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Isotopic evidence for broad diet including anadromous fish during the mid-Holocene in northeastern North America

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ABSTRACT

Archaeological evidence, including riverine and lake settlements, as well as fishing and netting artifacts, suggests that there was an increased reliance on inland fisheries during the mid-Holocene (ca. 4500–1800 cal BP) in northeastern North America. Unfortunately, more direct lines of evidence investigating this idea have not been thoroughly examined due to several factors, including inconsistent excavation techniques, and limitations in destructive analysis of human material remains. Here, we measured stable carbon and nitrogen isotope values from one human female and fifteen terrestrial and aquatic faunal taxa from deposits within the mid-Holocene site, Dutchess Quarry Cave 1 (Orange County, NY), to assess dietary source proportions and determine whether anadromous fish were a prominent dietary component for this individual. Using cluster analysis, potential prey species were grouped into three sources consistent with anadromous fish ("prey 1"), carnivores and omnivores ("prey 2"), and terrestrial herbivores and game birds ("prey 3"). We evaluated the relative contributions of the stable isotope values of the three prey groups using Bayesian analysis with MixSIAR. Our results indicate that animals within prey 3 made up the largest component of this individual's diet, implying that terrestrial herbivores and game birds likely dominated her diet. Fauna from isotope groups prey 1 (anadromous fish) and 2 (carnivores and omnivores) supplemented the diet. Based on these data, it appears that anadromous fish were a seasonal component of human diet and that the incorporation of these resources did not involve the dramatic reduction of other year-round protein sources.

1. Introduction

Increased numbers of habitation sites located near estuaries, rivers, and other bodies of freshwater, along with developments in fishing technology have driven the hypothesis that human subsistence became increasingly focused on riverine, estuarine, and lake resources during the mid-Holocene (ca. 4500–1800 cal BP) in eastern North America (Anderson, 2001; Cleland, 1976; Custer, 1988; Ellis et al., 1990; Hodges, 1991; Kinsey, 1972; Mouer et al., 1981; Salwen, 1975; Whyte, 1988). It is suggested that migratory and spawning patterns of anadromous fish such as sturgeon (Acipenseridae), striped bass (*Morone saxatilis*), shads and herrings (Clupeidae), and the American eel (*Anguilla rostrata*) motivated the placement of temporary camps near rivers (Custer, 1988). Despite these observations, evidence for freshwater and anadromous fish remains are rare at archaeological sites until the late Holocene, around 1800–1000 cal BP. Freshwater resources were likely exploited by the early Holocene in the Americas (Petersen et al., 1984), however, identification of evidence for fishing and harvesting can be difficult to find archaeologically.

The absence of direct zooarchaeological evidence may be due to collecting bias (e.g., screen size, absence of screening) which strongly affects bones of small taxa such as fish and has less of an effect on large taxa like deer (Casteel, 1976; Garson, 1980; Madrigal, 1999; Reitz, 1982). In NY, screens were not typically used in excavations until the 1980s/1990s. Additionally, isotopic analyses of human remains for dietary reconstructions is generally not undertaken due to laws protecting Native American human burials and requirements for consultation with descendant communities prior to destructive analysis. Therefore, direct evidence for increased fish consumption is limited, and the understanding of the role of fishing strategies relative to other dietary strategies during the mid-Holocene is incomplete. In addition to difficulty in finding fish remains, fishing related technology such as nets or boats are often made from perishable materials and are not frequently found at sites (King, 1978; Parmalee et al., 1972). As a result, in northeastern North America, the idea that subsistence strategies shift to a high reliance on fish in the mid-Holocene is based mainly on

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settlement changes rather than direct evidence of fish bones or technology at archaeological sites (with some exceptions, see Brumbach, 1978, Petersen et al., 1984).

Stable isotope analysis of bone collagen is particularly useful for separating marine and terrestrial components of diet (Richards et al., 2003; Schoeninger et al., 1983). $\delta^{13}C$ and $\delta^{15}N$ isotope values from recovered animal tissues, like bone collagen, derive from the animals' diets, allowing researchers to reconstruct subsistence within the analyzed species (DeNiro and Epstein, 1978; DeNiro and Epsten, 1981). As one of the major focuses of this study is to explore the dietary sources of the human diet during the mid-Holocene in northeastern North America, we focus on sampling bone collagen, because collagen stable isotope values specifically reflect the protein component of the consumer's diet (Ambrose and Norr, 1993; Tieszen and Fagre, 1993). Dietary protein stems from consumption of both animals and plants.

Comparison of marine and terrestrial food resources in coastal populations has been the focus of many isotopic studies from the northeastern North America, and these have demonstrated a heavy reliance on marine resources by coastal groups (e.g., Bourque and Kreuger, 1994; Little and Schoeninger, 1995; Yesner, 1988). Research on inland freshwater resource use has focused around the Great Lakes in southern Ontario. Studies in this region have found stable nitrogen isotope values suggesting reliance on fish and shellfish (Harrison and Katzenberg, 2003; Schwarcz et al., 1985). Apart from southern Ontario, analysis of dietary resource use by inland groups in northeastern North America, particularly through isotopic analysis, has been underexplored, leaving questions about the incorporation of fish resources into diet and how fishing strategies relate to seasonal and regional behavior.

In this study, we utilize stable isotope analysis of a human individual and possible food species from a mid-Holocene site in New York, Dutchess Quarry Cave 1 (DQC-1), to search for direct evidence of anadromous or freshwater fish consumption during this period. The isotopic analysis of this individual provides some insight into the relative consumption of fish and terrestrial resources during the mid-Holocene, and thus will help develop our understanding of subsistence behavior in this period. These data are also a baseline from which we can direct future studies on both direct and indirect evidence of inland fishery practices in North America.

2. Background

2.1. Stable isotope paleodiet reconstruction

Stable carbon isotope values are useful for diet studies because the three different photosynthetic pathways used by plants, C_3, C_4, and Crassulacean Acid Metabolism (CAM), impart different $\delta^{13}C$ values within plant tissues, and these values become incorporated up the food chain (van der Merwe, 1982). C_3 plants, which account for about 85% of plant species, have a mean $\delta^{13}C$ value of −28.5‰ and a range from −20‰ to −37‰ (Ehleringer and Monson, 1993; Ehleringer et al., 1991; Farquhar et al., 1989; Koch, 1998; Kohn, 2010; O'Leary, 1988; Quade et al., 1992). Tropical, warm-season grasses and sedges using the C_4 photosynthetic pathway have a mean $\delta^{13}C$ value of about −13.0‰ and a range from −9‰ to −19‰ (Ehleringer and Monson, 1993; Ehleringer et al., 1991; Farquhar et al., 1989; Koch, 1998; O'Leary, 1988; Quade et al., 1992). The CAM pathway is characteristic of succulents and incorporates intermediate ratios of $\delta^{12}C$ and $\delta^{13}C$ (Ehleringer and Monson, 1993; Ehleringer et al., 1991; O'Leary, 1988). In northeastern North America, C_4 and CAM plants are rare in both diversity and abundance, thus, bone collagen of herbivores will reflect lower $\delta^{13}C$ values consistent with the consumption of C_3 plants (Vogel and van der Merwe, 1977). Even within C_3-dominated ecosystems, however, variability in $\delta^{13}C$ values exists under differing environmental conditions. Processes, such as variation in light intensity, temperature, nutrient availability, and water stress, affect the $\delta^{13}C$ value in C_3 plants (Ehleringer and Monson, 1993; Farquhar et al., 1989; Koch, 1998; O'Leary et al., 1992).

Differences in $\delta^{13}C$ values are frequently used in studies to identify marine versus terrestrial resources. Although marine plants mainly utilize the C_3 photosynthetic pathway, the carbon source is derived from dissolved bicarbonate, which has a $\delta^{13}C$ value of 0‰ (Ambrose et al., 1997); rather than atmospheric CO_2 that currently has an average $\delta^{13}C$ of about −8‰. Because of the higher $\delta^{13}C$ value for the source carbon, marine plants average about −19‰. The importance here is that $\delta^{13}C$ values will be more positive in marine ecosystems than they are in the C_3-dominated terrestrial ecosystems of northeastern North America. Marine vertebrates generally have more positive $\delta^{13}C$ values than terrestrial animals (Fry and Sherr, 1984; Keegan and DeNiro, 1988; Schoeninger and DeNiro, 1984). Freshwater plants often have $\delta^{13}C$ values that overlap with terrestrial C_3 plants, however, some bodies of water can have distinct ranges of source carbon that are either much lower or much higher than terrestrial ecosystems (Fry, 1991).

Fractionation of carbon isotopes is fairly small between prey and consumer, resulting in about 0–1‰ increase per tropic level (Fry and Sherr, 1984). Therefore, humans consuming some marine resources are expected to have higher $\delta^{13}C$ values than those reliant completely on terrestrial protein resources. Humans consuming freshwater resources can have more variable $\delta^{13}C$ values and are better estimated from isotope values of known freshwater resources (i.e., fish isotope data). Anadromous fish in the diet would produce higher $\delta^{13}C$ values, because these species spend most of their lives in the ocean and only return to freshwater and rivers to spawn during warm months.

The nitrogen isotope composition in archaeological species derives from values within ingested food. These values are influenced by trophic position within the food web, environmental conditions, and the metabolism of the individual (Gröcke et al., 1997; Heaton et al., 1986; Koch, 1998; Robinson, 2001; Schwarcz et al., 1999). $\delta^{15}N$ increases along the food chain; therefore, as each consumer ingests animal product, the nitrogen values in their tissues is approximately 3–5‰ higher than their prey (Hedges and Reynard, 2007). Freshwater and marine food webs have more trophic levels, and marine plants often have higher $\delta^{15}N$ values than terrestrial plants leading to higher nitrogen values throughout these food webs; although certain algae and seagrass may have lower $\delta^{15}N$ values more like those found in terrestrial plants (France et al., 1998). As a result, marine and freshwater vertebrates generally have higher $\delta^{15}N$ values than terrestrial animals (Fry and Sherr, 1984; Keegan and DeNiro, 1988; Schoeninger and DeNiro, 1984).

2.2. Site

The sample used in this study comes from the archaeological site DQC-1 located in the Hudson River Valley in Orange County, NY, USA (Fig. 1). This region of New York contains many small rivers and lakes, and the rock shelter itself is located next to a former bog, and five kilometers from the Wallkill River, a tributary of the Hudson River (Guilday, 1969). DQC-1 is one of a series of eight limestone rock shelters within a few hundred meters of each other. This particular cave is located approximately 100 ft. from the ground surface on the northwest side of Mt. Lookout in Warwick, NY (Guilday, 1969). The Orange County Chapter of the New York State Archaeological Association excavated the site between 1965 and 1967 (Funk et al., 1969b). These excavations uncovered evidence of human activity in the cave, along with three dozen stone projectile points from Late Archaic through the Late Woodland periods (Funk et al., 1969b). The majority of artifacts, faunal remains, and all of the human remains were found within Stratum 1 (Funk et al., 1965), and Stratum 2 contained very few remains. The chronology and strata of rock shelters are commonly difficult to interpret because they are subject to human, animal, and geological disturbances altering spatial contexts and artifact associations. The degree of disturbance of the uncovered artifacts and bone was not clear, and as a result there are multiple interpretations of the