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Preliminary evidence for the efficacy of the Canine Surrogacy Approach in the Great Lakes

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ABSTRACT

Isotopic analyses of human remains have been used to gain insights into aspects of subsistence and provide insights into mechanisms behind changes in material culture. Midwest archaeologists have used them to track major shifts such as the introduction of maize and associated changes in social organization. However, these destructive tests can create ethical and legal issues concerning the treatment of human remains. The Canine Surrogacy Approach (CSA) is the use of domestic dog remains as a proxy for human remains. Dog isotope values generally mirror their human companions', thereby circumventing the need to destroy human remains without sacrificing scientific research. This paper addresses the efficacy of CSA in the western Great Lakes.

1. Introduction

For many thousands of years, humans and domesticated dogs (*Canis lupus familiaris*) have shared a unique relationship around the world. This special relationship is seen in the fact that dogs are often afforded special attention at death, and that dogs' bodies are ritually disposed of through burial or other means (Crockford, 2009; Morey, 2006, 2010; Schwartz, 1997). For example, in the American Midwest, dog burials occur very early in the archaeological record (Morey and Wiant, 1992) and are much more common than any other non-human species (e.g., Morey, 2006; Perri et al., 2015). In addition, much research has focused on the role dogs have played in human cosmological systems (Morey, 2006).

DNA and isotopic analyses of bone have been the primary means to use dogs as a proxy for human landscape-use and food consumption (Burleigh and Brothwell, 1978; Noe-Nygaard, 1988; Witt et al., 2015). When it is not possible to conduct isotopic tests on human remains, dogs can provide considerable insight into the behavior of their associated people. For example, it is possible to track human movements through oxygen, carbon, or strontium isotope ratios in dogs (Clutton-Brock and Noe-Nygaard, 1990; Fischer et al., 2007; Noe-Nygaard, 1988). As humans move, their dogs will follow. One of the most promising directions, however, has been the use of dog remains to gain insights into the diet of their human companions. This technique has been called the Canine Surrogacy Approach (CSA) (Burleigh and Brothwell, 1978; Cannon et al., 1999; Clutton-Brock and Noe-Nygaard, 1990; Guiry, 2012, 2013; Noe-Nygaard, 1988). The focus of this project is to demonstrate that the Canine Surrogacy Approach is a useful proxy for examining prehistoric subsistence patterns in the western Great Lakes region. Preliminary tests of dog isotopic values at several Wisconsin and Illinois sites show that they do approximate the values of human remains from those sites.

1.1. Isotopes

As animals consume food and it is metabolized, the isotope chemistry of dietary elements is incorporated into bone collagen and hydroxyapatite. In this study we monitor the ratio of the rare to common isotopes of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) often used in the reconstruction of prehistoric diets in the region (e.g., Fischer et al., 2007). The rare isotopes of these elements have an extra neutron in the nucleus of the atom and thus have more mass. ^{12}C is the common stable isotope of carbon making up approximately 98.89% of global carbon; whereas ^{13}C, with an extra neutron, comprises approximately 1.11% of the earth's carbon. When atmospheric carbon (CO_2), dissolved CO_2, or marine bicarbonates (HCO_3^-) are incorporated into plant tissues during photosynthesis, metabolic processes alter or fractionate the ratio of ^{13}C to ^{12}C depleting it relative to the substrate from which it was taken. This ratio is expressed in delta ($\delta^{13}C$) notation as parts per mil (‰) difference from an internationally recognized standard (Craig, 1957). ^{14}N is the most common stable isotope of nitrogen occurring in frequencies similar to that of ^{12}C. The ratio of $^{15}N/^{14}N$ increases at each step up the food web and is also expressed in delta notation ($\delta^{15}N$).

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1.1.1. δ^{13}Carbon isotope analyses

The δ^{13}C is particularly useful for differentiating between plants with different photosynthetic pathways (Farquhar et al., 1989). Lichens, cool-season grasses, trees and most bushy plants employ C_3 photosynthetic mechanisms that discriminate heavily against ^{13}C. Modern C_3 plants express a mean δ^{13}C value of − 26.7 ± 2.7‰ (n = 370) (Cerling et al., 1998) and range of − 37‰ to − 20‰, the enriched value associated with drought stress and the lower value characteristic of canopy effect depletion (Kohn, 2010). Alternatively, warm-season grasses, those growing in regions where daytime growing-season temperature exceeds 22 °C and precipitation exceeds 25 mm (Ehleringer et al., 1997), use a C_4 pathway resulting in less discrimination against ^{13}C and an average δ^{13}C value of − 12.5 ± 1.1‰ with a range of − 16‰ to − 10‰ (n = 455) (Cerling et al., 1998). Plants grown before fossil fuel depletion of atmospheric CO_2 are enriched 1–2‰ relative to these averages (Marino and McElroy, 1991; Tieszen and Fagre, 1993).

δ^{13}C values are transferred up the food web leaving a diagnostic signature in the tissue of consumers that does not covary with the skeletal element analyzed or sex of the sample independent of gender differences in feeding ecology (Hobson and Schwarcz, 1986; Lovell et al., 1986). Fractionation between primary producers and consumers approximates 5‰ and enrichment at higher trophic levels approaches 1‰ (Burton and Koch, 1999; Katzenberg, 1993). Adult bone collagen δ^{13}C values represent a weighted average of long-term diet since the carbon in human bone collagen turns over slowly, requiring approximately 30 years to replace existing carbon with an equivalent amount of carbon (Harkness and Walton, 1972; Libby et al., 1964; Stenhouse and Baxter, 1977, 1979).

1.1.2. δ^{13}C isotope analysis in the Great Lakes

The vast majority of plants native to the Great Lakes are C_3 plants (von Fischer et al., 2008). Aquatic resources also undoubtedly contributed to prehistoric Midwestern diets; however such resources, whether profundal, pelagic or littoral express δ^{13}C values in C_3 plant range (Vander Zanden and Rasmussen, 1999). Thus, maize is the only C_4 plant or resource with an enriched δ^{13}C value identified as a significant contributor to the prehistoric Midwestern diet (Bender et al., 1981). When archaeological evidence for maize consumption is present, reported human δ^{13}C values generally range between − 9‰ and − 18‰ (Bender et al., 1981; Bochrens et al., 2006; Katzenberg et al., 1995; Romond et al., 2011; Vogel and van der Merwe, 1977). This pattern has been used in the Midwest to evaluate the introduction and cross-cultural importance of maize (e.g., Bender et al., 1981; Emerson et al., 2005; Emerson et al., 2010; Vogel and van der Merwe, 1977, but see Hart and Lovis, 2013). Likewise, bulk δ^{13}C values of food residues from cooking pots has been used to track the introduction of maize in the Eastern United States, but significant regional variation in the quality and quantity of data paints a complex picture, highlighting the crucial need for multiple lines of evidence (Hart et al., 2003, 2007, 2012).

1.1.3. δ^{15}Nitrogen analyses

Ecologists traditionally use δ^{15}N analyses to determine the trophic level of consumption, which follows from the understanding that $^{15}N/^{14}N$ increases ≈ 2–4.5‰ with each increase in trophic level. This increase is associated in part with discrimination against isotopically heavy urea at renal membrane boundaries, enriching the isotope signature of nitrogen available for protein synthesis (Ambrose and DeNiro, 1986; Schoeller, 1999). Archaeologists often use this method to determine the role hunting and other meat sources played in the diet (Ambrose, 1987; Ambrose and Norr, 1993; Bochrens et al., 2006; Fischer et al., 2007; Guiry, 2012).

Although archaeologists have applied both carbon and nitrogen isotopic methods to human remains from the American Midwest (e.g., Ambrose et al., 2003; Bender et al., 1981; Emerson et al., 2005; Emerson et al., 2010; Lynott et al., 1986; Schoeninger, 2009; Vogel and van der Merwe, 1977), these tests destroy human remains. The destruction of archeologically recovered Native American human bone often creates both ethical and legal concerns. When investigating human remains it is ethically imperative that archaeologists balance the value of scientific inquiry with the beliefs and desires of descendant communities or other affected parties (Walker, 2008). Furthermore, there may be legal restrictions in some circumstances, such as NAGPRA at the U.S. federal level, or state laws such as Wisconsin's Burial Law, Statute 157.70. Under certain circumstances, these laws may prohibit destructive testing without the approval of Native American tribal governments or the state agency. Regardless of whether the issue is legal, ethical, or both, it is incumbent upon archaeologists to use the least harmful strategy possible to answer archaeological questions.

1.1.4. Issues with application and implementation of isotopic studies

One of the greatest strengths of the Canine Surrogacy Approach is that it may provide answers to archaeological questions previously achieved only by destruction of human remains (Cannon et al., 1999; Guiry, 2012, 2013). Archaeologists have long recognized the unique bond shared between humans and dogs (Morey, 2006). Because of this close relationship, dogs often consume a suite of foods similar to their human companions (Guiry, 2012, 2013; White et al., 2001, 2004; but see also Lovis and Hart, 2015). Dogs also scavenge human scrap food and consume human feces (Allitt et al., 2008; Cannon et al., 1999; Katzenberg, 1989; White et al., 2004). Dogs may also scavenge food from off-site (i.e., non-human provided) animals, but in domesticated animals such scavenging would be a small part of the diet and we do not expect occasional behavior to alter their overall nitrogen or carbon values. The broadly shared diet between humans and their canine companions provides an expectation that dogs will reflect the carbon and nitrogen isotope chemistry of their human owners. Therefore, if dog remains are available from a site, it is possible to answer isotope-based research questions without conducting destructive tests on human remains. Furthermore, inferences can be made about the diet at sites that do not contain human remains if dog bones have been recovered (e.g., Cannon et al., 1999). It is important to note that this approach only works with domestic dogs. Wild canids, such as coyotes or wolves, live independently of humans so their diets are likewise independent (Cannon et al., 1999; Clutton-Brock and Noe-Nygaard, 1990; Guiry, 2012; Noe-Nygaard, 1988; Rick et al., 2011).

Around the world, archaeologists have compared the isotopic signatures of dogs to closely associated human remains and have found that in almost all cases, dog values closely mirror human values (e.g., Bochrens et al., 2006; Burleigh and Brothwell, 1978; Guiry, 2012, 2013; Noe-Nygaard, 1988; Tankersley and Koster, 2009). In a few studies, the samples did not closely resemble the associated human populations; however, most were due to very specific and localized causes. For example, one study of dog tooth pendants indicated that dog remains were being exchanged among groups with significantly different diets (Eriksson and Zargorska, 2003). In this case, the dogs' isotopes did reflect the diet of the humans that raised them, but not the diet of the final owners of the remains. In another, Mesoamerican dogs killed for rituals often had a tightly controlled diet, which was different than the associated human populations (White et al., 2001). Dogs used as a source of food may also have a diet somewhat different from their human consumers, although typically only to a minor degree (Guiry, 2012). Guiry (2012, 2013) points out that when researchers are aware of the potential sources of bias and attempt to minimize its impact in sample selection CSA is generally a good source for dietary analogy. By avoiding archeologically curated items (e.g., jewelry), and testing the similarity of dogs' diets in different contexts, appropriate samples can be chosen. CSA appears to be a successful strategy in most cases where it has been applied, it needs to be demonstrated empirically in any given region that dogs serve as effective proxies for humans.