PALAEODIET IN VIRGINIA AND NORTH CAROLINA AS DETERMINED BY STABLE ISOTOPE ANALYSIS OF SKELETAL REMAINS

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ABSTRACT

The high molecular weight organic fraction of bone or tooth from 139 individuals from twelve archaeological sites in Virginia and three sites in North Carolina was isolated via a dialysis procedure and analyzed for stable nitrogen and carbon isotopic composition. The sites represent three physiographic provinces: the Coastal Plain, the Piedmont, and the Appalachian Valley. Three time periods were examined: the Middle Woodland (0 - A.D. 900), the first part of the Late Woodland (A.D. 900 - 1400), and the second part of the Late Woodland (1400 - 1600). The $\delta^{13}C$ values for six of the sites reflect a strong C_3 plant component of the diet; the remaining sites had a strong C_4 plant component. A shift from predominantly C_3 plants in the Middle Woodland period to predominantly C_4 plants at the start of the Late Woodland was observed. The $\delta^{15}N$ values suggest a diet rich in terrestrial animal proteins for all three time periods. Piedmont sites had the most diverse diet; Appalachian Valley sites had the least diverse. Coastal Plain sites reflected a substantial marine or aquatic influence in the diet. The temporal patterns observed for $\delta^{13}C$ values are consistent with the general trends seen throughout the eastern part of North America.

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To my children

INTRODUCTION

Analysis of the stable carbon and nitrogen isotopes in human skeletal remains was undertaken in order to learn more about the subsistence base of prehistoric populations in Virginia and North Carolina. Unlike other lines of evidence, the stable isotopes of carbon and nitrogen in human bone reflect the chemistry of the diet and therefore provide a direct measure of the foods consumed. Traditional methods of diet determination focus on an often incomplete and sometimes misleading archaeological record of faunal and floral remains, artifacts, or other cultural evidence associated with a site to provide information on available food resources, procurement strategies, and processing methods. However, population mobility and differential artifact preservation make quantification of the relative inputs of foods difficult. Ethnohistoric accounts generate a general outline of potential food items and their relative importance, but such accounts are usually biased by the observer and present an idealized view of past cultures at a single point in time. Observations of dental attrition, caries, and general health also provide information about what may have been consumed.

For this project, the high molecular weight organic fraction of bone or tooth from 139 individuals from twelve archaeological sites in Virginia and three sites in North Carolina was isolated and analyzed for its stable nitrogen and carbon isotopic composition. The primary objective of this research is to characterize the diet of Native American populations in Virginia and North Carolina through the use of the stable isotopes of carbon and nitrogen. A secondary objective is to trace the role of C_4 plants, such as maize, and other dietary components temporally (prehistorically to the Contact Era) and spatially throughout the study area. The data obtained will be integrated with existing isotope data from the eastern half of North America into a regional perspective.

RESEARCH PLAN

Twelve archaeological sites in Virginia and three in North Carolina were chosen for inclusion in this study (Table 1). The sites chosen for this research initially were selected to reflect an interest in palaeodiet at Virginia burial mound sites. The study was expanded to include a broader interest in prehistoric diet, and an effort was made to include sites from the major time periods and physiographic provinces in Virginia. A lack of available samples suitable for stable isotope analysis and restrictions against destructive analysis eliminated many of the original sites from consideration. While seeking approval for analysis of the Virginia collections, the opportunity to examine skeletal material from three North Carolina sites became available. The Parker site provided the only Middle Woodland period site; the Flynt site added a Coastal Plain site dating to the first part of the Late Woodland Period; and the Donnaha site added another Piedmont site dating to the first part of the Late Woodland Period.

Approval for destructive testing was necessary before sample collection could begin. The United Indians of Virginia granted permission for isotope analyses on the Indian bones from the Hayes Creek Mound, Rapidan Mound, Cabin Run, and Hansonville sites. Approval to analyze human remains from the Flynt, Parker, and Donnaha sites was granted by the North Carolina Commission of Indian Affairs. The remaining sites were cleared by the Smithsonian Office of Repatriation and approved by the Smithsonian collections committee.

Skeletal remains from these sites were obtained from the Smithsonian Museum of Natural History, the University of Virginia Archaeology Laboratory, the Virginia Department of Historic Resources, the Jamestown Museum, and Wake Forest University. Bone samples were selected in cooperation with the curator of each collection. The availability and state of preservation of sample material affected the absolute number of individuals analyzed from a given site. Each sample represented a discrete individual. Although intact, complete bones were the least likely to be contaminated, in most cases they were reserved for nondestructive analysis. Alternatively, dense cortical bone from identifiable longbone shaft fragments was selected for analysis. The Smithsonian Institution permitted the use of only bone fragments or ribs for destructive isotope analysis.

The sites selected represent three physiographic provinces (Fenneman, 1916) within the study area: the Coastal Plain, the Piedmont, and the Appalachian Valley (Figure 1). The Coastal Plain is a portion of the former continental shelf that has been raised above sea level without essential deformation. It encompasses the area from the Atlantic Ocean to the river fall line. The Piedmont is bordered on the west by the Blue Ridge Mountains and on the east by the fall line. It is characterized by a gently rolling topography of plains and plateaus, eastward flowing waterways such as the Rappahannock, Rapidan, James, and Yadkin Rivers, and rich alluvial terraces. The Appalachian Valley province is a longitudinal belt of parallel valleys and mountains formed by erosion of the underlying folded rock strata. This province is bordered by the Blue Ridge Mountains on the east and by the Appalachian Plateau on the west. The Appalachian Valley includes the Shenandoah and Allegheny Mountains, as well as the Shenandoah Valley. Vertical relief is greatest in this region.

Table 1. Archaeological sites included in this study.

Site	Site Location	Institution Curating Human Remains
Brown Johnson	Bland Co., VA	Smithsonian Museum of Natural History
Cabin Run	Warren Co., VA	Smithsonian Museum of Natural History
Donnaha	Yadkin Co., NC	Wake Forest University
Flynt	Onslow Co., NC	Wake Forest University
Governor's Land	James City Co., VA	Jamestown Museum
Hansonville	Russell Co., VA	Va. Dept. of Historic Resources
Hayes Creek	Rockbridge Co., VA	Va. Dept. of Historic Resources
John East	Augusta Co., VA	Smithsonian Museum of Natural History
Koehler	Henry Co., VA	Smithsonian Museum of Natural History
Lewis Creek	Augusta Co., VA	Smithsonian Museum of Natural History
Parker	Davidson Co., NC	Wake Forest University
Potomac Creek	Stafford Co., VA	Smithsonian Museum of Natural History
Rapidan Mound	Orange Co., VA	University of Virginia
Shannon	Montgomery Co., VA	Smithsonian Museum of Natural History
Trigg	Montgomery Co., VA	Smithsonian Museum of Natural History

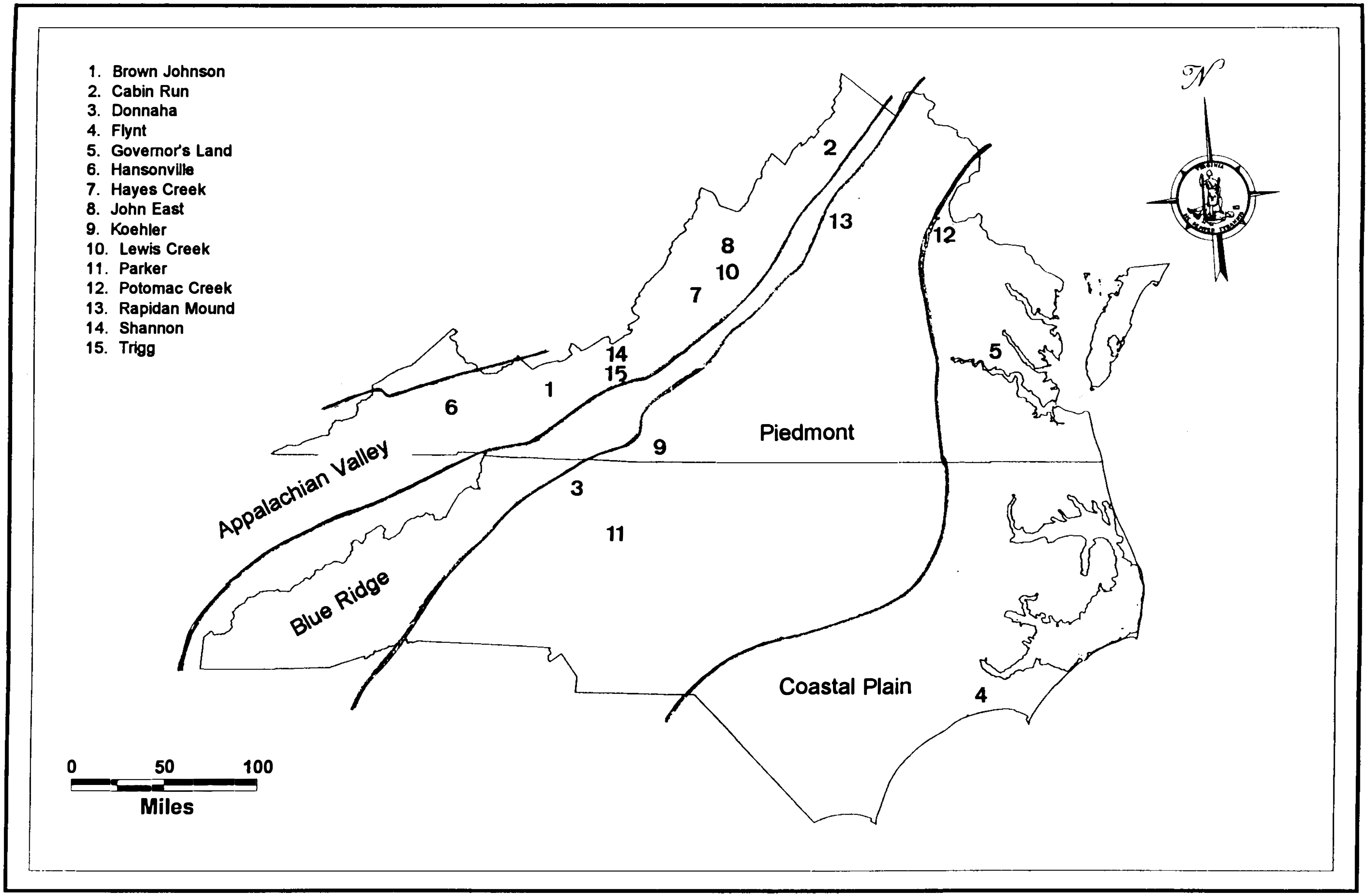

Figure 1. Physiographic provinces and site locations.

The chronological affiliations of the sites examined in this study span from the Middle Woodland Period (0 - A. D. 900) into the Contact Period (post A.D. 1600) (Table 2; Figure 2). General characteristics of the Middle Woodland include an increase in the number of sites located along major streams and tributaries, a shift from predominantly sand or crushed rock ceramic temper to coarse shell temper (Stewart, 1992), stemmed and side-notched projectile points, and primary burials and cremations. Changes in the first part of the Late Woodland Period (A.D. 900 - 1400) include larger, more permanent settlements along the floodplains of major rivers (Hantman and Klein, 1992), large triangular projectile points, and the introduction of ossuary burials. In the latter part of the Late Woodland (A.D. 1400 - 1600), ceramics become thinner and more ornate, ossuary burials predominate (Potter, 1993), and projectile points become smaller and the use of non-local stone for points increases (Parker, 1989). Based on the findings of other stable isotope paleodiet studies (e.g. van der Merwe and Vogel, 1978; Bender et al., 1981), little evidence of C_4 plant agriculture (e.g., maize) consumption is expected for the Middle Woodland Period. The first part of the Late Woodland Period (A.D. 900 - 1400) is expected to be the time of transition to C_4 plant agriculture. Reliance on C_4 plants is expected to increase in the latter part of the Late Woodland Period, the time of initial European contact in this region. Although the dates for three of the sites (Koehler, Trigg, and Potomac Creek) extend into the Contact Era (post A.D. 1600), the primary occupation of these sites was in the latter part of the Late Woodland period, and any contact with Europeans was limited. Consequently, the chronological affiliation of these three sites will be classified as the second part of the Late Woodland period.

Table 2. Chronology of Mid-Atlantic prehistory.

Period	Approximate Dates
Paleo	pre 8000 B.C.
Early Archaic	8000 - 6000 B.C.
Middle Archaic	6000 - 4000 B.C.
Late Archaic	4000 - 1000 B.C.
Early Woodland	1000 B.C. - 0
Middle Woodland	0 - A.D. 900
Late Woodland	A.D. 900 - 1600
Contact/Historic Era	post A.D. 1600

In order to assess the primary dietary components, it was also necessary to measure the isotopic compositions of as many potential food items, both vegetal and animal, as possible from archaeological collections. Ideally, macrobotanical and faunal remains representing potential food sources were to be sampled from each archaeological context from which human remains were sampled, thereby eliminating possible misinterpretation of the isotope data owing to regional or temporal variations in the isotopic signatures of the various food items. Unfortunately, suitable samples from most of the species desired either were not recovered from archaeological sites, not curated, or unavailable for this project.

The high molecular weight organic fraction of each sample was isolated via a dialysis procedure and analyzed for its stable carbon and nitrogen isotope composition. Descriptive statistics and analysis of variance tests aided in data interpretation.

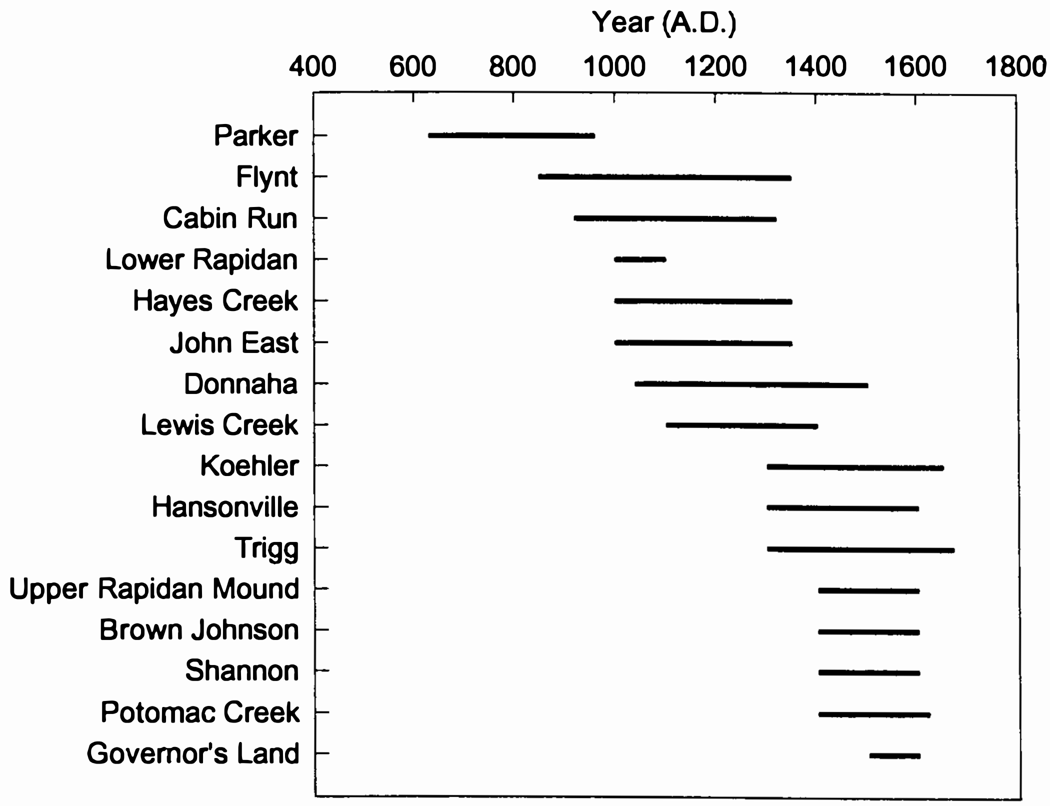

Figure 2. Approximate dates for each site. (See site descriptions for supporting data.)

BACKGROUND

Site Descriptions

Brief descriptions of each site are provided to illustrate the context from which the skeletal remains came. The information on each site was compiled from survey, site, and analytical reports. Where available, information about each site includes location, when excavated, site type, burial type, botanical and faunal remains, and site date. The quality and quantity of data pertaining to archaeological sites have improved as excavation and analytical techniques have improved. For example, flotation and fine mesh screening are used routinely now to recover botanical remains. A site excavated 50 years ago may lack evidence of agriculture solely because techniques to recover floral remains were not used. Artifacts, radiocarbon dates, and ethnohistoric accounts aid in determining approximately when a site was occupied. These dates should not be considered absolute. The faunal and floral remains provide general indicators of food resources that were available and possibly utilized. Differences between sites may be a function of sampling technique rather than variable resource exploitation. Sites are described in chronological order and summarized by time period (Table 11).

Parker

The Parker site (31DV4) is located on Horseshoe Bend of the Yadkin River in Davidson County, North Carolina. The site was excavated in 1971 and 1972 by J. Ned Woodall of Wake Forest University (Newkirk, 1978). Numerous trash deposits, artifacts, and one substantial structure were observed in this small village. The 25 burials were all primary burials in the flexed or semi-flexed position. Only one burial pit contained more than one individual. There were no definite grave goods associated with the burials.

Fauna identified at Parker included deer, squirrel, rabbit, wild turkey, fish, and mussel and flora identified included maize, hazelnut, hickory nut, and a few other single seeds (Table 3). Dan River ceramics at the site date to the Late Woodland period (ca. A.D. 1100 - 1600); the Uwharrie ceramics have been associated with a radiocarbon date of A.D. 1015 (Egloff, 1992). Radiocarbon dates of A.D. 960 ± 86 and A.D. 634 ± 64 were obtained from two charcoal samples from within the site.

Table 3. Faunal and floral remains recovered from Parker.*

Common name	Scientific name
Maize	*Zea mays*
Hazel	*Corylus sp.*
Hickory	*Carya sp.*
Virginia white-tailed deer	*Odocoileus virginiana*
Beaver	*Castor canadensis*
Squirrel	*Sciurus sp.*
Fox	*Urocyon cinereoargenteus*
Groundhog	*Marmota monax*
Raccoon	*Procyon lotor*
Cottontail rabbit	*Sylvilagus floridana*
Turkey	*Meleagris gallopavo*
Garfish	*Lepisosteus sp.*
Catfish	*Ictalura sp.*
Eastern box turtle	*Terrapene carolina*

* from Newkirk, 1978

Flynt

The Flynt site (31ON305) is located on Chadwick Bay near Sneads Ferry in Onslow County, North Carolina. The site was excavated from 1982 to 1987. This small coastal village consisted of a habitation area, two shell middens, and over 50 refuse pits (Bogdan, 1989; Bogdan and Weaver, 1990). A minimum of 158 individuals were identified in a circular ossuary burial. Botanical remains from the site include hickory, maize, and acorn. Faunal remains include deer, oyster, clam, scallop, and fish. The predominant ceramics, White Oak and Onslow, date to the latter part of the Late Woodland period. Radiocarbon dates place the principal occupation of the village around A.D. 850 - 1300 (Bogdan and Weaver, 1990; Mathis, personal communication).

Cabin Run

Cabin Run (44WR300) is located on the South Fork of the Shenandoah River, between Cabin Run and Punches Run, in Warren County, Virginia. The Cabin Run area was surveyed by the Thunderbird Research Corporation in the late 1970s, and various loci within the survey area were partially excavated in the early 1980s (Walker, 1978; Gardner and Rimmler, 1980; Snyder and Fehr, 1984). House patterns, hearths, and pits defined this small village site (44WR300); the larger palisaded village of Cabin Run (44WR3) was located nearby (Walker, 1978; Walker and Miller, 1992). Five burials were associated with 44WR300. One burial was a single interment. The remaining four individuals were buried in two layers in a single pit. The faunal and floral remains provide evidence for a varied diet (Table 4). The ceramic assemblage contained 90% Albemarle wares, suggesting a date in the early part of the Late Woodland period. Radiocarbon dates range from A.D. 930 ± 80 to A.D. 1320 ± 50 (Gleach, 1985).

Table 4. Faunal and floral remains recovered from Cabin Run.*

Common name	Scientific name
Black walnut	*Juglans nigra*
Hickory nuts	*Carya glabra*
Acorn	*Quercus sp.*
Pokeberry	*Phytolacca americana*
Persimmon	*Diopyros virginiana*
Virginia white-tailed deer	*Odocoileus virginianus*
Elk	*Cervus canadensis*
Black bear	*Ursus americanus*
Beaver	*Castor canadensis*
Muskrat	*Ondatra zibethicus*
Gray squirrel	*Sciurus carolina*
Gray fox	*Urocyon cinereoargenteus*
Rabbit	*Sylvilagus sp.*
Opossum	*Didelphis virginianus*
Raccoon	*Procyon lotor*
Turkey	*Meleagris gallopavo*
Turtle	*Clemmys insculpta*
Eastern box turtle	*Terrapene carolina*
Freshwater mussels	*Elliptio sp.*
Fish	

* from Snyder and Fehr, 1984

Hayes Creek

Hayes Creek Mound (44RB2) is located on the south bank of Hayes Creek near its confluence with Walker's Creek, which joins the Maury River approximately two miles downstream near Rockbridge Baths in Rockbridge County, Virginia. This burial mound site was excavated by Edward Valentine in 1901 (Valentine, 1903). Dunham (1994) describes the burial sequence as follows: primary individual burials in the flexed position were at the base of the mound, followed by a thin ash and gravel lens and a pile of cremated bones; at the center of the mound were layers of primary flexed burials that were covered with large stones and contained associated grave goods; later primary burials contained neither grave goods nor stones; collective interments occurred in the uppermost regions of the mound.

A lack of diagnostic artifacts and radiocarbon dates makes it difficult to determine the chronological affiliation of Hayes Creek Mound. Comparison with other mounds in the region, such as John East Mound, suggests that the inner mound was developed during the first half of the Late Woodland period (ca. A.D. 1000 - 1350). Like Rapidan Mound and Lewis Creek Mound, the shift to collective burials probably dates to the latter portion of the Late Woodland period (Dunham, 1994).

John East

John East Mound (44AU35) is located in Augusta County, Virginia, on the floodplain of the Middle River between Churchville and Staunton. This burial mound was partially excavated in 1952 by C. Holland and others (Holland et al., 1953; Holland, 1960) and again in 1965 by Olier Valliere and Gilbert Kinzie (Valliere and MacCord, 1986). The mound contained over 100 individuals. Primary, individual burials in the flexed position, usually covered with stones, are the earliest burial form at the mound. A few primary double burials also occurred early in the burial sequence. Ossuary burials and stone-covered secondary burials occur in the upper levels of the mound.

Triangular projectile points (primarily Madison and Levanna) associated with the burials date to the Late Woodland period (ca. A.D. 900 - 1600). Charcoal samples yielded three radiocarbon dates: A.D. 960 ± 290 years; A.D. 1240 ± 90 years; and A.D. 1320 ± 150 years (Valliere and MacCord, 1986). The latter date is directly associated with a sub-mound secondary burial feature. The other two dates are from charcoal associated with the mound fill and may represent fires unrelated to mound construction; therefore, they should be considered terminus dates for certain portions of the mound. These dates suggest that mound formation occurred in the first part of the Late Woodland period, ca. A.D. 1000 - 1350.

Donnaha

The Donnaha site (31YD1/31YD9) is situated on the Great Bend of the Yadkin River in Yadkin County, North Carolina. The site was partially excavated in 1973, 1975, and 1983 (Woodall, 1984). The small village of Donnaha consists of a midden area, storage pits, and postmolds that could not be differentiated into structures. Eighty primary flexed burials were placed in round or oval burial pits; marine shell beads were associated with many of the burials (Hancock, 1987). The faunal and floral remains from Donnaha provide evidence of a mixed subsistence economy, including the cultigens maize, beans, and squash (Table 5). Fishing weirs were identified in the Yadkin River near Donnaha. Radiocarbon dates from midden debris range from A.D. 1040 to A.D. 1480 (Hancock, 1987).

Table 5. Faunal and floral remains recovered from Donnaha.*

Common name	Scientific name
Maize	*Zea mays*
Beans	*Phaseolus vulgaris*
Cucurbit	*Curcurbitaces*
Sumpweed	*Iva annua*
Black walnut	*Juglans nigra*
Hickory nuts	*Carya glabra*
Hazelnut	*Corylus sp.*
Acorn	*Quercus sp.*
Butternut	*Juglans cinerea*
Persimmon	*Diopyros virginiana*
Plum	*Prunus sp.*
Maypops	*Passiflora incarnata*
Grape	*Vitis sp.*
Elk	*Cervus canadensis*
Beaver	*Castor canadensis*
Groundhog	*Marmota monax*
Gray squirrel	*Sciurus carolina*
Fox squirrel	*Sciurus niger*
Black bear	*Ursus americanus*
Cottontail rabbit	*Sylvilagus floridana*
Opossum	*Didelphis virginianus*
Raccoon	*Procyon lotor*
Gray fox	*Urocyon cinereoargenteus*
Duck	*Anas sp.*
Turkey	*Meleagris gallopavo*

Table 5. (Cont.)

Common name	Scientific name
Bobwhite quail	*Colinus virginianus*
Passenger pigeon	*Ectopistes migratorius*
Snapping turtle	*Chelydra serpentina*
Eastern box turtle	*Terrapene carolina*
Bullfrog	*Rana catesbeianna*
Gar	*Lepisosteus sp.*
Catfish	*Ictalurus sp.*
American eel	*Anguilla mostrata*
Buffalo fish	*Ictibus sp.*
Redhorse sucker	*Moxostoma sp.*
Madtom	*Noturus sp.*
Gizzard shad	*Dorosoma sp.*
Alabama shad	*Alosa sp.*
Yellow perch	*Perca flavenscens*

* from Hancock, 1987

Lewis Creek

Lewis Creek Mound (44AU20) is located on the east bank of Lewis Creek about 1.5 miles south of the Middle River, in Augusta County between Verona and Staunton. The Lewis Creek burial mound has a long history of excavations (Manley, 1963; MacCord and Valliere, 1965; and Holland, 1960). Lewis Creek Mound consisted of three distinct layers. At the base of the mound were primary individual burials placed in pits, accompanied by grave goods, and covered with a stone. Collective secondary burials in the form of bone beds were located near the top of the mound. The middle layer contained both primary individual interments and secondary burials. Artifacts associated with the burials included shell beads, a shell pendant, stone pendants, a quartzite knife, projectile points, antler projectile points, an antler flaker, and eagle talons.

Triangular projectile points, primarily the Clarksville type, found at the site date to the Late Woodland period (ca. A.D. 900 - 1600). Radiocarbon dates from charcoal in the lower portion of the mound are A.D. 1140 ± 240 years and A.D. 1370 ± 200 years (Valliere and MacCord, 1986).

Koehler

Koehler (44HR6) is located on the right bank of the Smith River in Henry County, Virginia, approximately three miles west of Martinsville. Portions of the site were excavated in 1968 (Gravely, 1976) and in 1976 (Coleman, 1976). Postmolds revealed a small, possibly palisaded, village with hearths, refuse pits, and clay pits. Eleven primary burials were recovered. Floral remains included nuts and the cultigens maize and beans; faunal remains included deer, turkey, fish, and freshwater mussels (Table 6) (Coleman, 1976).

Dan River ceramics were found throughout the burial pit fill and are affiliated with the latter part of the Late Woodland period (ca. A.D. 1100 - 1600). The European artifacts recovered (kaolin pipe fragments, iron pot fragments, iron nails, and a brass buckle) suggest that the site was in use during the Contact period (post A.D. 1600). Three radiocarbon dates were obtained: A.D. 1305 ± 70 years; A.D. 1340 ± 70 years; and A.D. 1405 ± 55 years (Gravely, 1976).

Table 6. Faunal and floral remains recovered from Koehler.*

Common name	Scientific name
Maize	*Zea mays*
Beans	*Phaseolus vulgaris*
Grape	*Vitis sp.*
Walnut	*Juglans nigra*
Acorn	*Quercus sp.*
Hickory	*Carya sp.*
Virginia white-tailed deer	*Odocoileus virginiana*
Muskrat	*Ondatra zibethicus*
Beaver	*Castor canadensis*
Gray squirrel	*Sciurus carolinensis*
Fox	*Urocyon cinereoargenteus*
Turkey	*Meleagris gallopavo*
Eastern box turtle	*Terrapene carolina*
Freshwater mussels	*Elliptio sp.*
Snails	*Mudalia sp.*
Fish	

* from Coleman, 1976

Hansonville

The Hansonville site (44RU7) is located between Mountain Creek and the North Fork of Little Moccasin Creek, about 0.3 miles northeast of Hansonville in Russell County, Virginia. Hansonville was partially excavated in 1970 by Holland (1970); the remainder was excavated by the Virginia Research Center for Archaeology in 1979 (Bott, 1981). The site contained a small, possibly palisaded, village and five small burial pits. Unidentified animal bones and riverine shells were recovered. Some of the ceramics were decorated with corncob impressions, suggesting that maize was available as a potential food source. The projectile points (Levanna, Madison, Dallas, and Dallas/Clarkesville) suggest that the site was occupied periodically throughout the Late Woodland period; the ceramics (over 80% shell tempered New River wares) suggest a Late Woodland date of A.D. 1350 - 1600.

Trigg

The Trigg site (44MY3) is located on the southern bank of the New River in Radford, Virginia, just north of the Rt. 11 bridge, near the Montgomery/Pulaski County border. The site was excavated in 1974 and 1975 under the supervision of Howard MacCord and William Buchanan with the support of the Virginia State Library, the Archaeological Society of Virginia, and the City of Radford (Sternheimer, 1983). Postmolds at the site revealed a concentrical palisaded village, approximately 220 feet in diameter, with a central courtyard and circular or oval dwellings ranging from 8 to 23 feet in diameter. Hearths indicated the location of 29 house sites. A second ring of postmolds, identified as an outer stockade, surrounded the village. The majority of the 311 burials were located in the courtyard area; additional burials were located between the inner and outer stockades. Grave goods included ceramics, projectile points, European glass beads, bone and shell beads, copper ornaments, animal teeth and claws, and bone and stone tools. The subsistence economy included agricultural products and fish. Burned corn cobs, pumpkin seeds, squash seeds, and unidentified beans were interred with several individuals. Fishing weirs were identified in the river adjacent to the Trigg site. Coastal shellfish and mussel remains were also recovered from the site.

The Trigg site appears to have had a long term occupation. Many of the postmolds delineating the houses overlapped the inner stockade but not the outer, suggesting that the inner stockade was built prior to the outer one. Some of the houses may predate both stockades; others may be contemporaneous with one or both stockades. The predominant ceramic types (Clarkesville, Radford, Wythe, and New River) from the site have been associated with radiocarbon dates elsewhere of about A.D. 1200 to A.D. 1600 (Evans, 1955; Holland, 1970; Gleach, 1985). The projectile point types (Dallas, Clarksville, Hamilton, Levanna, and Madison) associated with burials were typical of the Late Woodland period. European glass beads from the site are identical to beads found elsewhere that have been dated to about A.D. 1575 - 1650. An ethnohistoric account by Batts and Fallam stated that the area was unoccupied in 1671 (Swanton, 1946). Two radiocarbon dates of A.D. 1715 ± 80 and A.D. 1575 ± 60 were obtained (Buchanan, 1986). The Trigg site appears to have been occupied throughout the Late Woodland period, primarily during the later part, and was abandoned by 1671.

Rapidan Mound

Rapidan Mound (44OR1) is an accretional burial mound located on the west bank of the Rapidan River in Orange County, Virginia. The northern edge of the site was excavated in 1892 by Gerard Fowke, and a small test excavation was done in 1979 by the Archaeological Society of Virginia. The remainder of the mound was fully excavated from 1988 to 1990 under the direction of Gary Dunham and Jeffrey Hantman of the University of Virginia (Dunham, 1990). The latter excavation revealed eight burial features: three sub-mound layered burial pits and five bone beds within the mound itself. It has been estimated that the mound contained over 1000 individuals (Dunham, 1994). No artifacts were found in intentional association with the burials.

Use of the Rapidan Mound location may have begun during the Middle Woodland period, but the most intensive use appears to have occurred in the latter part of the Late Woodland. A few Late Woodland (Clarkesville) projectile points were recovered from the mound fill. A human bone sample had a radiocarbon date of A.D. 1440 ± 110 years, and a charcoal sample from a sub-mound pit yielded a radiocarbon date of A.D. 660 ± 110 years (Dunham, 1994). The similarity between the burial forms observed at Rapidan and at other Virginia burial mounds suggests dates of A.D. 1000 - 1100 for the sub-mound pits and A.D. 1400 - 1600 for the bone beds (Dunham, 1994). Individuals from both types of burial are present in the sample assemblage and will be considered separately.

Brown Johnson

The Brown Johnson Site (44BD1) was a palisaded village located on Wolfe Creek approximately two miles north of Bastion, Virginia (MacCord, 1971). The site was excavated by Howard MacCord and the Archaeological Society of Virginia in 1970. Postmolds showed a circular palisaded village approximately 140 feet in diameter, 13 circular houses within the palisade, and a central plaza. Storage pits, hearths, and cooking pits were associated with the houses. Fourteen primary burials with shell and copper grave goods were located within the palisade. Faunal and floral remains include deer, turkey, turtle, and maize (Table 7). Triangular projectile points and elaborately decorated ceramics at Brown Johnson suggest a primary date of occupation in the latter part of the Late Woodland period. Two samples yielded radiocarbon dates of A.D. 1490 ± 75 and A.D. 1520 ± 90 (MacCord, 1971). No historic trade goods were recovered.

Table 7. Faunal and floral remains recovered from Brown Johnson.*

Common name	Scientific name
Maize	*Zea mays*
Hickory nuts	*Carya glabra*
Virginia white-tailed deer	*Odocoileus virginianus*
Elk	*Cervus canadensis*
Gray squirrel	*Sciurus carolina*
Turkey	*Meleagris gallopavo*
Eastern box turtle	*Terrapene carolina*
Freshwater mussels	*Elliptio complanatus*
Snails	*Mudalia carinata*
Fish	

* from MacCord, 1971

Shannon

The Shannon Site (44MY8) is located on a ridge overlooking the floodplain of the North Fork of the Roanoke River approximately five miles east of Blacksburg in Montgomery County, Virginia. This site was excavated by Joseph Benthall in 1966 and 1967 (Benthall, 1969). The postmold pattern showed a 322 foot by 210 foot palisaded village comprised of a central plaza and 11 circular houses 8 to 23 feet in diameter. Fire and refuse pits were associated with each house. Nearly all of the 100 human burials were individual burials in the flexed position. The numerous grave goods included shell and bone beads, stone and bone tools, animal teeth and claws, ceramics, and native copper fragments. The faunal and floral assemblages from Shannon provide evidence for a varied diet (Table 8). Plant remains included maize, beans, and nuts. Animal remains included mammals, birds, reptiles, mussels, snails, and fish (Barber and Baroody, 1976).

Based on the ceramics (New River, Clarksville, and Radford) and projectile points (Caraway, Peedee, and Randolph), the Shannon Site was occupied most intensively during the Late Prehistoric around A.D. 1400 to A.D. 1600. An absence of European artifacts suggests that occupation probably did not continue into the Historical Period. The presence of Palmer, Big Sandy, and Savannah River projectile points indicates that the site may have been occupied periodically during the Archaic Period.

Table 8. Faunal and floral remains recovered from Shannon.*

Common name	Scientific name
Maize	*Zea mays*
Beans	*Prosopis sp.*
Black walnut	*Juglans nigra*
Hickory nuts	*Carya glabra*
Virginia white-tailed deer	*Odocoileus virginiana*
Beaver	*Castor canadensis*
Elk	*Cervus canadensis*
Groundhog	*Marmota monax*
Gray squirrel	*Sciurus carolina*
Black bear	*Ursus americanus*

Table 8. (Cont.)

Common name	Scientific name
Rabbit	*Sylvilagus floridan*
Muskrat	*Ondatra zibethicus*
Dog	*Canis familiaris*
Raccoon	*Procyon lotor*
Gray fox	*Urocyon cinereoargenteus*
Skunk	*Mephitis mephitis*
Bobcat	*Lynx rufus*
Mountain lion	*Felis concolor*
Turkey	*Meleagris gallopavo*
Bald eagle	*Haliaetus leucocephalus*
Canada goose	*Branta canadensis*
Ruffed grouse	*Bonasa umbellus*
Bobwhite	*Colinus virginianus*
Passenger pigeon	*Ectopistes migratorius*
Terrapin	*Terrapene carolina*
Mussels	*Elliptio complanatus* (Roanoke River); *Villosa constricta conrad* (Roanoke River); *Cyclonaias turbiculata Rafinesque* (New River)
Snails	*Mudalia carinata variabilis lea*, *Oxytrema symmetrica Haldeman.*

* from Benthall, 1969; Barber and Baroody, 1976

Potomac Creek

Potomac Creek (44ST2) is located on Potomac Neck, which is bounded by the Potomac River on the east, Potomac Creek on the south, and Accokeek Creek on the west in Stafford County, Virginia. The site was excavated intermittently from 1935 to 1940 by Judge William J. Graham and by T. Dale Stewart (Stewart, 1992). Postmolds revealed a palisaded village and other circular and elongated structures. The palisade was made up of seven concentric lines, suggesting that the site was either maintained regularly or rebuilt and reused. The innermost palisade had a maximum diameter of 175 feet, entrances on the north and southwest sides, and was surrounded by a ditch or moat. The outermost palisade was outside the ditch and had a maximum diameter of 280 feet. A minimum of 722 individuals were buried in five ossuaries, a burial pit, and a single grave. Most of the burials in the ossuaries were bundled, whereas the burial pit contained mostly primary burials in the flexed position. Faunal remains include deer, fish, oysters, mussels, and crabs (Table 9). No botanical remains were recovered.

Potomac Creek appears to have been occupied over a long span of time, either continuously or sporadically, as evidenced by the multiple palisade lines, stone projectile points (stemmed, Levanna, Madison, and Clarksville), and the various burial locales. Each ossuary may represent a separate phase in the occupation of the site. The presence of ornamental European trinket type objects (e.g., beads, bells, buttons) artifacts in the burial assemblages indicates that the site was occupied at the start of the Contact/Historic period. The lack of larger utilitarian European objects, such as kettles, hoes, knives, axes, and guns, suggests that contact with Europeans was limited. Although the projectile point types support a long term occupation of the Potomac Creek, the ceramics (Potomac Creek, Rappahannock, Keyser) suggest a date in the latter part of the Late Woodland period for the primary occupation.

The individuals sampled for stable isotope analysis were all from Ossuary 5, which contained only artifacts of native origin except for 2 small copper pendants. It is concluded that the individuals sampled from Potomac Creek date to the latter part of the Late Woodland period, no later than about A.D. 1620.

Table 9. Faunal remains recovered from Potomac Creek.*

Common name	Scientific name
Virginia white-tailed deer	*Odocoileus virginiana*
Beaver	*Castor canadensis*
Gray squirrel	*Sciurus carolina*
Muskrat	*Ondatra zibethicus*
Raccoon	*Procyon lotor*
Bobcat	*Lynx rufus*
Turkey	*Meleagris gallopavo*
Red tailed hawk	*Buteo jamaicensis borealis*
Garfish	*Lepisosteus sp.*
Sturgeon	*Acipenser sp.*
Catfish	*Ictalura sp.*
Sucker	*Catostomus sp.*
Yellow perch	*Perca flavescens*
Terrapin	*Terrapene carolina*
Mussels	

* from Stewart, 1992

Governor's Land

Governor's Land (44JC308) is located in James City County, Virginia, on the east bank of the Chickahominy River, approximately 2500 feet upstream from its confluence with the James River. Excavations at the site by the James River Institute for Archaeology from 1990 to 1992 revealed a village with 34 possible longhouses (Hodges and Hodges, 1994). Seven primary burials and two ossuaries were identified. Vertebrate fauna identified at Governor's Land include terrestrial herbivores, turtle, and fish (Barber and Whyte, 1994); plant foods identified include both cultigens and wild plants (Table 10) (Gardner, 1994).

The occupation of Governor's Land appears to have been relatively brief in the Late Woodland/Contact period. The ceramics represented (primarily Roanoke simple-stamped ware) all date post A.D. 1500. Radiocarbon testing of charred hickory nuts associated with refuse deposits above two of the burials yielded dates of A.D. 1657 ± 70 and A.D. 1478 ± 60 (Hodges and Hodges, 1994). An early map by John Smith shows two Paspahegh villages in the vicinity of Governor's Land that were abandoned after an attack by the English in 1610. There was no evidence of rebuilding among the structures identified.

Table 10. Faunal and floral remains recovered from Governor's Land.*

Common name	Scientific name
Maize	*Zea mays*
Chenopodium	*Chenopodium sp.*
Little barley	*Hordeum pusillum*
Hickory nuts	*Carya glabra*
Black walnut	*Juglans nigra*
Acorn	*Quercus sp.*
Persimmon	*Diopyros virginiana*
Strawberry	*Fragaria sp.*
Maypops	*Passiflora incarnata*
Gray squirrel	*Sciurus carolinensis*
Raccoon	*Procyon lotor*
Virginia white-tailed deer	*Odocoileus virginianus*
Eastern box turtle	*Terrapene carolina*
Long-nosed gar	*Lepisosteus osseus*
Catfish	*Ictalurus sp.*
White catfish	*Ameiurus catus*
Yellow bullhead catfish	*Ameiurus natalis*
Madtom catfish	*Noturus sp.*
Perch/striped bass	*Morone sp.*

* from Gardner, 1984; Barber and Whyte, 1994

Table 11. Summary of sites by time period.

Time period	Site	Province	Site and burial type
Middle Woodland (0 - A.D. 900)	Parker	P	Small village; 25 primary burials
First part of Late Woodland (A.D. 900 - 1400)	Cabin Run	AV	Small village; primary burials
	Donnaha	P	Small village; 80 primary burials
	Flynt	CP	Small village; ossuary burial
	Hayes Creek	AV	Burial mound only: ossuary and primary burials
	John East	AV	Burial mound only: ossuary and primary burials
	Lewis Creek	AV	Burial mound only: ossuary and primary burials
	Rapidan (lower levels)	P	Burial mound only: burial pits
Second part of Late Woodland (A.D. 1400 - 1600)	Brown Johnson	AV	Palisaded village; 14 burials
	Governor's Land	CP	Large village; 2 ossuaries and 7 primary burials
	Hansonville	AV	Small village, possibly palisaded; 5 burial pits
	Koehler	P	Small village, possibly palisaded; 11 primary burials
	Potomac Creek	CP	Palisaded village; 5 ossuaries, 1 burial pit, and 1 primary burial
	Rapidan Mound (upper levels)	P	Burial mound only: Ossuary
	Shannon	AV	Palisaded village; 100 primary burials
	Trigg	AV	Palisaded village; 311 primary burials

Theoretical Background

Stable Isotope Theory

The isotopic concentrations of carbon and nitrogen are expressed as

$$\delta^{13}C\ (‰) = \left(\frac{^{13}C/^{12}C\ \text{sample}}{^{13}C/^{12}C\ \text{standard}} - 1 \right) \times 1000$$

$$\delta^{15}N\ (‰) = \left(\frac{^{15}N/^{14}N\ \text{sample}}{^{15}N/^{14}N\ \text{standard}} - 1 \right) \times 1000$$

The $\delta^{13}C$ and $\delta^{15}N$ values are expressed relative to the international standards Pee Dee Belemnite (PDB) and atmospheric nitrogen (N_2), respectively. A substance with an isotope ratio less than that of the standard will have a negative δ value, and is said to be depleted in the heavy isotope relative to the standard. A substance that is enriched relative to the standard will have a positive δ value.

Isotopic fractionations that occur during the uptake and conversion of CO_2 into plant carbon influence the carbon isotope ratios of terrestrial plants. Carbon dioxide in the atmosphere has a $\delta^{13}C$ value of about -7‰. Plants with the Calvin/Benson (C_3) photosynthetic pathway use the enzyme ribulose bisphosphate (RuBP) to convert atmospheric CO_2 to three carbon phosphoglyceric acid (PGA) (Vogel, 1980). The Hatch/Slack (C_4) photosynthetic pathway uses the enzyme phosphoenolpyruvate (PEP) to convert CO_2 to four carbon dicarboxylic acid (Vogel, 1980). Stomatal resistance in C_3 plants is low, diffusion of CO_2 is rapid, and carboxylation is the limiting step in photosynthesis. The overall fractionation factor associated with photosynthesis is about -19‰ (O'Leary, 1981;1988). Conversely, stomatal resistance in C_4 plants is high, and diffusion is limiting. The associated fraction factor is about -4‰ (O'Leary, 1981;1988). It has been well established that C_4 plants have average $\delta^{13}C$ values around -12.5‰

relative to PDB, whereas C_3 plants have average $\delta^{13}C$ values around -26‰ (Bender, 1968; van der Merwe and Vogel, 1978; Vogel, 1980; van der Merwe, 1982; Matson and Chisholm, 1991). Most terrestrial plants are C_3 plants. Most edible C_4 plants in North America are species that have been domesticated, such as maize, sugar cane, sorghum, millet, grains belonging to *Amaranthus sp.*, and some members of the *Chenopodiaceae* family (e.g., *Atriplex sp.* and *Kochia sp.*). The domesticated *Chenopodium berlandieri* found at some archaeological sites is a C_3 plant (Smith, 1985; Spielmann et al., 1990).

The observed isotopic fractionation that results from the assimilation of dietary carbon and nitrogen varies according to the tissue type sampled and the diet. Based on a study of mice and insects raised on known, monotonous diets, the $\delta^{13}C$ value for the homogenized whole body of a consumer is enriched by about 1‰ over the diet; bone collagen may be enriched by about 2.0‰ to 3.7‰ over a vegetarian diet (DeNiro and Epstein, 1978; Bender et al., 1981). A study by Schoeninger and DeNiro (1984) of modern terrestrial and marine food webs showed an enrichment of about 5‰ between plants and the bone collagen of herbivores; the enrichment between the bone collagen of subsequent trophic levels (e.g., herbivore and carnivore) was only 0‰ to 1‰. Using an average collagen enrichment of about 2‰ for a consumer relative to the plant base, the bone protein of a terrestrial herbivore eating only C_3 plants should have $\delta^{13}C$ of about -26‰ plus 2‰, or about -24‰, whereas a consumer of only C_4 species should have a $\delta^{13}C$ of -12.5‰ plus 2‰, or -10.5‰. Intermediate $\delta^{13}C$ values would indicate a mixed diet of C_3 and C_4 plants. The $\delta^{15}N$ values for bone protein consistently have been shown to be enriched about 3‰ relative to the food source (DeNiro and Epstein, 1981; Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984). Terrestrial herbivores and carnivores have average $\delta^{15}N$ values of 5.3‰ and 8.0‰ respectively.

It has been demonstrated that the combination of stable carbon and nitrogen isotopes can be used to distinguish between terrestrial and marine food sources (DeNiro and Epstein 1978, 1981). Marine plants use dissolved bicarbonate, rather than atmospheric CO_2, during photosynthesis. Bicarbonate is about 8.5‰ more enriched in ^{13}C than atmospheric CO_2 (Schoeninger and DeNiro, 1984). Marine plants utilize dissolved nitrate and ammonium and are about 7‰ to 10‰ more enriched in ^{15}N than terrestrial plants. Thus, the $\delta^{15}N$ value for marine animals feeding on fish is 16.5‰, and the $\delta^{15}N$ value for marine animals feeding on invertebrates is 13.3‰ (Schoeninger and DeNiro, 1984). It follows that marine animals have higher $\delta^{15}N$ and $\delta^{13}C$ values than terrestrial animals, owing to the more positive $\delta^{15}N$ and $\delta^{13}C$ of marine plants. This difference will be passed on to human consumers of marine foods (Norr, 1981; Tauber, 1981; Chisholm et al., 1982, 1983; Schoeninger et al., 1983; Hobson and Collier, 1984).

Applications of Stable Isotope Analysis to Paleodiet Research

Isotopic studies of paleodiet are based on the observation that the stable carbon and nitrogen isotopes of an organism appear to be maintained in its bone following death (DeNiro and Epstein, 1978, 1981). The earliest applications of stable isotope analysis to human dietary research utilized stable carbon isotopes and focused on the timing of the introduction of maize agriculture to various regions throughout North America. Isotopic analysis of human bones from archaeological sites throughout New York State revealed a shift in diet from the Late Archaic period (around 3000 BC) to the Late Woodland period (around AD 1000). For the Late Archaic period, a $\delta^{13}C$ value of -21.3‰ suggested a lack of C_4 plants (presumably maize) in the diet, whereas for the Late Woodland period, an average $\delta^{13}C$ value of -14.4‰ suggested that a C_4 plant had become a dietary staple (Vogel and van der Merwe, 1977).

The $\delta^{13}C$ values for human bone collagen (-21.9‰ to -21.1‰) from sites in Ohio, Illinois, and West Virginia indicated that maize was not an important dietary component in that area prior to the Late Woodland period (van der Merwe and Vogel, 1978; Bender et al., 1981). The $\delta^{13}C$ values for the human bones from Hopewell sites in Ohio, Illinois, and Wisconsin dating to the Middle Woodland period (around AD 350) averaged -21.9‰. The $\delta^{13}C$ values increase from -18.1‰ for the Late Woodland period to -11.0‰ for the Upper Mississippian period (around AD 1300). It appears that reliance on maize increased steadily through this period. A similar shift in $\delta^{13}C$ values was seen in southeast Missouri and northeast Arkansas around AD 1000 (Lynott et al., 1986). Late Archaic, Woodland, and early Mississippian samples had $\delta^{13}C$ values of -21.7‰ to -19.9‰, whereas the later Mississippian and Euro-American samples had $\delta^{13}C$ values of -15.8‰ to -10.4‰.

At sites near the cultural center of Cahokia in Illinois there was a noticeable shift through time in $\delta^{13}C$ values for human bone, from -17.6‰ in the Late Woodland to about -11.7‰ in the Mississippian period (Buikstra and Milner, 1991). Human bones from other contemporary sites from the Late Woodland period had $\delta^{13}C$ values ranging from -21.3‰ to -17.6‰, providing evidence for spatial variation in access to maize and its utilization as a food source.

In the American southwest, faunal and floral samples of potential food items from archaeological sites in Cedar Mesa, Utah, provided baseline $\delta^{13}C$ values of -9.9‰ for maize, -23.8‰ for pine nuts and rice grass, -17.0‰ for mountain sheep, and -20.6‰ for deer (Matson and Chisholm, 1991). All of the Anasazi Indian bone samples had $\delta^{13}C$ values ranging between -7.1‰ and -7.9‰, clearly indicating a heavy reliance on a C_4 plant such as maize. There was no evidence of other C_4 plants in the coprolite and floral samples from these sites that could account for the high $\delta^{13}C$ values.

Stable carbon and nitrogen isotopes have also been used to distinguish between marine and terrestrial food sources. Populations subsisting on a marine economy (Alaskan Eskimos and Northwest Coast Indians) had $\delta^{15}N$ values ranging from 17‰ to 20‰, whereas populations with an agricultural economy (manioc farmers from Columbia, South America, Mesoamerican maize agriculturalists, and grain growers from the Neolithic period in Europe) had $\delta^{15}N$ values ranging from 6‰ to 12‰. Groups utilizing a mixture of marine and terrestrial foods had intermediate $\delta^{15}N$ values (Schoeninger et al., 1983). In areas devoid of C_4 plants, $\delta^{13}C$ values are useful in differentiating between consumers of terrestrial versus marine foods. The Greenland Eskimos are known to have derived the majority of their sustenance from marine foods and have $\delta^{13}C$ values around -13‰. Prehistoric samples from the Mesolithic period (around 5000 BC) in Denmark have similar values, and are probably marine consumers as well (Tauber, 1981). Earlier estimates that Mesolithic peoples were terrestrial hunter-gatherers were based on the lack of fish bones and shells at these sites. Fish bones do not preserve well in most soils, and those that do are often overlooked owing to poor archaeological sampling techniques. A shift to a terrestrial food source was seen in the Neolithic (beginning around 4000 BC) as represented by $\delta^{13}C$ values around -20‰.

Chisholm et al. (1982, 1983) compared $\delta^{13}C$ values from prehistoric human populations in British Columbia to the $\delta^{13}C$ values for a variety of dietary items and to the $\delta^{13}C$ values for humans with known diets. Terrestrial animals in that area have an average $\delta^{13}C$ value of -25.7‰ whereas marine animals averaged -17.8‰. Similarly, the $\delta^{13}C$ values for the human coastal consumers were around -13.4‰, which was within 1‰ of the results given by Tauber (1981). The interior populations appeared to have a mixed marine/terrestrial diet, as represented by $\delta^{13}C$ values around -15.4‰. This figure is about 4‰ less than that for populations known to have strictly terrestrial diets. Although it could be argued that the $\delta^{13}C$ values for human consumers of terrestrial foods were a result of ingestion of C_4 plants, plants such as maize were not available in British Columbia at that time. Additionally, the fact that there appears to be little change in the proportion of marine foods in the human diets over a 5000 year span does not support the introduction of a cultigen such as maize.

High Molecular Weight Approach

Although most stable isotope studies report an isolation of bone collagen for analysis, it is not clear that true bone collagen survives post mortem deposition (DeNiro, 1985; Masters, 1987; Tuross et al., 1988). The organic fraction of fresh bone consists of 90% collagen, 5% noncollagenous proteins, and 5% lipids and carbohydrates. Lipids and carbohydrates leach rapidly from bone after burial. Collagen is relatively insoluble, owing to linkages between its triple helix polypeptide chains, and is not strongly bound to the inorganic matrix of the bone. Noncollagenous proteins are acidic polypeptides which adsorb strongly to the bone mineral matrix of hydroxyapatite. As bone degrades, the adsorbed acidic proteins and peptide fragments are preferentially retained, whereas the collagen is lost (Hare, 1980; Tuross et al., 1980; Masters, 1987; Gurley et al., 1991). Therefore, fossil bone most likely contains noncollagenous proteins and collagen in proportions different from fresh bone; highly degraded bone may contain only traces of collagen.

The most common method of sample preparation to isolate organic matter from bones is the method of DeNiro and Epstein (1981) as modified by Schoeninger and DeNiro (1984). Briefly, in this method powdered bone is demineralized by soaking in 1 M HCl for 20 minutes, washed with distilled water, soaked in 0.125 M NaOH for 20 hours, washed, hydrolyzed by placing it in 0.001 M HCl at 90°C for 10 hours, filtered, and freeze dried. This process results in a gelatinous material that is equated with collagen. However, the amino acid profile of this material often differs from true collagen standards and may more closely resemble that of noncollagenous proteins in older bone samples (Tuross et al., 1988; Schoeninger et al., 1989; Weiner and Bar-Yosef, 1990). Interpretations of paleodiet based on samples prepared by this method may therefore be based on noncollagenous proteins, not collagen. Collagen from modern bone is characterized by high concentrations of the amino acids glycine and proline and the presence of hydroxyproline and hydroxylysine; noncollagenous proteins are characterized by high concentrations of glutamic acid and aspartic acid and little hydroxylysine (Wycoff, 1972; Hare, 1980).

The process used in this research isolates the high molecular weight (HMW), organic fraction from the bone or tooth, without discriminating against any specific protein (Ostrom et al., 1990). As described below, cleaned powdered bone is dissolved in cold 6N HCl, placed in dialysis tubing (molecular weight cut off of 8000), and dialyzed at low temperature (2° to 5° C) against distilled water to separate the HMW fraction from the low molecular weight fraction. This method requires less sample material and results in a greater yield of organic matter than the hydrolysis procedure (Schoeninger et al., 1989). The amino acid profiles of modern HMW extracts are similar to collagen (Hare, 1980); the profiles for highly degraded bone, although consistent with a collagenous origin, are most likely derived from both collagenous and noncollagenous proteins (Schoeninger et al., 1989; Ostrom et al., 1990). As suggested by Masters (1987), the composition of these proteins in the organic fraction of bone or dentin should not affect the isotopic ratios of carbon and nitrogen. Although the amino acid compositions for collagen and noncollagenous proteins differ, the averaged isotopic contributions of the major amino acids in each protein to the total isotopic composition of the protein are the same. Therefore, an enrichment of 3‰ for nitrogen is expected per trophic level; for carbon, an enrichment of about 2‰ between plants and herbivores and 1‰ between subsequent trophic levels is expected.

METHODOLOGY

Laboratory Methods

Dialysis was used to collect the HMW organic fraction from each bone or tooth. First, each bone sample was washed in distilled water, scrubbed with a soft brush, if necessary, and scoured to remove surficial contaminants. The sample was then etched in 30% cold HCl, rinsed thoroughly in distilled water, dried, and powdered. A portion of the cleaned, powdered bone or tooth was dissolved in cold 6N HCl, placed in dialysis tubing (molecular weight cut off of 8000), and dialyzed at low temperature (2° to 5° C) against distilled water to separate the HMW fraction from the low molecular weight fraction. The HMW material was lyophilized prior to analysis. Floral samples were cleaned surficially, acid etched in 10% cold HCl, rinsed thoroughly in distilled water, dried, and powdered.

Each sample was combusted in the presence of copper and copper oxide while under vacuum. The resulting gases were cryogenically separated; carbon dioxide and nitrogen were analyzed on a V.G. PRISM isotope ratio mass spectrometer for the $\delta^{13}C$ and $\delta^{15}N$ values, respectively. Instrumental precision is $\pm 0.05‰$. All values were rounded to one decimal place.

Approximately every seventh sample was replicated to verify the reproducibility of the measurements (Table 12). The variation between replicates was 0.2 to 1.5‰ for $\delta^{15}N$ values and 0 to 1.8‰ for $\delta^{13}C$ values. The greatest variation in $\delta^{15}N$ values was for samples YD9-34-143 (1.5‰) and North Carolina deer (1.2‰). Both samples were prepared and analyzed early in this study; variation between $\delta^{15}N$ values in subsequent replicates decreased to less than 0.5‰ as the laboratory techniques were perfected. The missing $\delta^{15}N$ values in Table 12 can be attributed to sample loss in the mass spectrometer, insufficient sample size, or air contamination. Maximum variation in $\delta^{13}C$ values was for samples 383744-JE88 (1.8‰), YD9-34-143 (0.9‰), and ON305-195 (0.9‰). As for the $\delta^{15}N$ values, variation in $\delta^{13}C$ values decreased to less than 0.5‰ as the study progressed.

Table 12. $\delta^{13}C$ and $\delta^{15}N$ values for replicate samples.

Sample	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
N.C. deer	-19.8	6.4
	-19.5	5.5
	-19.5	6.7
YD9-34-143	-14.6	9.9
	-15.5	9.9
	-14.8	11.4
YD9-38-11b	-14.9	11.0
	-14.8	10.5
ON305-4	-12.9	
	-14.9	
	-13.1	
ON305-195	-12.5	9.4
	-12.2	9.8
	-13.1	9.8
10B	-14.4	12.6
	-14.4	12.4
383744 (JE 88)	-22.7	
	-24.5	
	-23.9	
382013C (LC)	-15.3	
	-15.3	
382013D (LC)	-10.2	
	-10.9	
382013E (LC)	-11.3	
	-12.1	

Table 12. $\delta^{13}C$ and $\delta^{15}N$ values for replicate samples.

Sample	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
DV4-3	-17.4	
	-17.2	
DV4-13Bb	-19.3	10.6
	-19.1	9.9
DV4-19	-20.3	9.6
	-20.4	9.2
384660 (PC 33)	-14.2	
	-14.9	
OR1-198	-14.0	8.4
	-13.8	8.9
OR1-32	-19.4	
	-19.3	
OR1-71	-16.1	
	-15.7	
OR1-98	-16.9	11.3
	-17.0	11.0

Statistical Methods

Descriptive statistics will be used to characterize the general diet at each site in terms of the $\delta^{13}C$ and $\delta^{15}N$ values. Parametric and non-parametric analysis of variance tests will be used where appropriate to examine differences between isotopic compositions.

RESULTS

The HMW organic fraction of bone from 136 individuals and tooth from five individuals was analyzed for its stable carbon and nitrogen composition (Table 13). The range of $\delta^{13}C$ values for all samples was -23.7‰ to -7.5‰; the $\delta^{15}N$ values were 6.4‰ to 15.8‰ (Figures 3, 4). Intrasite variation between $\delta^{13}C$ values, as reflected by the standard deviations (σ), was most pronounced at John East (σ = 3.2‰), Potomac Creek (σ = 2.2‰), Governor's Land (σ = 2.3‰), and Trigg (σ = 2.2‰) and least pronounced at Brown Johnson (σ = 0.8‰), Shannon (σ = 0.8‰), and Flynt (σ = 1.0‰) (Table 14). Maximum intersite difference between mean $\delta^{13}C$ values was -8.6‰, between John East (mean = -19.6‰) and Shannon (mean = -11.0‰). In contrast, the maximum intersite difference between mean $\delta^{15}N$ values was only 3.1‰, John East (mean = 8.6‰) and Flynt (mean = 11.7‰). Intrasite variation between $\delta^{15}N$ values was lowest at John East (σ = 0.3‰) and Lewis Creek (σ = 0.7‰), and highest at Governor's Land (σ = 2.9‰) and Flynt (σ = 1.9‰).

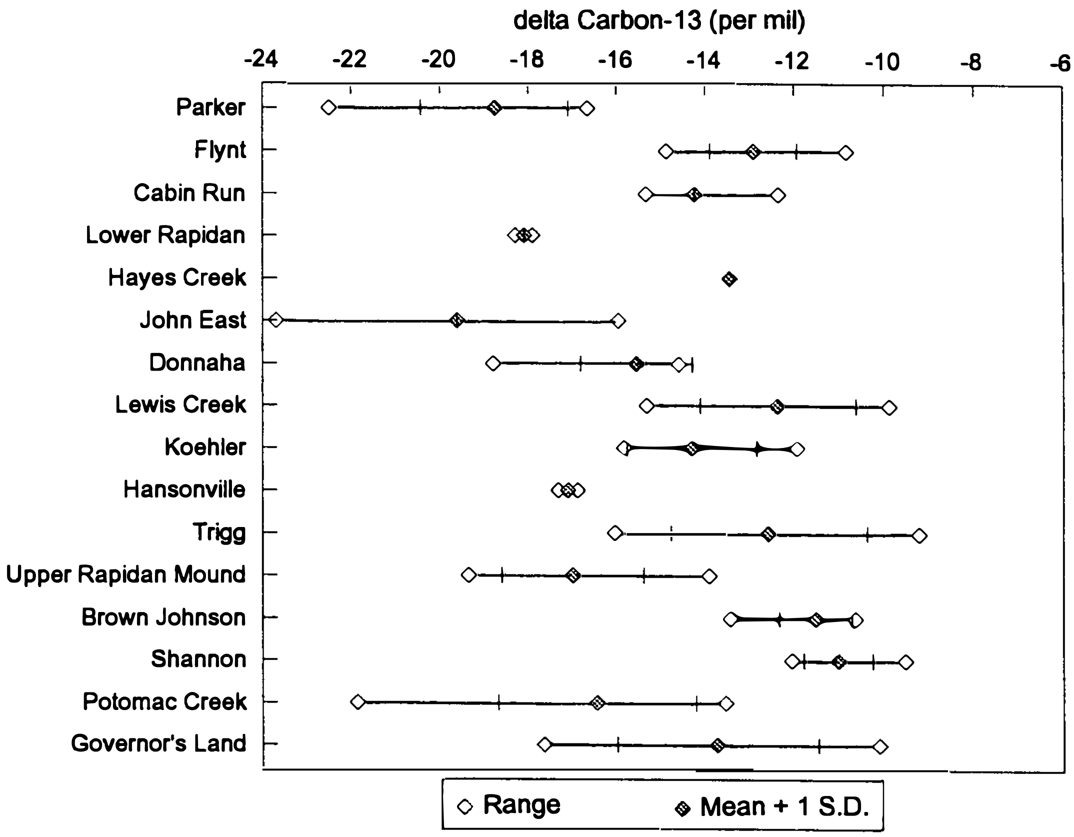

Figure 3. Range of $\delta^{13}C$ values for each site and mean $\pm$ 1 S.D

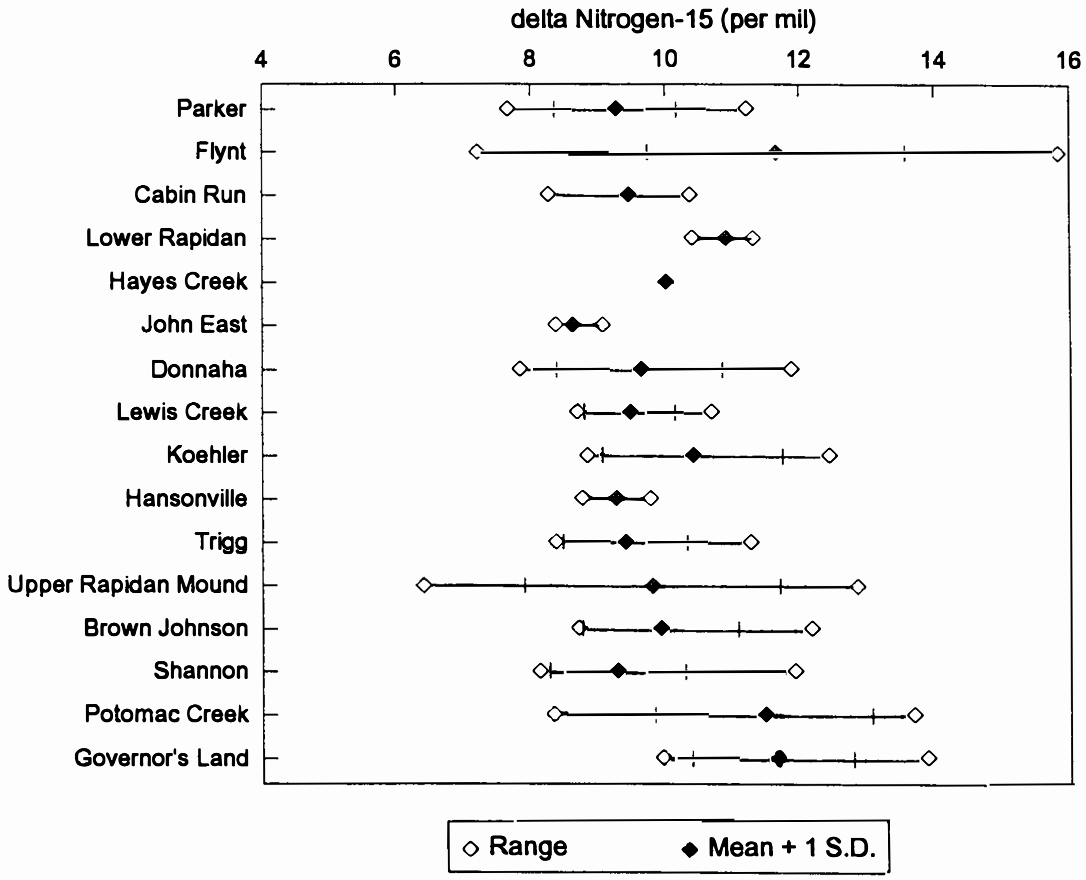

Figure 4. Range of $\delta^{15}N$ values for each site and mean ± 1 S.D.

Table 13. Stable carbon and nitrogen values for each sample.

Site	ID Number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Age *	Sex
Parker	DV4-13B	-19.2	10.2	I	F
(Middle Woodland)	DV4-14	-16.8	8.6	I	F
	DV4-15	-16.7	9.1	A	F
	DV4-16	-18.2	9.0	C	
	DV4-18	-19.6	9.1	T	F
	DV4-19	-20.3	9.4	I	
	DV4-2	-22.5	7.7	A	
	DV4-3	-17.3	9.6	C	
	DV4-5	-18.0	8.9	A	
	DV4-XX	-18.9	11.2	C	F
Flynt	ON305-104	-12.8	10.0	A	
(1st part of Late Woodland)	ON305-127	-12.8	15.8	I	
	ON305-128	-14.8	13.8	C	
	ON305-133	-12.0	13.4	A	
	ON305-134	-11.5	12.5	A	
	ON305-174	-13.3	11.8	A	
	ON305-195	-12.6	9.7	A	
	ON305-234	-13.1	10.0	A	
	ON305-249	-12.5	12.4	A	
	ON305-252	-12.9	12.2	A	
	ON305-253	-13.2	11.3	A	
	ON305-256	-10.8	12.5	A	
	ON305-257	-13.9	12.6	A	
	ON305-285	-14.9	7.2	A	
	ON305-4	-14.3	9.3	A	
	ON305-64	-12.6	12.3	A	

Table 13. (Cont).

Site	ID Number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Age *	Sex
Flynt, Cont.	ON305-7	-12.4	13.2	A	
	ON305-88	-12.5	13.2	C	F
	ON305-MA	-12.3	9.7	A	M
	ON305-MC	-12.9	10.5	A	
Cabin Run	WR-300-1	-15.3	8.3	A	F
(1st part of Late Woodland)	WR-300-3	-15.0	9.7	A	F
	WR-300-4	-12.3	10.4	A	M
Rapidan Mound	OR-1-15C (SMF8)	-18.3	10.4	A	M
(1st part of Late Woodland)	OR-1-20C (SMF7)	-17.9	11.3	A	
Hayes Creek	RB-2-14	-13.4	10.0	A	
(1st part of Late Woodland)					
John East	383731 (JE #34)	-16.0	8.4	A	
(1st part of Late Woodland)	383744 (JE #88)	-23.7	9.1	A	
	383747 (JE #105)	-19.2	8.4	A	
Donnaha	YD1-31-3	-15.4	7.8	A	M
(1st part of Late Woodland)	YD1-34-144F	-14.6	11.9	C	M
	YD1-36-19	-15.6	8.4	T	M
	YD9-22-5A	-18.8	9.0	A	
	YD9-34-143	-15.0	10.4	T	
	YD9-37-7	-15.3	9.4	A	
	YD9-38-11B	-14.8	10.8	A	
	YD9-40-10	-14.9	9.3	A	

Table 13. (Cont).

Site	ID Number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Age *	Sex
Lewis Creek	382013A (LC)	-9.9	9.6	A	
(1st part of Late Woodland)	382013B (LC)	-14.4	9.1	A	
	382013C (LC)	-15.3		A	
	382013D (LC)	-10.6	8.7	A	
	382013E (LC)	-11.7	8.9	A	
	382014A (LC)	-12.9	9.1	C	
	382014B (LC)	-12.5	10.7	C	M
	382014C (LC)	-13.5	10.5	C	M
	382014D (LC)	-10.6	9.2	C	F
Koehler	385676 (K)	-15.8	11.3	A	
(2nd part of Late Woodland)	385677 (K)	-12.4	9.3	C	
	385678 (K)	-11.9	8.8	A	
	385679 (K)	-13.2	9.4	A	
	385680 (K)	-15.5	10.1	A	
	385681 (K)	-14.7	9.4	A	
	385682 (K)	-15.5	12.4	A	
	385683 (K)	-15.4	12.4	A	
Hansonville	RU-7-34A2-5	-17.3	8.7	A	
(2nd part of Late Woodland)	RU-7-34B-2	-16.9	9.8	A	
Trigg	385065 (T)	-11.0	8.8	A	
(2nd part of Late Woodland)	385066 (T)	-9.8	8.8	A	
	385067 (T)	-9.2	8.4	A	
	385105 (T)	-14.8		A	
	385106 (T)	-14.5	10.0	A	
	385107 (T)	-11.0	8.5	C	
	385108 (T)	-16.0	11.0	C	
	385110 (T)	-12.3	9.5	A	

Table 13. (Cont).

Site	ID Number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Age *	Sex
Trigg, Cont.	385116 (T)	-11.7	8.8	A	
	385168 (T)	-14.5	10.1	A	
	385169 (T)	-13.9	10.8	I	
	385171 (T)	-12.6	9.1	A	
	385172 (T)	-12.5	11.2	A	
	385227 (T)	-10.0	8.6	A	
	385272 (T)	-9.5	9.0	A	
	385273 (T)	-15.5	9.2	A	
	385365 (T)	-14.9	8.4	A	
Rapidan Mound	OR-1-198C (MF4)	-13.9	8.6	A	
(2nd part of Late Woodland)	OR-1-308C (MF10)	-17.7	12.9	A	
	OR-1-32C (MF9)	-19.3	10.0	A	
	OR-1-332C (MF10)	-16.5	10.7	A	
	OR-1-71C (MF9)	-15.9	8.0	A	
	OR-1-79C (MF10)	-16.7	6.4	A	
	OR-1-81 (1979)	-18.9	10.6	A	
	OR-1-98C (MF9)	-16.9	11.1	A	
Brown Johnson	382553 (BJ-1)	-11.2	9.4	T	M
(2nd part of Late Woodland)	382554 (BJ-2)	-10.9	9.7	A	F
	382555 (BJ-3)	-10.6	11.5	I	M
	382557 (BJ-5)	-11.3		C	
	382558 (BJ-6)	-12.1	9.3	A	
	382559 (BJ-7)	-11.9	8.7	A	M
	382560 (BJ-8)	-11.4	8.9	A	
	382561 (BJ-9)	-13.4	12.2	A	
	382564 (BJ-10C)	-10.8	9.5	A	

Table 13. (Cont).

Site	ID Number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Age *	Sex
Shannon	382413 (S)	-10.7	9.1	A	M
(2nd part of Late Woodland)	382414 (S)	-11.5	8.3	I	M
	382415 (S)	-11.4	9.6	C	M
	382417 (S)	-9.5	11.1	C	
	382418 (S-6)	-11.3	8.1	A	M
	382421 (S-9)	-11.7	9.1	A	
	382422 (S-10)	-11.7	10.0	A	F
	382456 (S-44)	-10.3	9.3	A	
	382458 (S)	-12.0	8.3	A	
	382460 (S-48)	-10.1	11.9	C	
	382465 (S-53)	-11.5	9.2	A	
	382488 (S-77)	-11.3	9.8	I	
	382492 (S-81)	-9.8	8.3	A	
	382496 (S-86)	-12.1	8.7	C	
	382502 (S-92)	-10.3	9.3	A	
	382600 (S-127)	-11.3	8.3	C	

Table 13. (Cont).

Site	ID Number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Age *	Sex
Potomac Creek	384641 (PC)	-18.1	8.3	A	
(2nd part of Late Woodland)	384659 (PC-32A)	-14.6	10.7	I	
	384660 (PC #33)	-14.5	12.4	C	
	384661 (PC #34)	-14.3	10.2	T	
	384666 (PC #36C)	-17.1	13.2	A	
	384667 (PC #37)	-17.0	13.1	A	
	384671 (PC)	-13.5	11.9	I	
	384674 (PC)	-17.2	11.9	A	
	384684 (PC)	-14.8	13.7	C	
	384685 (PC)	-18.7	12.2	A	
	384687 (PC #50)	-18.0	8.4	A	
	384726 (PC)	-16.7	11.5	A	
	384737 (PC)	-13.9	11.6	I	
	384747 (PC)	-21.9		A	
Governor's Land	10B	-14.4	12.5	A	
(2nd part of Late Woodland)	12D24**	-10.8	10.2	A	F
	1F12**	-10.1	10.8	A	M
	1F57E1**	-12.8	11.8	C	M
	24A	-15.4	11.0	A	M
	57	-16.9	13.9	A	F
	75H2-1	-14.9	9.9	A	
	75H2-2**	-12.2	12.6	A	M
	75J2-1**	-13.3		A	M
	75J2-3	-17.6	12.3	A	M
	9CH-2	-12.6	10.5	A	

* A = adult (> 18 yrs); T = adolescent (13 - 18 yrs); C = child (3 - 12 yrs); I = infant (0 - 2yrs)

** teeth

Table 14. Mean $\delta^{13}C$ and $\delta^{15}N$ values for all individuals at each site.

		$\delta^{13}C$		$\delta^{15}N$	
Site	n	mean (‰)	Std. dev.	mean (‰)	Std. dev.
Brown Johnson	9	-11.5	0.8	9.9	1.2
Cabin Run	3	-14.2	1.3	9.4	0.9
Donnaha	8	-15.5	1.3	9.6	1.2
Flynt	20	-12.9	1.0	11.7	1.9
Governor's Land	11	-13.7	2.3	11.6	1.2
Hansonville	2	-17.1		9.3	
Hayes Creek	1	-13.4		10.0	
John East	3	-19.6	3.2	8.6	0.3
Koehler	8	-14.3	1.5	10.4	1.4
Lewis Creek	9	-12.4	1.7	9.5	0.7
Parker	10	-18.8	1.7	9.3	0.9
Potomac Creek	14	-16.5	2.2	11.5	1.6
Rapidan Mound	10	-17.2	1.5	10.0	1.8
Shannon	16	-11.0	0.8	9.3	1.0
Trigg	17	-12.6	2.2	9.4	0.9

DISCUSSION

Interpretation of the stable isotope data will begin with a discussion of sample variation, followed by a general characterization of the diet endpoints. Temporal and spatial patterns in diet will be investigated. After a detailed discussion of the diet at each site, the data will be integrated with other stable isotope data into a regional perspective.

Sample Variation

The variation observed for these samples may be a function of systematic sampling errors, or it may be attributed to factors such as site location, site date, age or sex of the individual, and differential resource utilization. As discussed above, instrumental precision was $\pm$ 0.05‰, and the $\delta^{15}N$ and $\delta^{13}C$ values for replicate samples were generally within 0.5‰. The standard deviations for both the $\delta^{15}N$ and $\delta^{13}C$ values exceeded the reproducibility, indicating that a factor other than instrumental variation or laboratory technique was the cause of the variation.

Five of the samples examined were teeth rather than bone. The isotopic compositions of teeth reflect the diet during the time of tooth formation. Although Differences between the isotopic compositions of tooth enamel and dentin have been observed by the author, carefully isolated dentin is suitable for stable isotope analysis (Masters, 1987). Error introduced by the inclusion of teeth in the study would be related to the age of the individual, not the choice of sample media.

The ages of the individuals in this study range from infant to adult (Table 15). Where available, osteological reports were used to determine ages. Visual inspection of the bones showed no obvious discrepancies between the reported and observed ages. Teeth were assigned to the age category best representing the time of formation as

Table 15. Summary of $\delta^{13}C$ and $\delta^{15}N$ values by age for each site.

Time period	Site	Age *	n	$\delta^{13}C$ (‰) **	$\delta^{15}N$ (‰) **
Middle Woodland (0 - A.D. 900)	Parker	A	3	-19.1	8.5
		T	1	-19.6	9.1
		C	3	-18.1	9.9
		I	3	-18.8	9.4
First part of Late Woodland (A.D. 900 - 1400)	Cabin Run	A	3	-14.2	9.4
	Donnaha	A	5	-15.8 ± 1.5	9.3 ± 0.9
		T	2	-15.3	9.4
		C	1	-14.6	11.9
	Flynt	A	17	-12.8 ± 0.9	11.2 ± 1.6
		C	2	-13.7	13.5
		I	1	-12.8	15.8
	Hayes Creek	A	1	-13.4	10.0
	John East	A	3	-19.6	8.6
	Lewis Creek	A	5	-12.4 ± 2.1	9.1 ± 0.3
		C	4	-12.4 ± 1.1	9.9 ± 0.7
	Rapidan (lower level)	A	2	-18.1	10.9
Second part of Late Woodland (A.D. 1400 - 1600)	Brown Johnson	A	6	-11.7 ± 0.9	9.7 ± 1.1
		T	1	-11.2	9.4
		C	1	-11.3	--
		I	1	-10.6	11.5
	Governor's Land	A	6	-15.3 ± 1.6	11.7 ± 1.3
		T	2	-10.4	10.5
		C	3	-12.8	12.2

Table 15. (Cont.)

Time period	Site	Age *	n	$\delta^{13}C$ (‰) **	$\delta^{15}N$ (‰) **
Second part of Late Woodland, Cont.	Hansonville	A	2	-17.1	9.3
	Koehler	A	7	-14.6 ± 1.3	10.6 ± 1.4
		C	1	-12.4	9.3
	Potomac Creek	A	8	-18.1 ± 1.6	11.2 ± 1.9
		T	1	-14.3	10.2
		C	2	-14.7	13.0
		I	3	-14.0	11.4
	Rapidan Mound (upper levels)	A	8	-17.0 ± 1.6	9.8 ± 1.9
	Shannon	A	9	-11.0 ± 0.7	9.0 ± 0.6
		C	5	-10.9 ± 0.9	9.9 ± 1.4
		I	2	-11.4	9.0
	Trigg	A	14	-12.4 ± 2.1	9.2 ± 0.8
		C	2	-13.5	9.7
		I	1	-13.9	10.8

* A = adult (> 18 yrs); T = adolescent (13 - 18 yrs); C = child (3 - 12 yrs); I = infant (0 - 2 yrs)

** ± 1 S.D. for n>3

described by Steele and Bramblett (1988). Visual inspection and comparison to other bones in the assemblage were used to determine the ages of the remaining individuals.

The $\delta^{15}N$ and $\delta^{13}C$ values for individuals of different ages vary noticeably for some sites. For example, at Donnaha, the mean $\delta^{15}N$ value for children was 2.5‰ higher than for adults and adolescents, and it exceeded the standard deviation for adults. At Flynt, the $\delta^{15}N$ value for the infant was 4.6‰ higher than the mean $\delta^{15}N$ value for the adults. Similarly, the mean $\delta^{13}C$ values for infants, children, and an adolescent at Potomac Creek were about 4‰ more positive than the mean $\delta^{13}C$ value for the adults. In contrast, there was little difference between the stable isotope values for children and adults at Lewis Creek. A comparison of the standard deviations for the $\delta^{13}C$ and $\delta^{15}N$ values for adults versus the values for the site as a whole suggests that isotopic variation at these sites is not solely a function of age. The most conservative approach to data analysis would be to restrict intersite comparisons to a single age group. Therefore, investigations of temporal and spatial patterns will be restricted to adults, which comprise 70.2% of the total assemblage and are present at all sites (Table 16).

Table 16. Summary of age distribution for all samples.

Category	Age (years)	No. of Individuals	% of total population
Infant	0 - 2	11	7.8
Child	3 - 12	24	17.0
Adolescent	13 - 18	7	5.0
Adult	> 18	99	70.2

Characterization of Diet Endpoints

To assess the diet, a food web was constructed from the isotopic compositions of several potential dietary sources. Ecological resources that may have been exploited by the individuals interred at the Virginia and North Carolina sites can be divided into four isotopically distinct categories: terrestrial/C_3 plant based, agricultural/C_4 plant based, freshwater aquatic based, and marine based. The isotopic values for carbon and nitrogen for food resources from these four categories plus an appropriate trophic level shift ($\sim$1 to 2‰ for carbon, 3‰ for nitrogen) related to the isotopic fractionation for metabolism was compared to the isotopic compositions of the human bones recovered to assess the probable composition of the diet (Figure 5).

A sample of maize (*Zea mays*) from Governor's Land (44JC308) was representative of C_4 cultigens, and had a $\delta^{13}C$ value of -9.8‰ and a $\delta^{15}N$ value of 4.8‰ (Trimble and Macko, 1994). A diet consisting solely of C_4 plants would result in $\delta^{13}C$ value of -7.8‰ and a $\delta^{15}N$ value of 7.8‰ for the human bone. Hickory and walnut, C_3 species recovered from several sites in the Virginia Piedmont, had an average $\delta^{13}C$ value of -25.7‰ and $\delta^{15}N$ value of 3.0‰. The bone protein of herbivores such as deer, beaver, squirrel, and rabbit subsisting on C_3 plants would have a $\delta^{13}C$ of -23.7‰ and a

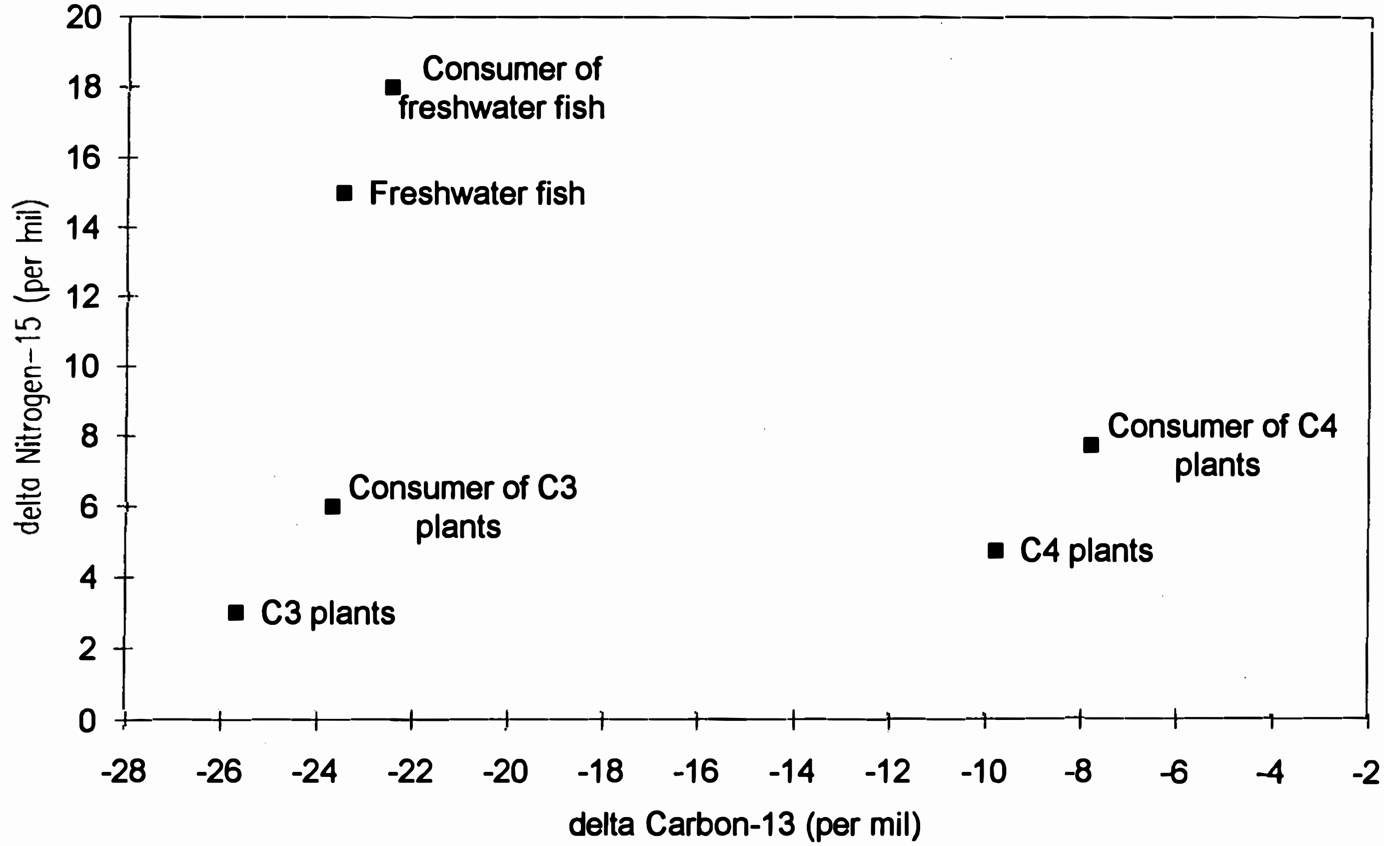

Figure 5. Stable carbon and nitrogen isotope values for three food types and for exclusive consumers of each food.

$\delta^{15}N$ of 6.0‰; humans eating these herbivores exclusively should have a $\delta^{13}C$ of -22.7‰ and a $\delta^{15}N$ of 9.0‰. The freshwater aquatic component might contain fish such as sunfish, bass, and sturgeon. Although the freshwater component could have $\delta^{13}C$ values similar to the terrestrial/C_3 plant based component, freshwater aquatic protein is more enriched in ^{15}N. Largemouth bass from the James River have an average $\delta^{13}C$ of -23.5‰ and $\delta^{15}N$ of 15.0‰ (Garman et al., submitted). Consumers of freshwater fish exclusively might have a $\delta^{13}C$ value of -22.5‰ and a $\delta^{15}N$ of 18.0‰. The marine component would also have higher $\delta^{15}N$ values than the terrestrial plant based components, but the $\delta^{13}C$ values would be intermediate between that of C_3 and C_4 plants. Modern marine fish have $\delta^{13}C$ values of -19.3‰ to -12.1‰ and $\delta^{15}N$ values of 11.1‰ to 14.7‰ (Chisholm et al., 1982; Schoeninger and DeNiro, 1984); Virginia shellfish have a mean $\delta^{13}C$ value of -21.0‰ and a mean $\delta^{15}N$ value of 9.0‰ (Macko, unpublished data). Mixed diets result in intermediate values.

Although the bulk isotope measurements cannot be used to differentiate between specific plants or animals consumed (e.g., walnut and dandelion, or raccoon and deer), they can be used to determine the major categories of foods that make up the diet. Additionally, the relative proportions of the diet endmembers (Table 17) can be determined through mathematical mixing equations. These equations are simplest for a diet with two endmembers and become increasingly complex with each additional endmember. The specific percentages of the components for the diet of each individual were not able to be determined for this research. The human diets were probably complex and to determine component percentages based on a simple diet with only three or four endmembers is pointless. Instead, these endmembers are used as a relative barometer of the major classes of foods that comprised each diet.

Table 17. Calculated potential $\delta^{13}C$ and $\delta^{15}N$ values for the bone protein of consumers of various diets.

Diet description	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
100% C_3 plants	-23.7	6.0
100% C_4 plants	-7.8	7.8
50% C_3 plants, 50% C_4 plants	-15.8	6.9
25% C_3 plants, 75% C_4 plants	-11.8	7.4
75% C_3 plants, 25% C_4 plants	-19.7	6.5
100% freshwater fish	-22.5	18.0
100% marine fish/shellfish	-20.0 to -11.1	12.0 to 17.7
33.3% C_3 plants, 33.3% C_4 plants, 33.3% freshwater fish	-17.6	10.6
100% herbivores feeding exclusively on C_3 plants	-22.7	9.0
100% herbivores feeding exclusively on C_4 plants	-6.8	10.8

Temporal Patterns

The $\delta^{15}N$ and $\delta^{13}C$ values for the adults were aggregated by temporal affiliation to investigate changes through time (Table 18). Because the variances are equal, the F test was used to test the null hypothesis that the mean $\delta^{13}C$ values are the same for each period. For an alpha level of 0.05, degrees of freedom$_1$ of 2, and degrees of freedom$_2$ of 98, F_α is approximately 3.0. For the $\delta^{13}C$ values, F is 4.1. Because F is greater than F_α, the null hypothesis is rejected, and it is concluded that the mean $\delta^{13}C$ values are not the same for each province. Sheffe's S test was used to test the null hypothesis that the $\delta^{13}C$ values for each pair of time periods are the same. If S for each pair is greater than or equal to the absolute difference between the means, the null is rejected. The results indicate that the $\delta^{13}C$ values for the Middle Woodland sites are different from all of the Late Woodland sites (Table 19). There is no difference in $\delta^{13}C$ values for the first and second parts of the Late Woodland period.

Initially, the F test was selected to test the null hypothesis that the mean $\delta^{15}N$ values for each period are the same, but because the variances for each period are not equal, the non-parametric Kruskal-Wallis test was used. For an alpha level of 0.05 and 2 degrees of freedom, K_{α} is 6.0. For the $\delta^{15}N$ values, K is 2.0. Because K is less than K_{α}, the null hypothesis is not rejected. It is concluded that the $\delta^{15}N$ values for all three periods are the same.

Table 18. Mean $\delta^{13}C$ and $\delta^{15}N$ values for each time period.

Period	n	$\delta^{13}C \pm 1$ S.D. (‰)	$\delta^{15}N \pm 1$ S.D. (‰)
Middle Woodland	3	-19.1	8.5
First part of Late Woodland	36	-14.2 ± 2.7	10.3 ± 1.6
Second part of Late Woodland	60	-14.2 ± 3.0	10.0 ± 1.6

Table 19. Results of Sheffe's S test to test null hypothesis (H_0) that the $\delta^{13}C$ values for each pair of time periods is the same. Reject H_0 if absolute mean difference > S.

Groups	Abs. mean dif.	S	Reject H_0?
Middle Woodland and 1st part of Late Woodland	4.9	4.3	yes
Middle Woodland and 2nd part of Late Woodland	4.9	4.2	yes
1st part of Late Woodland and 2nd part of Late Woodland	0.02	1.5	no

Middle Woodland Period

The Middle Woodland Period (0 - A.D. 900) is represented by the Parker site. Although the dates for Flynt extend into the Middle Woodland, its primary occupation was during the first part of the Late Woodland Period. The mean stable isotope values ($\delta^{15}N$ = 8.5‰, $\delta^{13}C$ = -19.10‰) for the three adults in this period are within the ranges expected for consumers of predominately C_3 plants and other terrestrial animal proteins.

First Part of the Late Woodland Period

The first part of the Late Woodland Period (A.D. 900 - 1400) is represented by Lewis Creek, Cabin Run, Hayes Creek, Flynt, Donnaha, the lower levels of Rapidan, and John East. Isotopic analysis of bones from 36 adults yielded mean $\delta^{13}C$ and $\delta^{15}N$ values of -14.2 ± 2.7‰ and 10.3 ± 1.6‰, respectively. The mean $\delta^{13}C$ value is almost 5‰ heavier than the mean $\delta^{13}C$ value for the Middle Woodland Period, indicating that the C_4 component of the diet increased in the first half of the Late Woodland. Alternatively, this difference could result from the introduction of a marine component. However, the $\delta^{15}N$

values are not high enough to support this interpretation and Flynt is the only site with immediate access to marine resources. Although the mean $\delta^{15}N$ value is over 1‰ heavier than in the Middle Woodland Period, it is close to the one standard deviation range and is not statistically significant.

Seventeen of the 36 individuals sampled were from Flynt, which has a mean $\delta^{13}C$ value of -12.8 ± 0.9‰ and a $\delta^{15}N$ value of 11.2 ± 1.6‰. The $\delta^{15}N$ value is higher than expected for a strictly terrestrial diet, indicating that either a marine or freshwater aquatic component was present in the diet. The $\delta^{13}C$ value is within the range expected for C_4 plants or marine resources. If the Flynt samples are excluded, both the mean $\delta^{13}C$ and $\delta^{15}N$ values for the first part of the Late Woodland Period are lower by about 1‰. This $\delta^{15}N$ value, 9.5‰, is indicative of a diet rich in terrestrial proteins. The $\delta^{13}C$ value, -15.0‰, is midway between the endpoints for C_3 and C_4 plant based diets, supporting a shift to C_4 agriculture.

Second Part of the Late Woodland Period

The second part of the Late Woodland Period (A.D. 1400 - 1600) is represented by Shannon, Trigg, Potomac Creek, Koehler, Hansonville, Brown Johnson, Governor's Land, and the upper levels of Rapidan Mound. Isotopic analysis of bones from 60 adult individuals yielded mean $\delta^{13}C$ and $\delta^{15}N$ values of -14.2 ± 3.0‰ and 10.0 ± 1.6‰, respectively. The mean $\delta^{15}N$ value is similar to that for the first part of the Late Woodland Period. The mean $\delta^{13}C$ values for the first and second parts of the Late Woodland are identical, -14.2 ± 2.7‰ and -14.2 ± 3.0‰, respectively. These values indicate that there was no dietary change in the latter part the Late Woodland. Trigg, Shannon, and Potomac Creek contributed the majority of the individuals in this subset (14, 9, and 8 individuals, respectively) and illustrate the variability of the samples in this period. Of these four sites, Potomac Creek had the lowest mean $\delta^{13}C$ value (-18.1 ± 1.6‰), followed by Trigg (-12.4 ± 2.1‰) and Shannon (-11.0 ± 0.7‰). There was little difference between the mean $\delta^{15}N$ values for Trigg and Shannon (9.2 ± 0.8‰ and 9.0 ± 0.6‰, respectively). The mean $\delta^{15}N$ values for Potomac Creek (11.2 ± 1.9‰) and Governor's Land (11.7 ± 1.3‰) were over 2‰ higher than the values for Trigg and Shannon. Utilization of freshwater aquatic and marine resources at Potomac Creek and Governor's Land would account for the observed isotopic compositions. Trigg and Shannon, both in the Valley and Ridge province, had little natural access to marine foods to account for the more positive $\delta^{13}C$ values, and most likely had a diet rich in C_4 plants.

Spatial Patterns

Because the variances are equal, the F test was used to test the null hypothesis that the mean $\delta^{13}C$ values are the same for each physiographic province. For an alpha level of 0.05, degrees of freedom$_1$ of 2, and degrees of freedom$_2$ of 98, F_α is approximately 3.0. For the $\delta^{13}C$ values, F is 30.3. Because F is greater than F_α, the null hypothesis is rejected, and it is concluded that the mean $\delta^{13}C$ values are not the same for each province. Sheffe's S test was used to test the null hypothesis that the $\delta^{13}C$ values for each pair of provinces are the same. If S for each pair is greater than or equal to the absolute difference between the means, the null is rejected. The results indicate that each province has distinct $\delta^{13}C$ values (Tables 20, 21).

Table 20. Mean $\delta^{13}C$ and $\delta^{15}N$ values for each physiographic province.

Period	n	$\delta^{13}C \pm 1$ S.D. (‰)	$\delta^{15}N \pm 1$ S.D. (‰)
Coastal Plain	31	-14.7 ± 2.6	11.3 ± 1.7
Piedmont	25	-16.4 ± 2.2	9.8 ± 1.6
Appalachian Valley	43	-12.9 ± 2.9	9.2 ± 0.8

Table 21. Results of Sheffe's S test to test null hypothesis (H_0) that the $\delta^{13}C$ values for each pair of provinces is the same. Reject H_0 if Abs. mean dif. > S.

Groups	Abs. mean dif.	S	Reject H_0?
Coastal Plain & Piedmont	2.4	1.4	yes
Coastal Plain & Appalachian Valley	1.6	1.2	yes
Piedmont & Appalachian Valley	4.0	1.3	yes

The variances for the $\delta^{15}N$ values are not equal; therefore, the Kruskal-Wallis test was used to test the null hypothesis that the mean $\delta^{15}N$ values for each physiographic province are the same. Because K (41.9) is greater than K_{α} (6.0), the null hypothesis is rejected. It is concluded that the $\delta^{15}N$ values for all three provinces are not the same. The mean $\delta^{15}N$ value for the Coastal Plain is different from the Piedmont and Appalachian Valley.

Coastal Plain

The Coastal Plain sites include Potomac Creek, Governor's Land, and Flynt (Figure 6). The similar mean $\delta^{15}N$ values (11.2 ± 1.9‰, 11.7 ± 1.3‰, and 11.2 ± 1.6‰, respectively) for each reflect a substantial marine or freshwater aquatic component. This is as expected for sites located on major waterways: Flynt is on Chadwick Bay; Governor's Land is at the confluence of the James and Chickahominy Rivers; and Potomac Creek is bounded by Accokeek Creek, Potomac Creek, and the Potomac River. The mean $\delta^{13}C$ value (-14.7 ± 2.6‰) for this province indicates that either marine foods or C_4 plants were a dietary component. Flynt and Governor's Land had direct evidence of maize in their floral assemblages; direct evidence of marine resources was present in all three faunal assemblages. Potential C_4 plant usage, as reflected by the $\delta^{13}C$ values, is highest at Flynt (mean $\delta^{13}C$ value = -12.8 ± 0.9‰) and lowest at Potomac Creek (mean $\delta^{13}C$ = -18.1 ± 1.6‰). The mean $\delta^{13}C$ value for Governor's Land is -15.3 ± 1.6‰.

Piedmont

The Piedmont province includes Rapidan Mound, Koehler, Parker, and Donnaha (Figure 7). The mean $\delta^{15}N$ values for the Piedmont are lower than for the Coastal Plain, although the ranges overlap. This suggests that aquatic resources may have been utilized less intensively than in the Coastal Plain province. Based on the $\delta^{13}C$ values, only Koehler ($\delta^{13}C$ value of -14.6 ± 1.3‰) has evidence of potentially heavy C_4 plant usage; the remainder reflect primarily a C_3 plant component or a 50/50 mixture of C_3 plants and C_4 plants. The ranges of $\delta^{13}C$ and $\delta^{15}N$ values are greater in the Piedmont than in the Appalachian Valley province, indicating a potentially more diverse diet. With the exception of the upper levels of Rapidan Mound, the $\delta^{13}C$ values for the sites in this province show an increase in possible C_4 plant consumption through time (Table 22). This difference may be a function of sample size or temporal placement of the site rather than diet.

Table 22. Summary of $\delta^{13}C$ values for Piedmont sites.

Site	Period	n	$\delta^{13}C$ (‰)	% C_4 plants
Parker	Middle Woodland	3	-19.1	25
Lower Rapidan	Late Woodland (1st part)	2	-18.1	25
Donnaha	Late Woodland (1st part)	5	-15.8 ± 1.5	50
Koehler	Late Woodland (2nd part)	7	-14.6 ± 1.3	50 - 75
Upper Rapidan	Late Woodland (2nd part)	8	-17.0 ± 1.6	25 - 50

Appalachian Valley

The Appalachian Valley province includes Lewis Creek, John East, Hayes Creek, Cabin Run, Shannon, Trigg, Brown Johnson, and Hansonville (Figure 8). The stable isotope values for two of these sites, John East and Hansonville, are indicative of a diet rich in C_3 plants, whereas the other six reflect a diet richer in C_4 plants. Excluding John East and Hansonville, intrasite variations in $\delta^{13}C$ and $\delta^{15}N$ values are small compared to those for the Coastal Plain and Piedmont, suggesting a more monotonous diet. The mean $\delta^{15}N$ value for the Appalachian Valley sites (9.2 ± 0.8‰) is similar to that in the Piedmont (9.8 ± 1.6‰), indicating that consumption of aquatic and terrestrial animals was about the same.

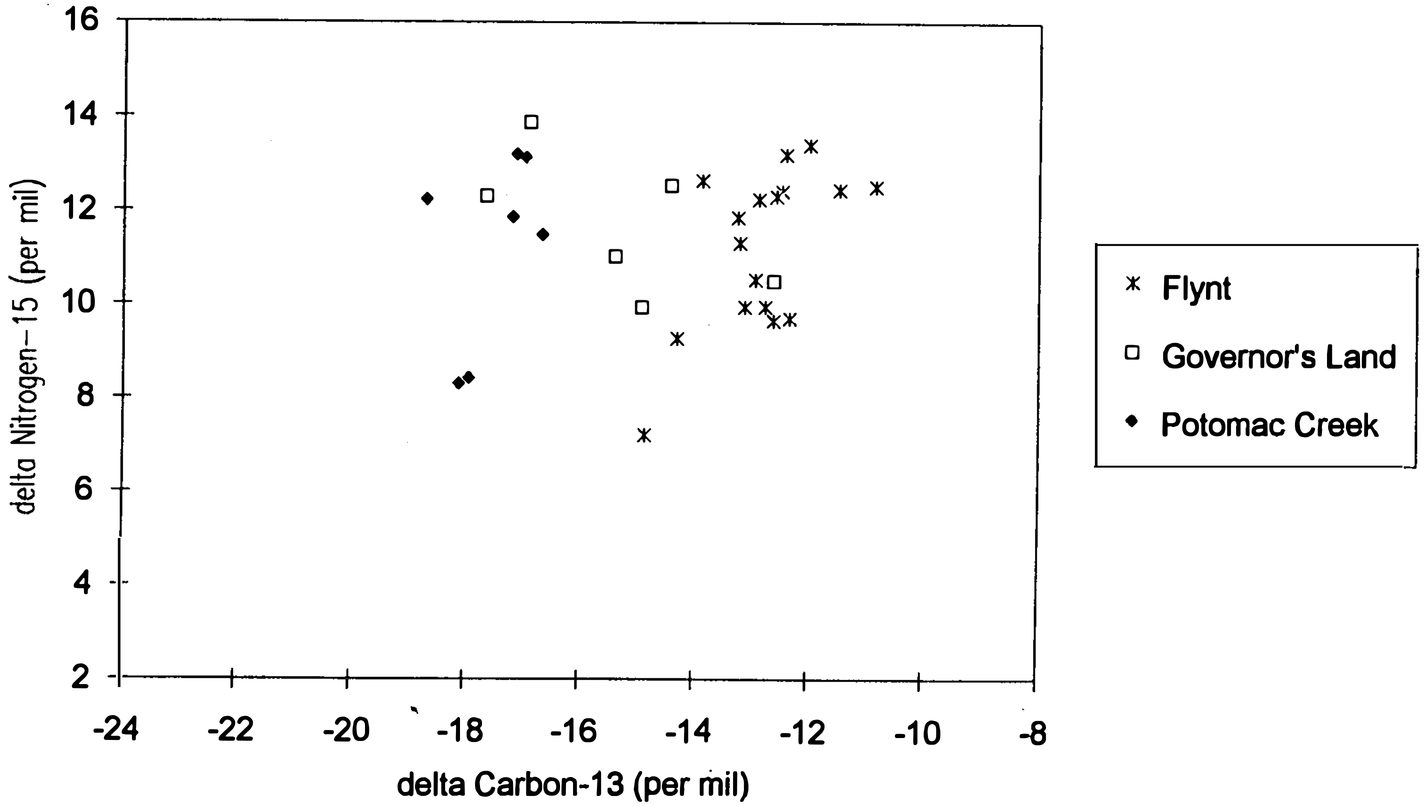

Figure 6. $\delta^{15}N$ and $\delta^{13}C$ values for adults at Coastal Plain sites.

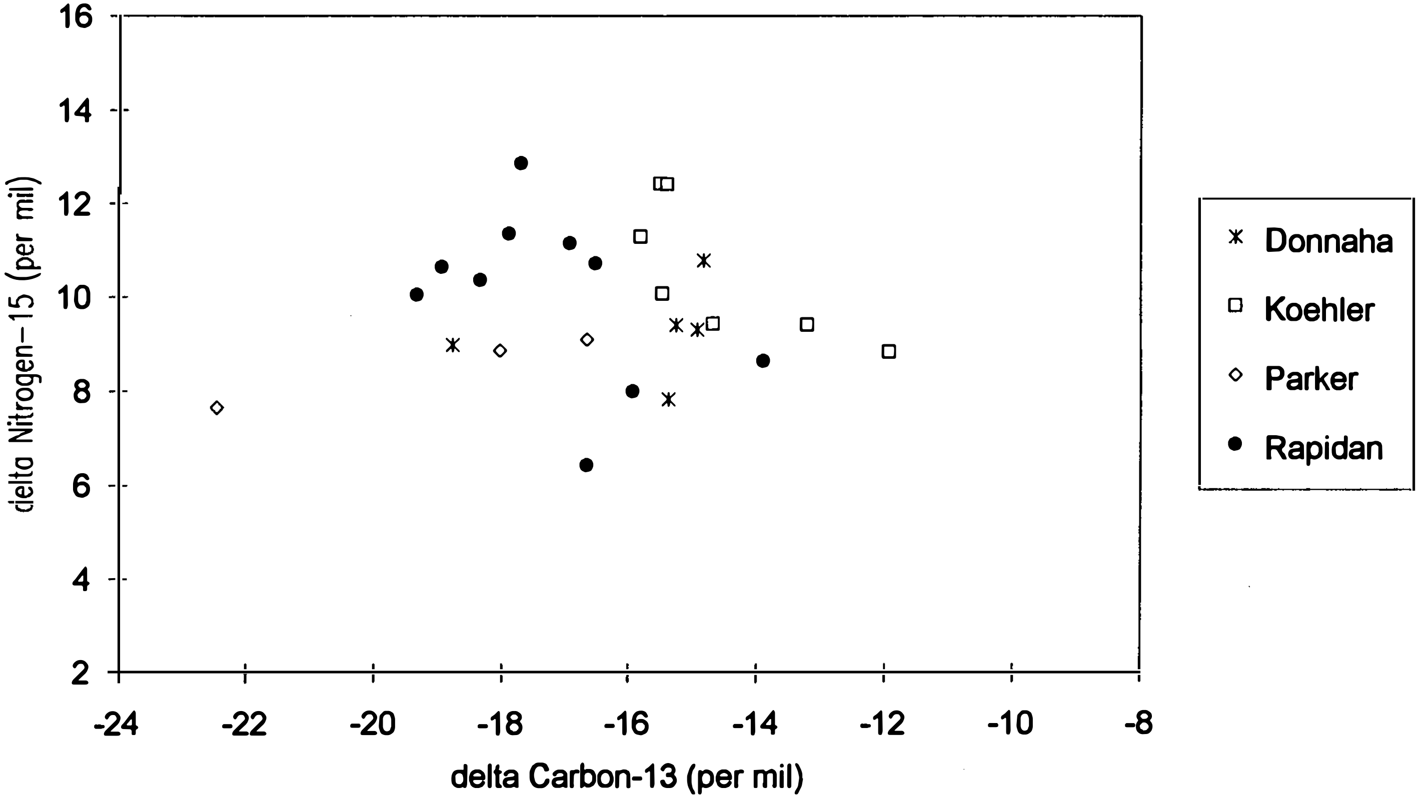

Figure 7. $\delta^{15}N$ and $\delta^{13}C$ values for adults at Piedmont sites.

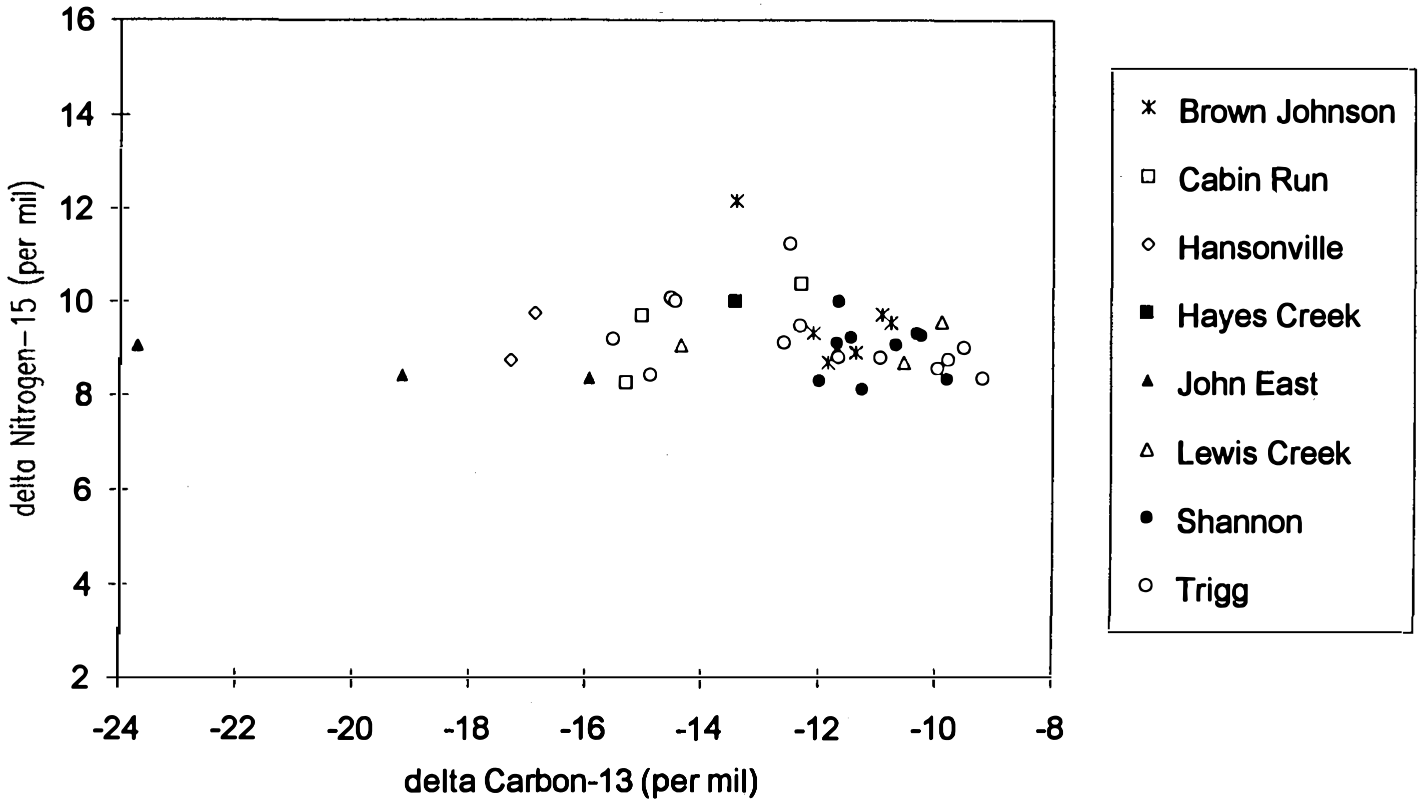

Figure 8. $\delta^{15}N$ and $\delta^{13}C$ values for adults at Appalachian Valley sites.

Results from Each Site

Parker

Isotopic analysis of bones from ten individuals from the Parker Site yielded mean $\delta^{13}C$ and $\delta^{15}N$ values of -18.8 ± 1.7‰ and 9.3 ± 0.9‰, respectively. The $\delta^{15}N$ values ranged from 7.7‰ to 11.2‰ and the $\delta^{13}C$ values ranged from -22.5‰ to -16.7‰. The stable isotope compositions for the individuals at Parker are clearly within the range expected for consumers of predominately C_3 plants and other terrestrial animal proteins. The diverse fauna identified at Parker support this observation. The presence of maize in the floral assemblage suggests that either C_4 agriculture was practiced at some time during the occupation of the site or contemporaneous trade networks existed to provide this resource. Like the lower levels of Rapidan Mound, the $\delta^{13}C$ values indicate that a C_4 plant component would have comprised about 25% of the plants consumed.

Only three of the ten individuals in the Parker sample are adults, all females greater than 31 years in age. One of the individuals is an adolescent; the remainder are infants and children (three each) (Table 23). The mean $\delta^{13}C$ and $\delta^{15}N$ values for each age group are similar (Table 13), suggesting the diets were the same for children and adults.

Table 23. Individuals sampled from Parker.*

Burial number	Sex	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
DV4 - 2	female	31 - 36 years	-22.5	7.7
DV4 - 3		8 years	-17.3	9.6
DV4 - 5	female	> 35 years	-18.0	8.9
DV4 - 13B		9 - 14 months	-19.2	10.2
DV4 - 14		0 - 6 months	-16.8	8.6
DV4 - 15	female	> 45 years	-16.7	9.1
DV4 - 16	female	5½ - 6 years	-18.2	9.0
DV4 - 18	female	13 - 15 years	-19.6	9.1
DV4 - 19		9 months	-20.4	9.4
DV4 - XX		Child	-18.9	11.2

* from Newkirk, 1978

Flynt

The twenty individuals at Flynt had a mean $\delta^{13}C$ value of -12.9 ± 1.0‰, with a range of -14.9‰ to -10.8‰. The mean $\delta^{15}N$ value was 11.7 ± 1.9‰, with a range of 7.2‰ to 15.8‰. These stable isotope values are indicative of a diet rich in marine protein and C_4 plants. The remains of oyster, clams, scallops, fish, and maize at the site support this interpretation. Two individuals have anomalous $\delta^{15}N$ values. The $\delta^{15}N$ value (15.8‰) for individual ON305-127 (an infant) is 2‰ higher than the next closest value, and 4.6‰ higher than the mean value for the adults. At birth, a child and its mother are isotopically identical. The $\delta^{15}N$ value of the infant increases relative to the mother as nursing progresses. As the child is weaned, the $\delta^{15}N$ value will decrease and eventually become indistinguishable from that of the adults. As expected, the two children from this site, ON305-88 and ON305-128, had a mean $\delta^{15}N$ value midway between the values for the infant and the adults. A similar shift in would be seen for the $\delta^{13}C$ values, although the magnitude would be smaller (about 1‰). The $\delta^{13}C$ values for the infant and children are within the one standard deviation range for the adults. The $\delta^{15}N$ value for individual ON305-285 (7.2‰) is 2.1‰ lower than the next closest value, suggesting that this individual may have been primarily a vegetarian.

Cabin Run

The $\delta^{15}N$ values for the individuals from Cabin Run were 8.3‰, 9.7‰, and 10.4‰ (burials 1, 3, and 4, respectively). The individuals from burials 1 and 3 had similar $\delta^{13}C$ values (-15.3‰ and -15.0‰, respectively), whereas the individual from burial 4 had a $\delta^{13}C$ value of -12.3‰. The $\delta^{15}N$ values suggest a diet based on plants and terrestrial herbivores. Based on the $\delta^{13}C$ values, the plant component appears to be about 50% C_3 and 50% C_4 plants. Cabin Run had a long history of occupation, and it is possible that the individual in burial 4 reflects a different time period than burials 1 and 3. The relationship of these individuals within the burial context is unknown.

Lower Rapidan Mound

Two samples, 20 and 15 from Sub-mound Features 7 and 8, respectively, had $\delta^{13}C$ values of -17.9‰ and -18.3‰, respectively. The $\delta^{15}N$ values for these two samples are 11.3‰ and 10.4‰, respectively. These values are indicative of a diet based on C_3 plants and other terrestrial animal proteins. The $\delta^{13}C$ values indicate that a C_4 plant component would have comprised about 35% of the plants consumed.

John East

The three individuals from John East Mound (burials 34, 88, and 105) had similar $\delta^{15}N$ values (8.4‰, 9.1‰, and 8.4‰, respectively) suggesting a comparable diet. However, the $\delta^{13}C$ values (-16.0‰, -23.7‰, and -19.2‰, respectively) are very different. The $\delta^{13}C$ value for burial 88 is what would be expected of a consumer of solely C_3 plant protein; the value for burial 34 is within the range expected for consumers of 50% C_4 plants and 50% C_3 plants; and the value for burial 105 is intermediate between the two. The $\delta^{15}N$ values suggest that plants and terrestrial herbivores, not fish, dominated the diet.

If C_4 agriculture was gradually adopted and retained at John East, the $\delta^{13}C$ values may represent different times during the occupation the site, with burial 88 being oldest and burial 34 youngest. According to Valliere and MacCord (1986), exactly the opposite appears to be true. Burials 34 and 105 were in sub-mound pits at depths of 40 inches and 34 inches, respectively; burial 105 was within the mound at a depth of 30 inches. This interpretation assumes that the deepest burials were deposited first. If the sub-mound pits were created by digging through the mound, then the stratigraphic interpretation would be invalid. No mention of disturbances above burials 34 and 105 is made. An alternative hypothesis is that C_4 agriculture was utilized and gradually abandoned at John East. Without dating burials 34, 88, and 105, the burial chronology cannot be correctly determined.

Another explanation for the differing $\delta^{13}C$ values would be that burial 34 had a marine component to its diet. Shell beads found with several of the burials, including burial 34, were from the Virginia Beach/Nags Head, North Carolina area and indicate that coastal trade networks existed. Although marine foods could have reached John East, the $\delta^{15}N$ values for the burials imply that it was unlikely that such foods were consumed in any quantity. The presence of beads with burial 34 may be indicative of status and the $\delta^{13}C$ values may result from status related differential access to food resources.

A third scenario for explaining the $\delta^{13}C$ values is that the differences can be attributed to gender or age. Burials 34 (male) and 105 (female) are middle aged adults; burial 88 is a young adult of undetermined sex. The data are insufficient to determine any patterns related to age or sex. In the absence of additional evidence to refute or support any of these explanations for the $\delta^{13}C$ values, it is assumed that the differences represent the range of sample variability within the burial population.

Hayes Creek

The sole representative from Hayes Creek Mound had a $\delta^{15}N$ of 10.0‰ and a $\delta^{13}C$ of -13.4‰, indicative of a diet with a significant C_4 plant component (50% to 75%), C_3 plants, terrestrial herbivores, and freshwater fish.

Donnaha

Eight individuals from Donnaha were sampled (Table 24). The $\delta^{13}C$ values ranged from -18.8‰ to -14.6‰ (mean = -15.5 ± 1.3‰); the $\delta^{15}N$ values ranged from 7.8‰ to 11.9‰ (mean = 9.6 ± 1.2‰). The diet at Donnaha appears similar to that at Cabin Run. If the individual from burial 22-5A is excluded, the range of $\delta^{13}C$ values, -15.6‰ to

-14.6‰, is less than 1‰. Individual 22-5A appears to have subsisted on primarily C_3 plants, terrestrial herbivores, and possibly fish. This individual may represent a different time period. The $\delta^{13}C$ values at Donnaha are characteristic of a population consuming a diet of about 50% C_4 plants and 50% C_3 plants. With the possible exception of individuals 34-143, 38-11, and 34-144f, the $\delta^{15}N$ values do not suggest the consumption of marine foods. The higher $\delta^{15}N$ values are probably related to greater intake of the readily available freshwater aquatic foods. The $\delta^{13}C$ values for the adolescents are indistinguishable from those for the adults.

The highest $\delta^{15}N$ value is from individual 34-144f, a young child 2½ - 4½ years old. This individual's $\delta^{15}N$ value may reflect the effect of nursing. The females represented in this sample had an average $\delta^{15}N$ value of 8.6‰ and an average $\delta^{13}C$ value of -15.4‰. A child deriving 100% of its nourishment from a mother with these stable isotope values would have a $\delta^{15}N$ value of 11.6‰ and a $\delta^{13}C$ value of -14.4‰. Clearly this child fits the predicted pattern.

Table 24. Individuals sampled from Donnaha.*

Burial number	Sex	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
22-5A	male	23 - 39 years	-18.8	9.0
31-3	female	25 - 40 years	-15.4	7.8
34-143	male	13 - 17 years	-15.0	10.4
34-144f	male	2½ - 4½ years	-14.6	11.9
36-19	male	15 - 18 years	-15.6	8.4
37-7	female	25 - 40 years	-15.3	9.4
38-11		adult	-14.8	10.8
40-10	male	17 - 21 years	-14.9	9.3

* from Hancock, 1987

Lewis Creek

The nine individuals from Lewis Creek had $\delta^{15}N$ values of 8.7‰ to 10.7‰ (mean = 9.5‰) and $\delta^{13}C$ values of -15.3‰ to -9.9‰ (mean = -12.4‰). The was little difference between the values of the children and the adults (Table 13), suggesting that the diets were comparable. The diet for Lewis Creek included 50% to 75% C_4 plants, 25% to 50% C_3 plants, terrestrial herbivores, and freshwater aquatic resources.

Koehler

Koehler was represented by eight individuals with a mean $\delta^{15}N$ value of 10.6 ± 1.4‰ (range of 8.8‰ to 12.4‰) and a mean $\delta^{13}C$ value of -14.6 ± 1.3‰ (range of -15.8‰ to -11.9‰). The $\delta^{13}C$ and $\delta^{15}N$ values suggest a diet similar to that of Brown Johnson, Lewis Creek, and Hayes Creek: 50% to 75% C_4 plants, 25% to 50% C_3 plants, terrestrial herbivores, and freshwater fish. Several of the individuals at Koehler may have utilized freshwater aquatic resources less than at Lewis Creek.

Hansonville

Two individuals from Hansonville (34B-2 and 34A2-5) had $\delta^{15}N$ values of 9.8‰ and 8.7‰, respectively, and $\delta^{13}C$ values of -16.9‰ and -17.3‰, respectively. The $\delta^{13}C$ values suggest a diet with a C_4 plant component of 25 - 50%, and the $\delta^{15}N$ values suggest a substantial terrestrial herbivore component or a minor aquatic component.

Trigg

At Trigg the $\delta^{15}N$ values for 17 individuals ranged from 8.4‰ to 11.2‰ (mean = 9.4 ± 0.9‰). The $\delta^{13}C$ values were -16.0‰ to -9.2‰ (mean = -12.6 ± 2.2‰). The $\delta^{13}C$ values suggest that 50 - 90% of the plants in the diet were C_4 plants (the mean was about 75%). The $\delta^{15}N$ values suggest that terrestrial animals and freshwater resources were consumed.

Upper Rapidan Mound

The eight individuals from the upper levels of Rapidan Mound had $\delta^{15}N$ values of 6.4‰ to 12.9‰ (mean = 9.8 ± 1.9‰) and $\delta^{13}C$ values of -19.3‰ to -13.9‰ (mean =

-17.0 ± 1.6‰). The mean $\delta^{13}C$ and $\delta^{15}N$ values for the mound samples are similar, -17.0‰ and 9.8‰, respectively. The isotope values suggest a reliance primarily on C_3 plants, terrestrial herbivores, and fish, with C_4 plants comprising less than 50% of the herbaceous portion of the diet. Relative to the other features, the individual from Mound Feature 4 exhibits the greatest potential reliance on C_4 plants ($\delta^{13}C$ value = -13.9‰).

Brown Johnson

The Brown Johnson sample was represented by nine of the fourteen individuals recovered from the site. The $\delta^{15}N$ values for all individuals ranged from 8.7‰ to 12.2‰ (mean = 9.9 ± 1.2‰), and the $\delta^{13}C$ values ranged from -13.4‰ to -10.6‰ (mean = -11.5 ± 0.8‰) (Table 25). The $\delta^{13}C$ values are within the range expected for a diet consisting of either 50% to 85% C_4 plants or 100% marine fish and shellfish. A mixture of these two food groups could also result in the $\delta^{13}C$ values observed. The addition of potential food resources makes determination of the specific diet more difficult. For example, human consumption of C_3 plants and deer eating C_4 plants would produce similar $\delta^{13}C$ values. More likely the diet consisted of a number of resources, including, but not limited to, C_3 plants, C_4 plants, terrestrial herbivores, and freshwater fish. Marine foods can be ruled out for Brown Johnson because of its location in southwestern Virginia in the Appalachian Valley province. Although trade networks to supply marine resources could have existed, it is not likely that they would have supplied sufficient foods to affect the $\delta^{13}C$ values in the manner observed.

The $\delta^{15}N$ values support a diet based on C_3 plants, C_4 plants, and terrestrial herbivores. Only two of the individuals at Brown Johnson have $\delta^{15}N$ values above the mean. The remaining $\delta^{15}N$ values range from 8.7‰ to 9.7‰, for a total variation of less than a trophic level fractionation factor of 3‰. BJ-3 ($\delta^{15}N$ = 11.5‰) is an infant, and, as described for Donnaha, the $\delta^{15}N$ exhibits the effects of nursing. BJ-9 ($\delta^{15}N$ = 12.2‰) is an adult female who may have consumed more riverine resources or possibly had access to marine foods. She may represent a different time period or a social class, or she may have preferred to eat fish. It is also possible that she was a visitor to the site or a newcomer to the area. Interestingly, her $\delta^{13}C$ value was the most negative one from the site. Consumption of a disproportionate amount of fish relative to the other individuals at the site would result in this lower $\delta^{13}C$ value.

Table 25. Individuals sampled from Brown Johnson.*

Burial number	Sex	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
382553 (BJ-1)	M	Adolescent	-11.2	9.4
382554 (BJ-2)	M	40 years	-10.9	9.7
382555 (BJ-3)		2 years	-10.6	11.5
382557 (BJ-5)		8 years	-11.3	
382558 (BJ-6)	M	Adult	-12.1	9.3
382559 (BJ-7)	M	Adult	-11.9	8.7
382560 (BJ-8)	M	Adult	-11.4	8.9
382561 (BJ-9)	F	Adult	-13.4	12.2
382564 (BJ-10C)	F	Adult	-10.8	9.5

* from MacCord, 1971

Shannon

Sixteen individuals were sampled from Shannon. The $\delta^{15}N$ values were 8.1‰ to 11.9‰ (mean = 9.3 ± 1.0‰) and the $\delta^{13}C$ values were -12.1‰ to -9.5‰ (mean = -11.0 ± 0.8‰). The $\delta^{13}C$ values suggest that greater than 75% of the diet could have been C_4 plants, and the $\delta^{15}N$ values suggest that fish and terrestrial animals were important dietary items. Maize, deer, fish and freshwater mussels all occur in the faunal assemblage. The location of Shannon makes it unlikely that marine foods would have influenced the stable isotope values. No distinct trends based on age or sex were observed (Table 26).

Table 26. Individuals sampled from Shannon.*

Burial number	Sex	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
382413		adult	-10.7	9.1
382414		infant	-11.5	8.3
382415		child	-11.4	9.6
382417		child	-9.5	11.1
382418 (S-6)		young adult	-11.3	8.1
382421 (S-9)	female	50 - 55 years	-11.7	9.1
382422 (S-10)	male	50 years	-11.7	10.0
138456 (S-44)	male	25 years	-10.3	9.3
382458		adult	-12.0	8.3
382460 (S-48)		5 years	-10.1	11.9
382465 (S-53)	male	40 years	-11.5	9.2
382488 (S-77)		1 - 6 months	-11.3	9.8
382492 (S-81)	male	25 years	-9.8	8.3
382496 (S-86)		5 - 6 years	-12.1	8.7
382502 (S-92)		adult	-10.3	9.3
382600 (S-127)		child	-11.3	8.3

* from Benthall, 1969

Potomac Creek

At Potomac Creek the $\delta^{15}N$ values for 14 individuals ranged from 8.3‰ to 13.7‰ (mean = 11.5 ± 1.6‰) and the $\delta^{13}C$ values ranged from -21.9‰ to -13.5‰ (mean = -16.5 ± 2.2‰). The relatively high $\delta^{15}N$ values indicate a reliance on marine or riverine resources. The wide range of $\delta^{13}C$ values could represent variable consumption of marine and freshwater aquatic foods, or it could represent variable intake of C_3 and C_4 plants. The location of Potomac Creek on Potomac Neck means that riverine and marine resources were readily available, and the remains of oysters, mussels, crabs, and various fish were present in the faunal assemblage. Although maize or other cultigens were not recovered from this site, their presence and potential use cannot be ruled out because specific sampling procedures to recover botanical remains were not used by the excavators (Stewart, 1992).

Three of the individuals in the Potomac Creek sample were infants. The mean $\delta^{13}C$ and $\delta^{15}N$ values for the infants are -14.0 ± 0.4‰ and 11.4 ± 0.5‰, respectively (Table 27). The mean $\delta^{13}C$ and $\delta^{15}N$ values for the eight adults are -18.1 ± 1.6‰ and 11.2 ± 1.9‰, respectively. As at Parker, there is a slight increase in the $\delta^{15}N$ value for the children relative to the adults. In contrast, the increase in $\delta^{13}C$ values for the children is more than expected. In agricultural societies the potential exists for children to be weaned earlier and fed a grain-based gruel similar to today's baby cereals. The isotopic fractionations resulting from consumption of this gruel and from nursing could produce the pattern in $\delta^{13}C$ values observed for the infants at Potomac Creek. The expected $\delta^{13}C$ value for the bone of a nursing child would be 17.1‰, about 1‰ higher than the parent (-18.1‰). If the child were fed maize-based gruel, the expected $\delta^{13}C$ value would be about -7.8‰. A combination of the two diets during early childhood would result in an intermediate $\delta^{13}C$ value. Alternatively, the infants could represent a time period in the occupation sequence at Potomac Creek for which maize or another C_4 plant was a dietary staple.

Table 27. Individuals sampled from Potomac Creek.*

Burial number	Age	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
384641	adult	-18.1	8.3
384659 (32-A)	newborn	-14.6	10.7
384660 (33)	4 years	-14.5	12.4
384661 (34)	15 years	-14.3	10.2
384666 (36C)	adult	-17.1	13.2
384667 (37)	adult	-17.0	13.1
384671	2 years	-13.5	11.9
384674	adult	-17.2	11.9
384684	child	-14.8	13.7
384685 (49)	20 - 30 years	-18.7	12.2
384687	adult	-18.0	8.4
384726	adult	-16.7	11.5
384737	1 year	-13.9	11.6
384747	adult	-21.9	

* from Stewart, 1992

Governor's Land

For Governor's Land the range of $\delta^{15}N$ values for nine individuals is 9.9‰ to 13.9‰ (mean = 11.6 ± 1.2‰), and the range of $\delta^{13}C$ values is -17.6‰ to -10.1‰ (mean = -13.7 ± 2.3‰). The $\delta^{13}C$ values suggest a reliance on C_4 plants such as maize, but the $\delta^{15}N$ values are more in line with a marine or riverine component. The Governor's Land samples suggest that C_4 plant or marine food consumption was greater during childhood ($\delta^{13}C$ = -12.8‰) than in adulthood ($\delta^{13}C$ = -15.3‰). The adult diet may include more diverse foods. Alternatively, the children and adults may represent different time periods.

Table 28. Diet characterization for the adults at each site (in chronological order).

Site	Major food groups	Possible % C_4 plants
Lower Rapidan Mound	C_3 plants, herbivores	~ 25%
Parker	C_3 plants, herbivores	~ 25%
Flynt	C_4 plants, marine foods	50 - 75%
Cabin Run	C_3 plants, C_4 plants, herbivores	50%
Hayes Creek	C_3 plants, C_4 plants, herbivores	50 - 75%
John East	C_3 plants, C_4 plants, herbivores	0 - 50%
Donnaha	C_3 plants, C_4 plants, herbivores	50%
Lewis Creek	C_3 plants, C_4 plants, herbivores	50 - 75%
Koehler	C_3 plants, C_4 plants, herbivores, riverine foods	50 - 75%
Hansonville	C_3 plants, C_4 plants, herbivores	25 - 50%
Trigg	C_4 plants, riverine foods	50 - 75%
Upper Rapidan Mound	C_3 plants, C_4 plants, herbivores	25 - 50%
Brown Johnson	C_3 plants, C_4 plants, herbivores	50 - 75%
Shannon	C_4 plants, riverine foods	> 75%
Potomac Creek	C_3 plants, C_4 plants, herbivores, riverine foods	25 - 50%
Governor's Land	C_3 plants, C_4 plants, marine or riverine foods	50 - 75%

Regional Synthesis

The stable isotopic compositions for sites throughout the eastern part of North America were compiled for comparison to the results from this study (Table 29). Only adults were considered, and the $\delta^{13}C$ and $\delta^{15}N$ values were averaged by time period for each site. The standard deviations were included if available or if they could be calculate from the data. Stable nitrogen isotope values were not available for most of the sites.

The absence of sufficient stable isotope data for food resources throughout the region makes it impossible to determine the effect of isotopic variation in resources on the isotopic compositions of the humans. For example, the $\delta^{13}C$ value for maize is variable (Table 30); therefore, human populations subsisting on the same percentage of maize may have different isotopic compositions. The inclusion of marine foods in the diet of a population may lead to misinterpretation of the percentage of C_4 plants consumed, particularly if the $\delta^{15}N$ values are unavailable. The synthesis that follows is discussed only in terms of the general trends observed. Interpretations of diet are based on the endmembers established in this report.

The fifteen sites examined in this study follow the same general trends observed throughout eastern North America. Non-coastal Archaic and Early Woodland sites have mean $\delta^{13}C$ values that range from -21.8‰ to -19.4‰. These values are indicative of a diet rich in C_3 plants. A potential C_4 plant component would be less than 25%. Sites along the Georgia coast have mean $\delta^{13}C$ values of -15.8‰ to -13.6‰ and mean $\delta^{15}N$ values of 11.1‰ to 14.4‰, indicating that marine foods comprised a large portion of the diet.

Table 29. Regional summary of $\delta^{13}C$ and $\delta^{15}N$ values for adults.

Site	State	Site date	Period	n	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Windover	FL	6050 - 5050 B.C.	MA	6	-15.5 ± 1.0		Tuross et al., 1994
Windover	FL	6050 - 5050 B.C.	MA	32		11.8 ± 0.9	Tuross et al., 1994
Rosenberger	KY	---	LA	8	-21.7		Collins and Lannie, 1979
Scatters	AR	3200 B.C.	LA	1	-21.1		Lynott et al., 1986
Koster	IL	3000 B.C.	LA	5	-21.7 ± 0.3		van der Merwe and Vogel, 1978
Dupont	OH	2500 B.C.	LA	10	-21.8		van der Merwe and Vogel, 1978
Frontenac	NY	2500 - 2000 B.C.	LA	1	-21.3		Vogel and van der Merwe, 1977
Lepold	MO	1980 B.C.	LA	1	-21.7		Lynott et al., 1986
Sand Ridge	OH	1500 B.C.	LA	1	-21.4		van der Merwe and Vogel, 1978
Deptford	GA	1000 B.C. - A.D. 1000	EW/MW	10	-15.9 ± 1.9	11.1 ± 1.1	Larsen et al., 1992
Cunningham Mound C	GA	1000 B.C. - A.D. 1000	EW/MW	1	-16.0	14.4	Larsen et al., 1992
McLeod Mound	GA	1000 B.C. - A.D. 1000	EW/MW	4	-15.8 ± 2.5	12.8 ± 0.3	Larsen et al., 1992
Cunningham Mound D	GA	1000 B.C. - A.D. 1000	EW/MW	1	-13.9	12.9	Larsen et al., 1992
Seaside Mound II	GA	1000 B.C. - A.D. 1000	EW/MW	2	-13.6	11.9	Larsen et al., 1992

Table 29. (Cont.)

Site	State	Site date	Period	n	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Billy Moore	MO	1000 B.C.	EW	1	-20.5		Lynott et al., 1986
Reigh	WI	710 B.C.	EW	5	22.0 ± 0.6		Bender et al., 1981
McCarty	AR	300 B.C.	EW	1	-21.7		Lynott et al., 1986
Vine Valley	NY	400 - 100 B.C.	EW	2	-19.4		Vogel and van der Merwe, 1977
Edwin Harness Mound	OH	---	MW	3	-22.7		Bender et al., 1981
Seip Mound	OH	---	MW	5	-21.9 ± 1.0		Bender et al., 1981
Gibson Mound 5	IL	---	MW	4	-21.1 ± 0.4		Bender et al., 1981
Gibson Mound 3	IL	---	MW	2	-20.8		Bender et al., 1981
Fairchance	WV	A.D. 100 - 200	MW	5	-21.1 ± 1.2		van der Merwe and Vogel, 1978
Gibson Mounds	IL	A.D. 200	MW	5	-20.9 ± 0.6		van der Merwe and Vogel, 1978
Millville	WI	A.D. 350	MW	3	-22.6		Bender et al., 1981
Nevens Cairn	MO	A.D. 500	MW	1	-20.1		Lynott et al., 1986
Christensen	MO	A.D. 500	MW	1	-19.9		Lynott et al., 1986
Koster	IL	A.D. 600	MW	5	-20.9 ± 1.3		van der Merwe and Vogel, 1978
Gard Island 2	MI	A.D. 610 - 850	MW	10	-14.0 ± 1.5	12.7 ± 0.6	Schurr and Redmond, 1991

Table 29. (Cont.)

Site	State	Site date	Period	n	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Parker	NC	A.D. 630 - 960	MW	3	-19.1	8.5	
Fingerhut	IL	A.D. 800 - 950	MW	2	-15.6		Bender et al., 1981
Flynt	NC	A.D. 850 - 1350	LWI	17	-12.8 ± 0.9	11.2 ± 1.6	
Zebree	AR	A.D. 900	LWI	3	-21.0		Lynott et al., 1986
Cahokia Mound 72	IL	A.D. 900 - 1050	LWI	4	-17.6		Bender et al., 1981
Nantucket Island	MA	A.D. 900 - 1400	LWI	6	-10.4 ± 0.2	15.3 ± 0.3	Little and Schoeninger, 1995
Cabin Run	VA	A.D. 920 - 1320	LWI	3	-14.2	9.4	
Round Spring	MO	A.D. 1000	LWI	1	-20.7		Lynott et al., 1986
Ledders Mounds	IL	A.D. 1000	LWI	5	-18.1 ± 2.2		van der Merwe and Vogel, 1978
Ledders	IL	A.D. 1000 - 1100	LWI	17	-17.4 ±		Buikstra et al., 1987
Lower Rapidan Mound	VA	A.D. 1000 - 1100	LWI	2	-18.1	10.9	
Mary's Mound	GA	A.D. 1000 - 1150	LWI	2	-14.5	12.4	Larsen et al., 1992
John's Mound	GA	A.D. 1000 - 1150	LWI	10	-14.1 ± 0.4	12.9 ± 0.6	Larsen et al., 1992
Dickson Mounds	IL	A.D. 1000 - 1175	LWI	2	-13.3		Buikstra and Milner, 1991
Dickson Mounds	IL	A.D. 1000 - 1175	LWI	2	-10.9		Buikstra and Milner, 1991

Table 29. (Cont.)

Site	State	Site date	Period	n	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Snell	NY	A.D. 1000 - 1300	LWI	2	-15.3		Vogel and van der Merwe, 1977
Hayes Creek	VA	A.D. 1000 - 1350	LWI	1	-13.4	10.0	
John East	VA	A.D. 1000 - 1350	LWI	3	-19.6	8.6	
Donnaha	NC	A.D. 1040 - 1500	LWI	5	-15.8 ± 1.5	9.3 ± 0.9	
46OH13	WV	A.D. 1050	LWI	1	-11.6		Farrow, 1986
Schild	IL	A.D. 1100 - 1200	LWI	19	-12.3		Buikstra et al., 1987
Lewis Creek	VA	A.D. 1100 - 1400	LWI	5	-12.4 ± 2.1	9.1 ± 0.3	
Kane Mounds	IL	A.D. 1150 - 1250	LWI	4	-10.3		Buikstra and Milner, 1991
Helton	IL	A.D. 1150 - 1250	LWI	22	-17.5		Buikstra et al., 1987
Irene Burial Mound	GA	A.D. 1150 - 1300	LWI	9	-13.0 ± 2.0	10.7 ± 1.1	Larsen et al., 1992
Orendorf	IL	A.D. 1175 - 1250	LWI	4	-9.2		Buikstra and Milner, 1991
Dickson Mounds	IL	A.D. 1175 - 1250	LWI	4	-10.4		Buikstra and Milner, 1991
46OH9	WV	A.D. 1200	LWI	3	-10.2 ± 0.8		Farrow, 1986
Round Spring	MO	A.D. 1200	LWI	1	-15.6		Lynott et al., 1986
Lilbourn	MO	A.D. 1200	LWI	1	-14.9		Lynott et al., 1986
Zebree	AR	A.D. 1200	LWI	1	-13.0		Lynott et al., 1986

Table 29. (Cont.)

Site	State	Site date	Period	n	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Schild Cemetary, Knoll B	IL	A.D. 1200	LWI	5	-14.1 ± 1.1		van der Merwe and Vogel, 1978
46MR29	WV	A.D. 1225	LWI	2	-9.2		Farrow, 1986
46OH16	WV	A.D. 1225	LWI	5	-11.0 ± 1.3		Farrow, 1986
Dickson Mounds	IL	A.D. 1250 - 1350	LWI	4	-10.8		Buikstra and Milner, 1991
E. St. Louis Stone Quarry	IL	A.D. 1250 - 1400	LWI	5	-11.4		Buikstra and Milner, 1991
Sloan Site	KY	A.D. 1250 - 1450	LWI	15	-9.7 ± 0.8		Broida, 1983
Turner	MO	A.D. 1300	LWI	3	-14.4		Lynott et al., 1986
Noble-Wieting	IL	A.D. 1300	LWI	1	-15.1		van der Merwe and Vogel, 1978
Norris Farms # 36	IL	A.D. 1300	LWI	5	-12.6		Buikstra and Milner, 1991
Turpin	OH	A.D. 1300	LWI	10	-11.8 ± 1.3		van der Merwe and Vogel, 1978
Irene Mortuary	GA	A.D. 1300 - 1450	LWI	11	-16.6 ± 1.4	9.8 ± 0.6	Larsen et al., 1992
Angel	IN	A.D. 1350 - 1430	LWI	40		8.9 ± 0.9	Schurr, 1992
Angel	IN	A.D. 1350 - 1430	LWI	41	-9.0 ± 2.2		Schurr, 1992
Hansonville	VA	A.D. 1300 - 1600	LWI	2	-17.1	9.3	

Table 29. (Cont.)

Site	State	Site date	Period	n	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Koehler	VA	A.D. 1300 - 1650	LWI	7	-14.6 ± 1.3	10.6 ± 1.4	
Trigg	VA	A.D. 1300 - 1670	LWI	14	-12.4 ± 2.1	9.2 ± 0.8	
Brown Johnson	VA	A.D. 1400 - 1600	LWI	6	-11.7 ± 0.9	9.7 ± 1.1	
Shannon	VA	A.D. 1400 - 1600	LWII	9	-11.0 ± 0.7	9.0 ± 0.6	
Upper Rapidan Mound	VA	A.D. 1400 - 1600	LWII	8	-17.0 ± 1.6	9.8 ± 1.9	
Potomac Creek	VA	A.D. 1400 - 1620	LWII	8	-18.1 ± 1.6	11.2 ± 1.9	
Engelbert	NY	A.D. 1450	LWII	2	-13.6		Vogel and van der Merwe, 1977
Man	WV	A.D. 1450	LWII	6	-10.0 ± 0.7	6.7 ± 0.4	Brashler and Reed, 1990
Governor's Land	VA	A.D. 1500 - 1600	LWII	6	-15.3 ± 1.6	11.7 ± 1.3	
Hardin Village	KY	A.D. 1500 - 1675	LWII/C	50	-11.6 ± 0.9		Broida, 1983
Hazel	AR	A.D. 1600	LWII/C	1	-12.9		Lynott et al., 1986
Campbell	MO	A.D. 1600	LWII/C	1	-10.4		Lynott et al., 1986
Berry	MO	A.D. 1600	LWII/C	1	-13.5		Lynott et al., 1986
Santa Catalina	GA	A.D. 1608 - 1680	LWII/C	22	-11.5 ± 1.0	9.4 ± 0.8	Larsen et al., 1992

Table 30. $\delta^{13}C$ values for maize from archaeological sites.

Site	$\delta^{13}C$ (‰)	Reference
Aztalan, WI	-11.1	Bender, 1968
Aztalan, WI	-11.3	Bender et al., 1981
Marr, OK	-12.6	Bender, 1968
Clement, OK	-12.4	Bender, 1968
Governor's Land, VA	-9.8	Trimble and Macko, 1994
Pecos Pueblo, NM	-11.2	Spielmann et al., 1990
Arica, Chile	-9.6	Tieszen and Fagre, 1993
Arica, Chile	-10.2	Tieszen and Fagre, 1993
Arica, Chile	-9.0	Tieszen and Fagre, 1993
Arica, Chile	-9.6	Tieszen and Fagre, 1993
Arica, Chile	-9.9	Tieszen and Fagre, 1993
Porteus, Ontario	-8.8	Schwarcz et al., 1985
Van Besien, Ontario	-8.7	Schwarcz et al., 1985
Boys, Ontario	-9.3	Schwarcz et al., 1985
Gunby, Ontario	-8.8	Schwarcz et al., 1985

The mean $\delta^{13}C$ values for most of the Middle Woodland sites range from -22.7‰ to -18.1‰. The $\delta^{13}C$ values for the Parker site and the lower levels of the Rapidan site are within this range. The similarity of these values to that of the earlier periods suggests that there was no change in diet from the Archaic through the Middle Woodland periods. However, two sites, Gard Island and Fingerhut, have mean $\delta^{13}C$ values of -14.0‰ and

-15.6‰, respectively, that indicate the inclusion of about 50% C_4 plants in the diet. Both sites date to the end of the Middle Woodland period. The transition to C_4 agriculture may been rapid or it may have been a localized occurrence.

The mean $\delta^{13}C$ values for sites dating to the first part of the Late Woodland period cover a wide range, from -21.0‰ to -8.9‰. These values indicate that C_4 plants were a major dietary staple for many sites, although usage varied from 25% to 90% of the total plant intake. The same pattern is observed for sites from the latter part of the Late Woodland period. Although the mean $\delta^{13}C$ values are variable, in general they suggest an increase in C_4 plant consumption relative to the Middle Woodland and earlier periods. The Virginia and North Carolina sites examined follow this general pattern.

SUMMARY

This research is unique with respect to other dietary reconstructions for native Virginia and North Carolina populations in that it provides a direct measure of the stable carbon and nitrogen incorporated from the diet. Because dietary components have characteristic stable isotopic signatures that will be incorporated into the body of the consumer in a systematic way, the primary components of the diet (e.g., marine foods, C_3 plants, or C_4 plants) can be ascertained.

Evidence for possible C_4 plant consumption was strongest for Brown Johnson, Cabin Run, Flynt, Hayes Creek, Koehler, Lewis Creek, Shannon, Trigg, and the children at Governor's Land and Potomac Creek. Sites with a strong C_3 plant component include Hansonville, Donnaha, John East, Parker, Potomac Creek, and Rapidan Mound. Flynt, Governor's Land, and Potomac Creek all had evidence of a substantial marine or aquatic component to the diet. The effect of nursing on the isotopic composition of young children was seen at Donnaha, Flynt, and Brown Johnson. Possible evidence of early weaning was observed at Potomac Creek.

Both temporal and spatial patterns of dietary difference were observed. The $\delta^{15}N$ values for all three periods suggest a diet rich in terrestrial animal protein. The $\delta^{13}C$ values indicate a shift from predominantly C_3 plants in the Middle Woodland diet to C_4 plants in the first part of the Late Woodland period. There was no change in potential C_4 plant consumption from the first ot the second part of the Late Woodland period. Diet appeared to be most diverse for the Piedmont sites; C_3 plants predominated. In contrast, diets for the Appalachian Valley sites were rich in C_4 plants and less diverse. The Coastal Plain sites reflected a substantial aquatic or marine influence; potential C_4 plant usage

was variable. The temporal patterns observed for $\delta^{13}C$ values are consistent with the general trends seen throughout the eastern part of North America.

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