M.B. Barber, and G.A. Tolley (eds.), Upland archaeology in the east: symposium 2. U.S. Forest Service, Southern Region, Cultural Resources Report no.5, Atlanta, Ga. 283 pp.

Twichell, A.R. 1939. Notes on the southern woodchuck in Missouri. J. Mammal. 20:71-74.

Verme, L.J. 1969. Reproductive patterns of white-tailed deer related to nutritional plane. J. Wildl. Manage. 33:881-887.

Wainio, W.W. and E.B. Forbes. 1941. The chemical composition of forest fruit and nuts from Pennsylvania. J. Agric. Res. 62:627-635.

Watt, B.K. and A.L. Merrill. 1963. Compositon of foods: raw, processesd, prepared. Handbook 8. U.S. Dept. Agric., Wash., D.C. 184pp.

Watts, W.A. 1979. Late Quaternary vegetation of the central Appalachians and the New Jersey Coastal Plain. Ecol. Mon. 49:427-469.

Watts, W.A. 1980. The Late Quaternary vegetation of the southeastern United States. Ann. Rev. Ecol. Syst. 11:387-409.

Watts, W.A. 1983. Vegetational history of the eastern United States: 25,000 to 10,000 years ago. Pages 294-310 *in* H.E. Wright Jr. (ed.), Late-Quaternary environments of the United States. Vol. 1. The late Pleistocene. Univ. of Minnesota Press, Minneapolis, Minn. 407pp.

Weiss, K. 1973. Demographic models for anthropology. Society for American Archaeology, Memoirs 27. 186pp.

West, F.H. 1983. The antiquity of man in America. Pages 364-382 *in* H.E. Wright Jr. (ed.), Late-Quaternary environments of the United States. Vol. 1. The late Pleistocene. Univ. of Minnesota Press, Minneapolis, Minn. 407pp.

Wheeler, R.J. 1944. Turkey investigation and management. Pittman-Robertson Quart. 4:1-2.

Wheeler, R.J. 1944. Turkey investigation and management. Pittman-Robertson Q. 4:50.

Wheeler, R.J. 1945. Turkey investigation and management. Pittman-Robertson Q. 5:41.

Wheeler, R.J. 1945. Turkey investigation and management. Pittman-Robertson Q. 5:85-86.

Wheeler, R.J. 1946. Turkey investigation and management. Pittman-Robertson Q. 6:1-2.

Wheeler, R.J. 1946. Turkey investigation and management. Pittman-Robertson Q. 6:40-41.

Wheeler, R.J. 1946. Turkey investigation and management. Pittman-Robertson Q. 6:89-90.

Wheeler, R.J. 1948. The wild turkey in Alabama. Alabama Department of Conservation, Game, Fish, and Sea Foods Division, Walker Printing Co., Montgomery, Ala. 92pp.

Wing, E.S. and A.B. Brown. 1979. Paleonutrition: method and theory in prehistoric foodways. Academic Press, New York, N.Y. 202pp.

Winterhalder, B. 1981. Optimal foraging strategies and hunter-gatherer research in anthropology: theory and models. Pages 13-35 *in* B. Winterhalder and E.A. Smith (eds.), Hunter-gatherer foraging strategies: ethnographic and archaeological analyses. Univ. of Chicago Press, Chicago, Ill. 268pp.

Winterhalder, B. 1981. Foraging strategies in the boreal forest: an analysis of Cree hunting and gathering. Pages 66-98 *in* B. Winterhalder and E.A. Smith (eds.), Hunter-gatherer foraging strategies: ethnographic and archaeological analyses. Univ. of Chicago Press, Chicago, Ill. 268pp.

Wood, R.K. 1943. The elk in Virginia. M.S. Thesis, VPI, Blacksburg, Va. 271pp.

Woods, F.W. and R.E. Shanks. 1959. Natural replacement of chestnut by other species. Ecol. 40:349-361.

Woodward, S.L. and W.F. Ruska, Jr. 1986. A Pleistocene legacy: arctic and boreal elements in the contemporary biota of Virginia. Pages 131-132 *in* J.N. McDonald and S.O. Bird (eds.), The Quaternary of Virginia--a symposium volume. Virginia Division of Mineral Resources, Charlottesville, Va. 137pp.

Yarnell, R.A. and J.M. Black. 1985. Temporal trends indicated by a survey of Archaic and woodland plant food remains from southeastern North America. Southeast. Archaeol. 4:93-106.

Yeager, L.E. 1937. Naturally sustained yield on a farm fur crop in Mississippi. J. Wildl. Manage. 1:28-36.

Yesner, D.R. 1981. Archaeological applications of optimal foraging theory: harvest strategies of Aleut hunter-gatherers. Pages 148-170 *in* B. Winterhalder and E.A. Smith (eds.), Hunter-gatherer foraging strategies: ethnographic and archaeological analyses. Univ. of Chicago Press, Chicago, Ill. 268pp.

Zawacki, A.A. and G. Hausfater. 1969. Early vegetation of the lower Illinois Valley. Illinois State Museum, Reports of Investigations 17. Normal, Ill.

Zvelbil, M. 1983. Site catchment analysis and hunter-gatherer resource use. Pages 73-114 *in* G. Bronitsky (ed.), Ecological models in economic prehistory. Arizona State Univ., Anthropological Research Papers No. 29. 290pp.

Appendices

Appendix A: Martha Wachacha Interview

This is an interview with Martha Wachacha, a 78 year old Cherokee woman, on July 29, 1987, in Graham County, North Carolina. The duration was 1 hour and 15 minutes. It was conducted by Seth Diamond in the home of Martha Wachacha. Lois Calonehuskie was present and, on occasion, helped translate. The following pages are a transcript prepared from a tape recording of the conversation.

SD: How did the Cherokee go about hunting animals?

MW: Well, they had dogs and they be a good hunter, you know. And the dogs will be the ones that smell out tracks. If it climbed up on the tree somewhere they be looking up there, and maybe bark at it. That's how they shot 'em. Used to have guns at times. They shot it. And some of them would have those blowguns and use that.

You blow through it there, you know, right where it is at. But sometimes they don't get killed. And one time me and Onee, when she was little, me and her went to huntin' but I didn't know how to shoot. So I started in shootin' and I shoot that squirrel's leg. I just shooted its leg and it got away from us for good.

And they even trapped those birds in winter. That snowbird. They would come, you know, hungry, and they would feed 'em . My daddy used to fix this here I don't know what you call it, that horsehair, that hair that's long. He used to fix that one and put a knot around there and hold it right there, you know, make round string right here (demonstrates a loop with her hands). He had a stick up this way, hanging like, you know, and he would have that, whatever it is, he'll have it down at the bottom. Then he'd have somethin' like, what do you call that? Rein. (?) And he would put that in one there and then that's why the bird would go down this way. And he got hold of 'em on his neck. And they got tied. They catch them that way.

SD: What kind of bird were they catching?

MW: Snowbirds.

SD: What are snowbirds?

MW: Well, its winter. Well, they eat 'em.

SD: What do they look like?

MW: Did you ever see 'em?

SD: I don't know.

MW: They came round, you know, every winter when its going to snow. The people would say it was going to snow. And the birds around here like that time called snowbirds. And they said it's gonna snow. And it did. They had lot of things they remember what was going to happen at that time. Even there was a lot of witches, too (laughs). Sometimes you could hear somebody, you know, hollerin' out. We never know what it is. About two years ago there was an old man who lived over there, Stecoah. My son's father-in-law. It hot up on the mountain on top. I was looking. I heared him. I asked that old lady, I said, 'Do you hear somebody hollerin?' And she said, 'No, I don't hear it.' And I said, 'You can hear it just as plain as ever.' It was hot. It was going 'Hoo...hoo...hoo...hoo,' like that (laughs). Then it stopped for good. Never heared it no more. Then we heard around here too, up on that mountain. I don't know what it was, some kind of.... I don't know what kind of..... Someone says it was a lion or one of those wildcats. I guess that's what it was.

There used to be a lot of chestnuts at that time. My daughter, the oldest one, was two year old. We went on toward Tellico Plains. Right on top of that mountain, had to walk all the way to where it was. A long way. Took us all day to go on up there. And on over the other side. Then we stayed over night over there.

SD: What did you go there for?

MW: We went to hunt some sing-sang. [ginseng] (Laughs) Didn't find much. We stayed two nights. And then we come back the same way we came. Then we fixed some chickens. A whole lot of 'em.

SD: How much chestnut would a tree give?

MW: Yeah, you could get a bushel of them. There's a lot of them at that time. Now its gone away. I don't know how many years now. First thing we know they was getting gone, the trees. I guessed they sold too much for, what do you call them, you know, cross ties. They split those things for rails.

I'll tell you something but they might get mad at me (laughs). About what they done, those people. They're the ones that got rid of stuff, all those things, by the Lord's ways. I believe that's what happened. They stealed all things, you know, like fish. Have to pay to go fishin' and have to pay to go huntin'. And if it was that much law they wouldn't be fair to people. Like it's been. I don't know what else I was thinkin' (laughs).

SD: Did they hunt turkeys back then?

MW: Yeah. They say there's some yet. Some of them. There is not a lot of them. But there is some there. My husband's brother used to be a hunter. Used to go up the mountains, I don't know, not far from here. Over Santeetlah. They used to go hunt and bring one big turkey.

SD: How long would he be gone?

MW: Gone a day. I don't know how far he went. At that time everything was free. Like, you know, we used to hunt sing-sang. I *liked* to do that. Get some sing-sang.

Its medicine for chests. But we sold it. Now can't get nothin' because of ranger's place.

I asked for White oak (for baskets), one time. And this man had to go with him. When there was someone had to get white oak. To tell him what kind to get. And I give up. I wasn't going to do this. I ain't going to follow that rule 'cause it's too hard. My boy. They was carrying off everywhere where they want to clear (white oak). That's how he got his. Just a short one. I told him I wanted it longer. It had to be longer for to go around the basket. Down the bottom, you don't have to worry about that. Some have to be that long (measures by hand). I've got a basket somewhere that I made (laughs).

SD: Did it take a long time?

MW: It don't take too long if you have everything ready. I'll tell you it's hard, though. To split 'em. I do that, all of it. But this time, the boy had to help me to split 'em by four. Then I'd get the rest of them finished. He didn't know how the first time but he had to try.

SD: How do you get the splits so thin?

MW: You just have to, you split all of them by four. Then you'd split the others. Split 'em all. You get about two or three on one split. When I get that one done, you still have to get them thin. It's a job, too. Whenever you get through with those from tearing them, you have to get you a rag and get those splits and scrape 'em. I tell you that's hard. That's what made me sick. I got arthritis on my arm. It really hurts.

SD: Did they hunt much deer back when you were growing up?

MW: Way back. They used to get white oak. That's how they lived on food. They wasn't no work much that time. I don't know why in the world, how we lived at that time. It's a hard work. Wash clothes. And get water to the spring. They had just fixed the spring. It don't matter how far it was. You had to walk about twenty-five yards. That's what it was. Too long. Just when they started say it would be better. That's when it started. Got a well. Some of 'em it ain't been too long without a well. We lived down yonder. There's a spring right down there. It was *cold*. That's where I used to wash, at that spring water. They used to have that big block, you know. They hard to wash, the men's pants. And they was the hardest ones to wash. They wouldn't get clean. And we just get a paddle and just paddle them. And then wash in the water again. And put in 'em, wash 'em. You had to rinse 'em. I bet everyone get sick on it, if you had to do it now. Some be cryin', I guess. You'd worry. They got these here wash nowadays, but it's worth it. But you have to pay all the light bills that goes on with the washin'.

Sometimes I think the way it says in the Bible. Everything's going to be destroyed. See, as soon as when they have the houses all built up the mountains, then everythings going to be done. Then it's going to be time for the Lord to come. I guess you know about that? If I want to find out something I always look in the Bible. And I tell 'em just as *clear* as ever sometimes I...I don't know. If it's written in the Bible, it's going to happen, anyway, you know. Well, I cry for my children. I don't want them to burn in that fire. And we see that they drink. Lot of people drink beer and stuff, marijuana. Everything. He's going to destroy that too. It's going to be *really* bad. A lot of people goin' get late. It wasn't long, about two years, a year, that lot of people was baptized. Now you don't hardly see people come to church. Like me, now when I was baptized I knew what I was doing. But still I done a little wrong way. But I had to be really careful. When I was baptized I had to be good to people. I'm still good to people. It's bad.

SD: Back when you were young, what kinds of animals were eaten most often?

MW: Turkeys were started to be eaten when the pilgrims came. They killed more then. It was free for them to kill them at that time. There was no law, the way it was. The people would just live anywhere they wanted to. I don't know how many years they started to have cancer for the Indians. It's been pretty many years ago. And I got a picture somewheres, but I don't remember where I got 'em. Got all kinds of papers, books, and stuff. When I was in school they had started fair, I don't know how many years, either. They used to have lots of stuff that they made. And lots of fruits and stuff and beans, corn. They put 'em on the ceiling and we used to eat fresh fry some of the stuff. And the way I was talkin', down there I made those baskets. And people would live on the food to buy groceries with it. They put the baskets in the store, trade for the food. We didn't hardly ever get any candies, you know. Just *once* in a while. Maybe about a year we'd have one. Just one. One. Everything was cheap at that time, though. But it was hard to get the money. Soda used to be 5 cents. And baking powder was 10 cents and peanuts in the box were 10 cents. In the box. And the soap was cheap. Soap was 5 cents. And salt 10 cents in the box. Its gone way up. Many people have been working. They think they got rich, you know. They had to put everything up, the food. Some of us poor people, we can't hardly get it yet. (laughs)

And some people, you know, when they killed that bear they put their meat up. Put it in deepfreeze. Well, they killed those wild hogs, too. It was roasted-like, you know, just hang 'em up. Guess it went through the winter. They keep that much, you know. Cutting it off, you know. How many years has it been that they got those refrigerators? Deepfreeze and refrigerators? It ain't been too long, either. And there were people killed their hogs. They had box about that long; maybe some of them might be smaller. They put that meat in there and just put salt on top of it. All the bones together, you know. They just put salt on top. Then whenever they wanted to cook they just let the salt fade off. That's the way it was. Anything like chicken. And they had lot of things to can. They just canned it to live on it. Nowadays, nobody hardly knows how to can now but some of 'em. I can just a few of 'em myself. They used to dry cabbage leaves. You know, them cabbage that be's covering the heads. They used to dry that kind and they'll hang 'em on outside. Maybe inside dry. They boil it in winter, you know. When got done they fry it. And they still fry fruit, I guess. And can 'em. Some people are smart and can. The Indians.

When we were young they just went huntin' anytime. Wild deer and pig. Well, you know, people were smart that time. You know, they raised corn, stuff. They cleared off the land. *Big* places. Now, you don't see nowhere, just all woods. Just some of them that could do the plantin'. Level ground like over toward town. Maybe Murphy or someplace like that. That's the only places they can plant stuff now. Everyone's got lazy with their ways (laughs). Like me. We used to have big field over the other side, and over here you see. Now they just building house like it was something planted. Like houses. Houses getting in the way now.

SD: If they went out squirrel hunting, how many would they get?

MW: As many as they want. Some of 'em would bring about three or four or five. Eight. They be a lot of squirrels. You know, they can't get 'em no more. They have 'em scared off. Same way those fish. Now, they get away. Raymond, that's my boy over there, he goes hunting in field. They go over to, whatever they call that place. Boarhead lodge.

SD: Did people kill many turkeys when you were young?

MW: Yep, they killed some turkeys. But it seem like there ain't many of 'em 'round here. But they say a lot of 'em over toward Asheville on the other side. That's where they killed those. And they killed swan ducks. They had all kinds of stuff to eat that time. Rabbits stopped going through it. There's so many dogs. The dogs fights over here all the times There's a lot of 'em. And them other side over at Maggie's, there's alot of dogs. They meet together, they fight. Right on top of that hill. If it's not here it's way down there, where my brother used to live.

SD: How did you prepare chestnuts?

MW: Well, as soon as they get brown, you know, they come off the trees. Chestnut burs. They come off and the wind blow 'em. When I pick mine I fix 'em, you know. I hull 'em out, bag 'em up and put 'em in deep freeze. But they say it's best to have the hulls off so when you bake 'em in a pot, make dumplings out of it. That's when always get mine out, you know. But I don't get the hulls. Just some of'em. But they bitter, though. Mama, when she used to make chestnut bread, she used to leave those skins on. They were a lot better to eat (laughs). We used that corn blades (to wrap dumplings). Just have to dry those and hang 'em up. Just like chestnuts, you know beans. We make dumplings out of beans. You can make dumplings out of meal and beans, that's all. But the best way is put blades on them, you know, cover 'em, put 'em in a pot. Tastes better.

SD: Did people gather plants in the woods to eat?

MW: I don't know the name (English) of it. There are three things that you can eat from the woods. Its something like... did you ever eat that parsnips? That white things? That roots? It's thick like parsnips. That's a kind that there is in the woods' but I don't know the name of it. If I ever think about it. If I get to the the woods, if I can, I'll take me a camera and take me a picture and show it to you (laughs and laughs). The leaf is eaten. The leaves is something like a lace-like. The leaves. It's just only where the rich dirt is. There is three different. Now might be more than that. I know how they call it but I don't know, I forgot. I'm getting old. I can't remember much of it (laughs). I got me about a bushel of it one time (laughs). I was wanting to go up that mountain every time, but I'm scared of those rangers (laughs). And we get berries, though. Blueberries. They don't say nothing to us when we go for them. We used to go over there Blue Ridge and we used to go up this mountain Suwanee, what they call. Down Suwanee, up there they big (shows). I got some in the bag in the freeze. I make cake. I make walnuts cake. They eat it up, you know, whenever I got it. They remember I got it. They say, 'When you going to bring that walnut cake?' And sometime I don't like to bake. And blueberries, they talk about blueberries. Everybody likes it. I don't use nothing, just butte sugar. Lard, milk. I don't know how much I put in. I just have to guess. I wish I had it. We had some yesterday. They eat it up, I guess. I took some over there to where they was singing. But my stove is tore up. I wish somebody would give me one. I tell you it's all but gone. You know, make those cakes I have to turn it over, you know, let it get done on top. I guess I can find it somewhere where they'll fix it. I got a stove down yonder, but I can't use gas stove. Because it's too much work. I didn't want to buy it. It was my son wantin' it. I got a daughter down living there. She's using that stove.

Now I have that long necklace I'm making. See what I'm making (a beautiful bead necklace)? I make all kinds of color. I sell 'em some times. People comes up here. You know a long time ago they used to make those baskets. They used to make them about that long and about that wide. They sold 'em for two dollar and a half. Now it's way up high. It's hard work. I made some baskets about that long and sold 'em for 10 cents. Then I made ten of them and took a dollar. Then I went to a store and bought me a cloth to make me a dress. When I was just eight years old I started making baskets with my mama and my aunt. They were making baskets. I tell you, I don't know who can stand that, to make baskets that long. They used to stay way up and used those lamps. At that time they didn't have no electricity or nothing. I guess they was too much hungry at that time (laughs). They had to make baskets. I got that way myself. I was getting myself a bolt of cloth.

They used to play ball with a stick. Indians. They had to go a level place somewheres, and that's where they wanted to play ball. They don't play ball stick now, do they? I guess they do, just one or two. But they really play rough, though. That ball stick they catch with, they use that, just hit right on the head.

And I wouldn't let my husband play that time. But he went on. He had to, about two times a year. And Abraham, he was mad because they hit him with that stick.

And the way I was telling, that there's people that don't expect nothing much now. People that go to school. They are spoiled. They're not working. I'm the only one that works around here. They just throw stuff down. They're spoiled. Anything to help with, you have to pay 'em.

Appendix B Selected plant resource constituents. (Literature sources are cited in the text).

Resource	Part	% NDS	% ether Extract	% Water	Metabolizable Kcal ME/g (dry)	Metabolizable Kcal ME/g (wet)
Blueberry/Huckleberry	Whole Fruit	64.1	5.1	76.4	2.819	0.665
Chestnut	Nut Meat	74.8	12.2	47.1	3.602	1.905
False Solomon's Seal	Rhizome	76.2	0.1	73.8	3.052	0.800
Hickories[1]	Nut meat	81.0	65.5	30.5	6.507	4.520
Jack-in-the-Pulpit	Corm	84.8	0.7	72.7	3.422	0.934
Sweet Oaks[2]	Seed	84.0	7.9	51.3	3.755	1.829
Bitter Oaks[3]	Seed	91.4	22.6	38.4	4.785	2.948

[1] Pignut hickory, mockernut hickory, and shagbark hickory.
[2] Chestnut oak and white oak.
[3] Northern red oak, scarlet oak, and black oak.