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MAIZE, FISH AND DEER: INVESTIGATING DIETARY STAPLES AMONG ANCESTRAL HURON-WENDAT VILLAGES, AS DOCUMENTED FROM TOOTH SAMPLES

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Abstract:	Following the entry of Zea mays to northeast North America, Northern Iroquoian populations expanded their numbers and range. What role did maize play? With permission of the Huron-Wendat Nation of Wendake, Quebec, we measured δ13Cenamel, δ13Cdentine and δ15Ndentine from 167 permanent teeth, retained before reburial of their ancestral skeletons, and δ13Ccollagen and δ15Ncollagen from adhering bone (n=53). Enamel values encapsulate diet from ca. 1.5 to 4 years of age, dentine values reflect later childhood. Teeth are from 16 ancestral Huron-Wendat sites in southern Ontario. Isotopic values show consistent reliance on maize from early fourteenth to sixteenth centuries, with higher reliance in the seventeenth century - the time of contact with Europeans and disruptive changes. We show a difference between the diets of children and adults; young children consumed more maize and less animal protein. White-tailed deer (Odocoileus virginianus) did not exploit maize fields, reflecting hunters' exploitation of distant regions. New values from fish species (n=21) are pooled with prior data, deomonstrating diverse C and N stable isotope patterns in exploited fish. American eel (Anguilla rostrata) is particularly variable. Dietary protein sources were variable compared to the stability of maize: a reliable source of carbohydrate food energy across four centuries

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Following the entry of *Zea mays* to northeast North America, Northern Iroquoian populations expanded their numbers and their range. Isotopic values from bone collagen have shown temporal and regional fluctuations in reliance on this dietary staple. With permission of the Huron-Wendat Nation of Wendake, Quebec, we measured $\delta^{13}C_{enamel}$, $\delta^{13}C_{dentine}$ and $\delta^{15}N_{dentine}$ from 167 permanent teeth, retained before reburial of their ancestral skeletons, and $\delta^{13}C_{collagen}$ and $\delta^{15}N_{collagen}$ from adhering bone (n=53). Enamel values encapsulate diet from ca. 1.5 to 4 years of age, dentine values reflect later childhood. Teeth are from 16 ancestral Huron-Wendat sites in southern Ontario. Isotopic values show consistent reliance on maize from early fourteenth to sixteenth centuries, with higher reliance in the seventeenth century – the time of contact with Europeans and disruptive changes. We show a difference between the diets of children and adults; young children consumed more maize and less animal protein. White-tailed deer (*Odocoileus virginianus*) did not exploit maize fields, reflecting hunters' exploitation of distant regions. New values from fish species (n=21) are pooled with prior data, demonstrating diverse C and N stable isotope patterns in exploited fish. American eel (*Anguilla rostrata*) is particularly variable. Dietary protein sources were variable compared to the stability of maize: a reliable source of carbohydrate food energy across four centuries.

Résumé : Suite à l'apparition du maïs (*Zea mays*) dans le Nord-est de l'Amérique du Nord, les populations iroquoiennes du nord ont accru leurs effectifs et élargi leur territoire, une situation qui peut-être induite par popularité envahissante de l'utilisation du maïs. Les valeurs isotopiques de collagène osseux ont été incompatibles avec cette hypothèse supposant des fluctuations temporelles et régionales fondées sur la dépendance de cet aliment de base. Suite à la suggestion de Katzenberg que la consommation de maïs devrait être mesurée à partir de l'apatite plutôt qu'à partir des protéines de tissus biologiques, et avec la permission de la Nation huronne-wendat de Wendake, au Québec, nous avons mesuré δ13Cémail, δ13Cdentine et δ15Ndentine de 167 dents ainsi que δ13Ccollagène et δ15Ncollagène à partir de 53 échantillons d'os adhérant à ces dents, lesquelles ont été obtenues avant la réinhumation de leurs squelettes ancestraux. Les valeurs d'émail se rapportent à l'alimentation de la petite enfance (environ 1,5 à 4 ans) tandis que les valeurs de la dentine reflètent plutôt l'enfance tardive. Les dents proviennent de 16 sites du territoire ancestral des hurons-wendat soit où se trouve maintenant le sud de l'Ontario. Les valeurs des isotopes démontrent une dépendance constante du maïs du début du 14ème au 16ème siècle, avec une plus grande dépendance au 17 ème siècle, soit la période de contact avec les Européens et où surviennent des changements sociétaux significatifs. Nous démontrons une différence entre les régimes alimentaires des enfants et des adultes, où les jeunes enfants consomment plus de maïs et moins de protéines animales que les adultes. Nous n'observons aucune évidence isotopique que le cerf de Virginie (*Odocoileus virginianus*) exploite les champs de maïs. Nous démontrons plutôt que les chasseurs exploitent cette ressource dans des régions plus éloignées. Vingt-et-une nouvelles valeurs ont été regroupées à des données antérieures pour fournir une meilleure évaluation des modèles d'isotopes stables de C et N dans différentes espèces de poissons exploités. L'anguille d'Amérique (*Anguilla rostrata*) démontre une grande variabilité. Les sources de protéines alimentaires chez l'humaines

étaient variables comparativement à la stabilité du maïs, ce dernier semble avoir été une source fiable d'énergie sous forme de glucides pendant quatre siècles.

THE HURON-WENDAT NATION

The focus of this study is the Huron-Wendat Nation, known by early French visitors to North America as the Huron. Their unique culture included palisaded villages of longhouses, well-defined political structures, production of maize, fishing, hunting, trade and warfare. It is well known through primary (Biggar 1922-36; Thwaites 1896-1901; Wrong 1939) and secondary ethnographic literature (Trigger 1976) as well as archaeological reconstructions (Birch and Williamson 2013). While there remains debate about the roles that migration events(s) and/or cultural diffusion play in the full realization of northern Iroquoian lifeways, it is clear that the adoption of maize by lower Great Lakes region populations about 2000 years ago set them on a course toward eventual settled village life (Birch 2015; Williamson 2014). In this paper we refer to those populations who lived along the north-central shore of Lake Ontario and eventually migrated northward to confederate with other groups in Simcoe County (Wendake) as ancestral Huron-Wendat (for a summary, see Williamson 2014).

Features of ancestral Huron-Wendat culture that are particularly relevant from a dietary perspective notably include village relocations every 10 to 30 years (Warrick 2008) that required adjustments to the location of agricultural fields and to strategies of fisheries exploitation and deer hunting. Observations by early visitors to the Huron-Wendat do not include substantial commentary about nursing and weaning of infants, although it was noted that the Huron-Wendat abstained from sex for two to three years while women were nursing (Thwaites 1896-1901; 8:127). We know of no special food practices directed toward children (Forrest 2010; Saunders and Melbye 1990). We thus assume that weaning occurred by three years of age, and that children in these early years had access to the same foods as adults. However, we note that in the historic period deer and fish were reserved mainly for feasts and were distributed according to status, with the prize pieces going to headmen. The impression given by observers is that maize prepared in several different fashions was the main meal, twice a day (Heidenreich 1971). Food availability depended on the seasons. For example in the midst of, or shortly after, a spawning run or deer hunt, meat was consumed regularly. During most of the year fish and meat were actually scarce (Tooker 1964:70).

Early villages (ca. A.D. 1300) were situated mainly on the Iroquois Sand Plain, a narrow band of sandy soils along the north shore of Lake Ontario. Within a century, populations had moved northward to the South Slope Till Plain, known for fertile, drought-resistant, loam-based soils (Birch and Williamson 2013; MacDonald 2002). Throughout the region, however, there were fewer heat units and frost-free days than those found in *Zea mays* production regions to the south. Major changes in settlement locales would also have led to adjustments in hunting territories and fisheries.

The quantity and types of fish remains that are recovered from village sites vary (Gates St-Pierre 2014), but all sites show yields from a variety of fish, reflecting different human behaviors as well as seasonal availability. Some fish from streams and rivers were likely obtained at times of spring spawning runs; exclusively lacustrine fish were mostly caught during fall spawning; some fish would have been more consistently available throughout the warmer months of the year (Hawkins and Caley 2012; Needs-Howarth and Thomas 1998; N.J. van der Merwe, Williamson, et al. 2003). The animal bones at a site may not reflect what humans actually consumed at that site because of behavioral and taphonomic factors. Some fish, such as the lake-dwelling Salmonidae, may have been processed at the catch site, so that predominantly vertebrae were left at the consumption site. Eel (*Anguilla rostrata*) may have been preserved and then used as travelling food or for trading, thereby dispersing their bones away from the processing site (Junker-Andersen 1988). The Recollect missionary Sagard (Wrong 1939:230) describes how the fish were preserved whole, by suspending them from the rafters of longhouses. If, as Samuel de Champlain describes, the preserved fish were crushed into prepared combinations of food before consumption (Biggar 1922-36:127), the bones and scales would be unrecognizable zooarchaeologically. There is evidence from historic accounts of trade in burbot (*Lota lota*) livers (oil) (Fox 2000), which may not have generated much material evidence on archaeological sites. The faunal evidence for a broad range of fish species from both village and processing sites, combined with the diverse life histories of Great Lakes fish species, adds further complexity to the picture (Needs-Howarth 1999; N.J. van der Merwe, Williamson, et al. 2003).

Both large and small mammals were hunted and trapped. Deer meat was consumed when available and dogs (*Canis lupus familiaris*) were raised as hunting companions and for ceremonial sacrifice; they were also consumed as food (Tooker 1964:66-67; Wright 2004:315). Woodchuck (*Marmota monax*) and other small rodents were also trapped and consumed although since their body size is so small, they probably did not contribute much to isotopic signatures.

Although the proportion of white-tailed deer (*Odocoileus virginianus*) bones on ancestral Huron-Wendat sites is variable and deer remains are rare on most sites in historic Wendake (D.A. Robertson, et al. 1995:77-80), we know hides would have been crucial for clothing and bedding. Both hunting and trade would have been necessary to meet these needs (Birch and Williamson 2013:111-117). By the turn of the sixteenth century, villages on the north shore of Lake Ontario required hunting territories the size of entire watersheds to meet their needs (Needs-Howarth and Willamson 2010). Maize would most likely have been traded to their northern Algonquian neighbors in exchange for hides.

Context for isotope-based study of Huron-Wendat diet

In all fields of scholarship, there is interplay between the questions that scholars ask and the methods available to answer those questions. The discovery that diet in life affects carbon isotope values as measured in body tissues, including bone collagen, allowed researchers to answer questions about the role of maize in the diets of some North American Indigenous societies (N.J. van der Merwe and Vogel 1978). Metabolically speaking, the plant life of the Northeast is predominantly C_3 (Calvin cycle), and the tropical grass *Zea mays* is metabolically C_4 (Hatch-Slack cycle). These two types of photosynthesis produce plant tissues with different $^{13}C/^{12}C$ ratios. Animal tissues incorporate these distinctive isotopic ratios in predictable ways, with collagen enriched in ^{13}C by about 5‰, and carbonate in bone apatite enriched by about 12-14‰ compared with the food consumed. As isotopic approaches to dietary reconstruction have developed, it has become possible to move beyond the information derived from the analysis of a single tissue such as bone collagen. Since collagen is a protein, its carbon derives preferentially from dietary protein, while carbonate in bone and enamel apatite comes from the whole diet: carbohydrates, proteins and lipids (Howland, et al. 2003; Kellner and Schoeninger 2007). Bone or enamel carbonate is therefore likely to be a more sensitive indicator of changes in the importance of maize, which contributes primarily carbohydrates to the diet.

A second isotopic framework, that of $\delta^{15}N$, can be measured in target tissues and interpreted relative to trophic effects within the local ecosystem to get information about protein sources (DeNiro and Epstein 1981). Nitrogen isotopic composition of tissues is used in paleodiet studies mainly to differentiate consumption of terrestrial versus aquatic foods (Schoeninger and Deniro 1984). With each shift from diet to consumer tissue, $\delta^{15}N$ values are enriched by +2 to +6‰. The $\delta^{15}N_{collagen}$ value of an organism's tissue will reflect the trophic level of the diet (Chisholm, et al. 1982; Hedges and Reynard 2007; O'Connell, et al. 2012). Because aquatic systems tend to be enriched in ^{15}N, $\delta^{15}N_{collagen}$ values can be used to distinguish marine and in some cases freshwater resource consumers from terrestrial resource consumers.

Models for the dietary interpretation of stable isotope ratios have been developed and refined over the past 35 years. Adoption of maize in northeast North America was an early focus of the work. Thanks to the agreement of Huron-Wendat descendants to allow retention of one tooth per ancestral skeleton as a means of learning about their past (Pfeiffer and Lesage 2014), we are able to revisit and refine the story of Aboriginal reliance on maize at its northernmost North American extent.

Prior studies of stable isotopes, chiefly from bone collagen, have documented the beginnings of maize agriculture in the region and subsequent intensification (M.A. Katzenberg, et al. 1995; Schwarcz, et al. 1985), but with considerable inter-site and even intra-site variability (N.J. van der Merwe, Williamson, et al. 2003) that does not correlate with other forms of dietary evidence (Hart and Lovis 2013). Schwarcz and colleagues postulated a peak in maize consumption at around A.D. 1350. Indeed, a large study of human teeth from the Moatfield ossuary (from around the turn of the fourteenth century) does show enriched $\delta^{13}C$. Did maize reliance subsequently decline? It has been recognized that exploration of dietary trends was hindered by the absence of isotope information from structural carbonate, which is a better tool for assessing whole diet (Harrison and Katzenberg 2003; M. A. Katzenberg 2006; M.A. Katzenberg and Harrison 1997), but human tissue samples for such studies have not been readily available. With respect to protein as assessed from nitrogen isotopes, fish intake appears to have been important, but it has been suggested that ingestion may have diminished as reliance on maize intensified (M.A. Katzenberg, et al. 1995). Maize is about 8% protein (Ellwood, et al. 2012), but is deficient in essential amino acids tryptophan and lysine. It has been suggested that maize ingestion would have necessarily tapered off, to avoid ill health effects (Schwarcz, et al. 1985; N. J. van der Merwe, Pfeiffer, et al. 2003). There is imprecision in our estimates of how zooarchaeological remains contributed to peoples' diets. There remains a need to clarify the roles of maize, fish and deer as dietary staples in the ancestral Huron-Wendat diets through time and space.

Since the request to sample dental tissue was introduced in association with the 1997 excavation of the Moatfield ossuary (Williamson and Pfeiffer 2003), descendants have often allowed controlled research on ancestors' teeth, in association with the reburial of their ancestors. Analysis of carbon and nitrogen isotopes from Moatfield tooth samples demonstrated substantial intra-site variability in maize intake and reliance on high trophic level fish for protein (N.J. van der Merwe, Williamson, et al. 2003). Subsequent work on retained teeth from seven recently excavated Iroquoian sites demonstrated consistent reliance on maize, and variable patterns of fish exploitation (Pfeiffer, et al. 2014). Most of the sites available for study have been from the fourteenth and fifteenth centuries, and most sample sizes have been modest (Moatfield excepted). For example, the basic pattern of maize introduction to the region was ascertained from 45 $\delta^{13}C_{\text{bone collagen}}$ values representing 14 archaeological sites, each of which was represented by one to five bone samples (Schwarcz, et al. 1985). There is value in expanding this developing story, to explore temporal and spatial patterns in diet strategies throughout Huron-Wendat culture history. The prior studies are greatly expanded in the study described here. This study adds new results to the previous datasets from teeth and small fragments of adhering bone representing eight additional archaeological collections that were reburied at a repatriation in 2013 (Pfeiffer and Lesage 2014). This brings the Northern Iroquoian study sample to 167 permanent teeth and 53 bone tissue samples from 16 archaeological sites representing the early fourteenth through seventeenth centuries, A.D. While this study does not address the initial adoption of maize in the diet, it allows for a rigorous exploration of the extent to which ancestral Huron-Wendat living along the north central shore of Lake Ontario relied on this dietary staple, regardless of relocations and disruptions, such as internal and external interpersonal conflict. It also allows for an examination of reliance on maize in historic Wendake.

Archaeological sites in this study

The archaeological sites in this study represent a cross-section of Huron-Wendat cultural development. Four sites from the late thirteenth through the fourteenth century are associated with a time when small, non-palisaded villages were organized in diverse ways along the north central shore of Lake Ontario. It is at this time that ossuaries with features consistent with the ceremonial Feast of the Dead first appear. There is negligible evidence of interpersonal violence at this time. In terms of food waste, fish bone often represents a substantial proportion of the animal bone identified to class (Birch and Williamson 2013:104). Five sites from the fifteenth century are associated with a period of coalescence and conflict, during which villages grew in extent and population through segmented amalgamation. These villages often had substantial palisades, and there is extensive evidence for violent conflict between communities. By the sixteenth century – represented by four sites – villages had coalesced into larger, integrated communities that yield little evidence of interpersonal conflict. There is evidence that the clan structure of the historic Huron-Wendat was established by this time. Finally, following direct contact with Europeans, the three sites from the seventeenth century represent a time of dramatic disruption. There were substantial reductions in population numbers in response to European-introduced diseases, warfare with non-Huron-Wendat Iroquoian speakers, and the dispersal of the Huron-Wendat Nation from historic Wendake (Trigger 1976). Christian Island, the most recent of the sites in our study, is from the time and place of the final stand of the Huron-Wendat in historic Wendake.

MATERIALS AND METHODS

The human samples

Samples consist of permanent teeth from sixteen archaeological sites, located between the north shore of Lake Ontario and Georgian Bay, in what is now Ontario, Canada (Fig. 1).

Information about types of sites and estimated dates is provided in Table 1. Huron-Wendat funerary practice focused primarily on secondary ossuary interments that were constructed at major rituals known as Feasts of the Dead. Most human remains come from those complex features. Occasionally, human remains are encountered on occupational sites, either as loose elements (including teeth) or as individual interments. Information from eight of the ancestral Huron-Wendat sites has been provided in earlier publications (Pfeiffer, et al. 2014; N.J. van der Merwe, Williamson, et al. 2003). Those sites include ossuaries and a special purpose site from the late thirteenth or early fourteenth century (Moatfield, Staines Road, Hutchinson), village sites and an ossuary from the fifteenth century (Damiani, Hidden Spring, Teston) and two village sites from the sixteenth century (Mantle and McKenzie). One site reported previously, Wainfleet, has been excluded because it represents a different Iroquoian-speaking group.

As Huron-Wendat communities grew in size, the ossuaries associated with their Feasts of the Dead became larger. Several of those large ossuaries were excavated by archaeological researchers from the University of Toronto, between 1946 and 1975. The excavated human remains were then curated by the Department of Anthropology, and various bioarchaeological studies were undertaken (Pfeiffer and Fairgrieve 1994). Following a memorandum of understanding with the Huron-Wendat Nation of Wendake, Québec, the skeletal remains of an estimated 1700 ancestors from twelve sites were reburied on September 14, 2013 (Pfeiffer and Lesage 2014). As a result of these activities, this paper reports on study of samples of retained teeth from the large ossuaries of Fairty, Uxbridge, Kleinburg, Maurice and Warminster (thought to be the historic site of Cahiagué, visited by Samuel de Champlain in 1615), as well as the smaller collections of Bosomworth, McKenzie-Woodbridge and Christian Island.

The use of teeth (enamel and dentine) for studying diet is informed by the biology of tooth development. The timing of first permanent molar formation from a complete outline of the crown to root apex is 1.5 to 8.5 years (AlQahtani and Liversidge 2010). The crown forms prior to the root. Enamel does not remodel subsequent to its formation, and dentine is capable of only minimal remodeling. These tissues differ from bone in this regard. Teeth chosen for this study are well-preserved, non-carious, lightly worn permanent teeth. Most are first mandibular molars. (The choice of permanent teeth was more varied in the Moatfield study.) Values from enamel and dentine provide information about the diets of children.

Teeth with some alveolar bone adhering to the roots were chosen for study whenever possible. After surface cleaning, enamel was ground from a broad surface on the side of the crown, using a variable speed, hand-held burr. The resulting powder was pre-treated and analyzed to yield a value for $\delta^{13}C_{enamel}$ that reflects childhood diet over the period of formation of the crown. One root of each molar was sliced parallel to the long axis, producing a chunk that was then processed to obtain collagen-based values for $\delta^{13}C_{dentine}$ and $\delta^{15}N_{dentine}$ that reflect childhood dietary intake subsequent to weaning, biased toward the protein component of the diet. A subset of teeth was identified to be sectioned horizontally for a study of age at weaning (forthcoming). For those teeth, values for three horizontal sub-samples from mid-root to apex were averaged to provide per-tooth values for $\delta^{13}C_{dentine}$ and $\delta^{15}N_{dentine}$. The alveolar bone available from 53 of the teeth from 13 of the sites was processed to generate collagen-based values for $\delta 13C_{bone}$ and $\delta 15N_{bone}$. This reflects adult dietary intake, with a bias toward the protein component. No bone apatite values were generated.

The laboratory protocols were the same for all samples, including past analyses (Pfeiffer, et al. 2014) and newly added samples. In order to extract collagen from bone and dentin, small chunks (a few millimetres in diameter) were surface-cleaned by sanding lightly with fine sandpaper, then weighed and placed in ca. 0.2M HCl until they had decalcified. After rinsing in distilled water, they were soaked in 0.1M NaOH overnight to remove humic acids. They were then left in distilled water, changed daily, for several days until the water remained neutral, then freeze-dried. Collagen weight was divided by starting weight and multiplied by 100 to give percentage collagen yield. Approximately half a milligram of collagen was weighed into a tin cup, combusted at 1020°C in an automated elemental analyzer, then swept in a stream of helium carrier gas through a Conflo inlet into a Delta V Plus light isotope mass spectrometer. Results are reported in parts per mille (‰) relative to international standards Vienna PeeDee Belemnite (for carbon) and AIR (for nitrogen). Isotope ratios are expressed in the delta notation, where $\delta = (R_{sample}/R_{standard}-1)*1000$ ‰. R is the ratio of the heavy to the light isotope. Repeated measurements of homogeneous in-house standard materials yielded standard deviations of less than 0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$.

For tooth enamel, approximately 5-10 mg of enamel powder was removed as described above, then was placed in a 1.5 ml microcentrifuge tube. Each powder was treated with 1mL of 1.75% sodium hypochlorite for 45 minutes to remove organics, centrifuged, rinsed three times in distilled water, treated with 1mL of 0.1M acetic acid for 15 minutes, rinsed three times with distilled water, and freeze-dried. Mass spectrometer analysis was performed at University of Cape Town Archaeometry Laboratory, using a Finnigan Gas Bench II coupled to a Delta Plus XP (Thermo-Finnigan) gas source mass spectrometer.

The sample was reacted with 100% phosphoric acid at 72°C to generate carbon dioxide. $\delta^{13}C$ measurements are expressed relative to the Vienna PDB standard, as above.

Samples of candidate foods: fish and deer

Previously published isotopic values for samples of archaeologically-derived fish bone representing diverse species have been supplemented by values for $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$ from 21 archaeological fish bone samples identified to at least the genus level, all recovered from Huron-Wendat sites. The new samples were chosen to expand our knowledge of less well-explored candidate food species including American eel and burbot. The dynamic ecology of the region's lakes and streams yields many fish species with diverse isotopic profiles. Fish species have been grouped according to trophic level and other attributes of their lifecycle or biology: (a) several members of the family Salmonidae, which are piscivorous and have oily flesh amenable to smoking or drying and thus to off-site processing and delayed consumption; (b) catadromous fish, namely, American eel (*Anguilla rostrata*), a partly piscivorous fish that also has oily flesh and may have been consumed sometime after capture in altered form; (c) piscivorous fish with an oily liver, namely burbot, which shares habitat and food preferences with Salmonidae and spawns in winter (Scott 1967); (d) various fish that are piscivorous as adults, considered desirable "game fish" in modern times; and (e) various benthic/pelagic prey species that are non-piscivorous. American eel spawn in the Atlantic Ocean. The young then migrate to freshwater, where they remain until sexual maturity approaches. At that point they return to the ocean to spawn and die.

Enamel and dentine from fifty-five deer teeth were also assessed. They were recovered from archaeological sites located in a broad geographic region that includes the Huron-Wendat sites. This data set is related to an ongoing study of population movements (Pfeiffer, et al. 2013). The laboratory methods used for sample preparation and measurement of isotope values from fish and deer were the same as those described for the human samples.

RESULTS

Enamel apatite is considered a reliable sample material due to its highly crystalline form and density (Lee-Thorp 2008; Lee-Thorp, et al. 1997). The human teeth analyzed here all showed excellent macroscopic enamel preservation; the enamel was hard and white, with minimal discoloration or evidence of cracks or fissures. Any such areas were avoided during enamel sampling. Nearly all collagen extracts from dentine, human bone and fish bone consisted of well-preserved collagen. Those with C:N ratios outside the 2.9 to 3.6 range (Ambrose 1990; Szpak 2011; Van Klinken 1999) were removed from further analysis. Indicators of collagen quality (%C, %N and C:N ratios) for the samples from the eight sites not previously reported appear in the supplementary information, Table S1. The reported isotopic results can be regarded with confidence, given the absence of evidence for diagenesis. Isotopic values from the 167 teeth and 53 samples of bone are summarized by each of the sixteen sites, organized into four centuries, in Table 2.

Analyses of the human isotope values are based on the premise that $\delta^{13}C_{enamel}$ will reflect the whole diet, while $\delta^{13}C_{dentine}$ and $\delta^{13}C_{bone\ collagen}$ will be oriented toward dietary protein (Warinner and Tuross 2009). Nitrogen in dentine and bone collagen derives from protein foods. In the context of dietary reconstruction, offsets of 5‰ in $\delta^{13}C$ and 6‰ in $\delta^{15}N$ (O'Connell, et al. 2012) are assumed between the ingested protein and human collagen, derived from either dentine or bone.

Isotope values from human enamel and dentine

The mean value for $\delta^{13}C_{enamel}$ for all 167 teeth in this study is -3.57 ± 1.45‰ (Table 2, Fig. 2). There are no significant differences among values from the fourteenth, fifteenth and sixteenth centuries, but these results are significantly different from the group dating to the seventeenth century (Kruskal-Wallis post-hoc multiple comparison test, $p=0.05$). This most recent group shows more enriched values, indicating greater consumption of maize. The coefficient of variation is greatest for the fourteenth century, where the standard deviation is 38.5% of the mean, compared to 35%, 33% and 35% in the subsequent centuries. Each of the four sites from the fourteenth century shows more variation than is typical of the subsequent centuries.

The mean value for $\delta^{13}C_{dentine}$ is -10.86 ± 1.18‰ ($n=164$). Comparison of results for different time periods shows no significant chronological differences (Kruskal-Wallis post-hoc multiple comparison test, $p=0.05$). Here, too, the variability is highest among the earliest sites. The two $\delta^{13}C$ measures from teeth are illustrated in Figure 2. The difference between $\delta^{13}C_{enamel}$ and $\delta^{13}C_{dentine}$, or the carbonate-collagen spacing, is 7.28 ± 1.59‰ ($n=164$). The centuries show mean values of 7.1 to 8.1‰. Within each site there is considerable variability of ranges when individuals are compared, with personal values of 0.6 to 11.4‰. Values for $\delta^{13}C_{enamel}$ are shown for sites arranged in approximate chronological order in Figure 3.

The mean value for $\delta^{15}N_{dentine}$ is 11.91 ± 0.98‰. Comparison of the four centuries (Fig. 4) shows that values from the fifteenth century are significantly different from the fourteenth (Mann-Whitney Z value = 4.44, $p<0.01$). The fifteenth and sixteenth centuries are not different (Mann-Whitney Z value = 0.99, $p=0.32$), but the seventeenth century is different from the sixteenth (Mann-Whitney Z value = 3.63, $p<0.01$). More positive $\delta^{15}N$ values occur in the fourteenth and seventeenth centuries, when sites were located near Lake Ontario and Georgian Bay respectively. The isotope values may reflect greater access to fish at those times. There is substantial variability from site to site (Table 2, Fig. 5). The variation in human $\delta^{15}N_{dentine}$ is assumed to derive from differences in the quantities and types of protein foods consumed. Values for $\delta^{15}N_{dentine}$ are shown for sites arranged in approximate chronological order in Figure 5.

Isotope values from human bone

Bones samples were available from 13 of the 16 sites, always in smaller numbers than tooth samples. The mean value for $\delta^{13}C_{bone}$ is -11.9 ± 1.1‰; for $\delta^{15}N_{bone}$ it is 12.2 ± 1.1‰.

Values of $\delta^{13}C_{bone}$ and $\delta^{15}N_{bone}$ from two of the sites in this study, Fairty and Kleinburg, have been reported previously (Schwarcz, et al. 1985), although with smaller samples. There is generally good agreement, with mean values within 0.2‰.

Isotope values from fish bone

The isotope values from 21 samples of archaeological fish bone chosen to expand our knowledge of candidate fish species are incorporated into a larger table of fish isotope values, provided as supplementary information (Table S2). The new values include seven American eel, eight burbot, five largemouth bass and one walleye. Together with values from the literature, the resulting 92 data points are organized into the five categories described above: salmonidae (Atlantic salmon, lake trout, whitefishes); catadromous species (American eel); fish with an oily liver (burbot); nominally piscivorous fish; and benthic/pelagic species that are prey of the piscivores. These values are plotted in Figure 6.

The isotopic values for American eel are distinctive in two ways. The $\delta^{13}C$ values are heavier than the typical fresh water benthic-pelagic feeders, and both $\delta^{13}C$ and $\delta^{15}N$ are highly variable (N=11, $\delta^{13}C = -18.5 \pm 3.69$‰; $\delta^{15}N = 8.9 \pm 1.32$‰). This variability may reflect diversity in the ages of the fish. Those that are older would retain less of the marine signal from their time in the ocean than would the elvers. The fish with the oily liver, burbot, (N=9, $\delta^{13}C = -19.8 \pm 1.26$‰; $\delta^{15}N = 12.0 \pm 1.19$‰) has a mean $\delta^{13}C$ value very similar to that of the Salmonidae (N=17, $\delta^{13}C = -20.1 \pm 0.84$‰; $\delta^{15}N = 9.91 \pm 1.23$‰). Each of these groups clusters tightly, with burbot having higher $\delta^{15}N$ values than the Salmonidae. The $\delta^{15}N$ values for the piscivorous fish (northern pike, yellow perch, and others) are about one trophic level above the values of their prey. The most positive $\delta^{13}C$ values among the fishes (with values that could mimic maize in target human tissues) are some of the American eel, the pumpkinseed (*Lepomis gibbosus*) and the freshwater drum (*Aplodinotus grunniens*). Most of the fishes, particularly the fishes that can be caught *en masse* during their spawning period (e.g., Salmonidae and non-Salmonidae piscivorous fish), have $\delta^{13}C$ values reflecting a C_3 ecosystem, but with highly variable $\delta^{15}N$ values.

Isotope values from deer tissues

Isotopic values from deer bone taken from the literature show C_3 diets and low variability (M. A. Katzenberg 2006; M.A. Katzenberg 1989; Morris 2015) (Table 3). Fifty-five deer teeth from sites in this study region generated a mean $\delta^{13}C_{enamel}$ of -15.0±1.2‰ (range -18.3 to -11.9) and $\delta^{13}C_{dentine}$ of -22.3±0.9‰ (range -25.9 to -20.5). These values are also consistent with C_3 diets, showing no evidence of foraging from maize fields. The markedly negative $\delta^{13}C$ values and the consistent absence of a C_4 signal from samples of this species may reflect an historic preference for forest plant species compared with contemporary behavior; the species is known to be an agricultural pest in modern times. The results may indicate that the deer were hunted from deeply forested regions, at a distance from maize fields (also noted by Morris 2015). $\delta^{15}N_{dentine}$ for the deer in this study is 6.2±1.0‰ (range 3.5 to 9.0).

DIETARY INTERPRETATIONS

Ethnographic and archaeological evidence indicates that the central components of the ancestral Huron-Wendat diet were maize, deer meat and fish, with many plants and animals supplementing these core items (Hart and Lovis 2013). This study confirms prior observations that the deer did not raid maize fields, but rather relied on a C_3 diet. While deer may have been hunted in local watersheds on sites situated along the north shore of Lake Ontario, ethnographic descriptions of historic period deer hunts indicate there were collective efforts involving hundreds of men in the fall to late winter when deer were gathering together in wintering areas in the forest. The hunters channeled deer into enclosures where they were then slaughtered, processed and meat brought back to the villages (Biggar 1922-36:60-61). This hunting method may explain the deer isotope signature observed for deer hunted in historic times in areas far from maize fields. We note that dog may have contributed to the isotopic signatures reported here, especially among late northern villages like Maurice where considerable amounts of dog bone was recovered; however, the Maurice village is not associated with the later Maurice ossuary from which our samples are derived (Williamson 2014:37).

Complexity is introduced to this picture by the diversity of fish isotopic patterns, with $\delta^{13}C$ values along a spectrum. Information from human $\delta^{13}C_{enamel}$ and $\delta^{13}C_{dentine}$ indicates that a substantial proportion of the foodstuffs consumed during childhood, from which teeth were built, followed the C_4 metabolic pattern. Given the consistently C_3 isotopic values from local deer, the primary source of C_4 food was the direct consumption of maize. However, some fish may also have contributed to enriched isotopic values. We recognize that there are significant problems with the application of mixing models in archaeological dietary reconstructions (Makarewicz and Sealy 2015). For heuristic purposes only, we consider a linear mixing model in which the C_3 and C_4 endpoints for enamel (i.e., 100% C_3 foods versus 100% C_4 foods) lie at -13 and +1 respectively (N.J. van der Merwe, Williamson, et al. 2003). The mean $\delta^{13}C_{enamel}$ value of -3.57 ± 1.4‰ suggests that substantially more than 50% of total dietary carbon came from C_4 foods: predominantly maize, supplemented by some fishes. Based on archaeological and ethnohistoric data, Heidenreich (1971:163) estimated that maize made up 65% of the Huron-Wendat diet during the early historic period of 1600 to 1650 A.D. This appears to be a quite reasonable figure.

For the sake of comparison with a tradition of research that approaches the exercise from the perspective of $\delta^{13}C_{bone\ collagen}$, using endpoints of -20 and -5‰ (as per Matson 2015), the mean value of -11.93‰ suggests that slightly less than half the diet as captured by this protein-biased signal came from C_4 foods. Contrary to studies that have suggested ill effects on health from over-reliance on maize (Schwarcz, et al. 1985; N. J. van der Merwe, Pfeiffer, et al. 2003; N.J. van der Merwe, Williamson, et al. 2003), this evidence suggests that intake of tryptophan and lysine would have been adequate.

Insights into peoples' behavior

Some indications of community dynamics can be seen in plots of the isotopic data for each site, organized in approximate chronological order. While different sample sizes must be kept in mind, the values for $\delta^{13}C_{enamel}$ (Fig. 3) illustrate features that are consistent with current understandings of the ancestral Huron-Wendat. In addition to an increased contribution of maize to diet in the seventeenth century, we note a trend of less internal site variation through time. This suggests a tendency toward more coordinated economic activity within villages. Initially, in the fourteenth century, lineages within villages may have been free to seek security through diversity in economic practice, resulting in substantial within-village variation with respect to dependence on maize. With time, and the formation of larger villages resulting from both population growth and coalescence, communities required more agricultural surplus to address the risk of crop failure and to trade with northern Algonquians in exchange for hides for clothing and other needs (Birch and Williamson 2013:117). This heightened commitment to agriculture resulted in community-wide, coordinated field clearance and cultivation systems, which would have reduced the time available for harvesting other, naturally occurring resources. Diet became more standardized among villagers. Ultimately, with the move to Wendake at the beginning of the seventeenth century, these same pressures, exacerbated later by the threat of interpersonal hostility, led to an actual proportional increase in the consumption of maize.

We note that a shift in the degree of reliance on maize over time is apparent from analyses of $\delta^{13}C_{enamel}$, but not from $\delta^{13}C_{dentin\ collagen.}$ We suggest that this is because the carbon in dentin and bone collagen is preferentially derived from protein foods. Values from enamel will be more sensitive to whole-diet shifts. In a situation where maize is already a major component of the diet, $\delta^{13}C_{dentin\ collagen}$ is therefore not very sensitive to modest increases in the amount of maize consumed. The carbon in tooth enamel carbonate is, however, derived from all components of the diet: proteins, carbohydrates and lipids. It is therefore a better tracer of the importance of maize in high-maize diets.

Nitrogen is obtained from protein foods, so $\delta^{15}N$ in consumers provides information about the protein component of the diet. In addition to deer and fish, the Huron-Wendat had access to other sources of animal protein such as dog, other small mammals, and birds. Those foods are not under consideration here. Detailed interpretation of consumer $\delta^{15}N$ values is difficult because of uncertainty about the magnitude of the diet-to-tissue spacing in $\delta^{15}N$ in humans and other consumers. This has been the subject of considerable debate in the literature; estimates range from 3-4‰ to 6‰ (Caut, et al. 2009; Hedges and Reynard 2007; O'Connell, et al. 2012). Examination of Fig. 6 shows that, for this Iroquoian population, diet to tissue spacing of 3-4‰ means average $\delta^{15}N_{diet}$ of approximately 9‰, precluding the consumption of significant quantities of deer with its $\delta^{15}N$ of approximately 6‰. Given that deer constitute the bulk of the mammalian meat weight represented on some ancestral Huron-Wendat sites, this scenario seems unlikely. Diet to tissue spacing of 6‰ means average $\delta^{15}N_{diet}$ of approximately 6‰, consistent with a diet in which almost all protein came from deer. The true value lies somewhere between the two, depending on the proportion of ^{15}N enriched fish in the diet. The most plausible interpretation is based on spacing larger than 3-4‰. When values for $\delta^{15}N_{dentine}$ are considered among sites organized chronologically (Fig. 5), the variations between sites appear to reflect local circumstances, both ecological and sociopolitical. Additional explorations on a site-by-site basis may help to elucidate meaning from the results presented here.

For the population analyzed in this study, mean $\delta^{13}C_{bone\ collagen}$ (-11.91 ± 1.05 n=53) is significantly more negative than $\delta^{13}C_{dentine}$ (-10.86 ± 1.18 n=164) ($t = 5.8$ d.f. = 215 $p<0.01$). Pairwise comparison of the two tissues based only on those individuals with both measures yields the same result ($t=7.70$ d.f.=53 $p<0.01$). A pairwise comparison of $\delta^{15}N_{bone\ collagen}$ (mean =12.24 ± 1.07 n=53) with $\delta^{15}N_{dentine}$ of the same individuals indicates that these values do not differ significantly ($t=0.13$ d.f. = 52 $p>0.05$). One possibility is that there is a previously unrecognized difference in ^{13}C enrichment from diet to dentine compared with diet to bone. The small number of studies in the literature that report both $\delta^{13}C_{bone\ collagen}$ and $\delta^{13}C_{dentine}$ for the same individuals do not, however, find a difference (France and Owsley 2013; Salazar-Garcia, et al. 2014), making a metabolic explanation such as this unlikely. We therefore infer that the diets of Iroquoian children (at the time of dentine formation) included a greater proportion of C_4 food (i.e., maize) than the diets of adults, as reflected in alveolar bone. Adults consumed more C_3-based foods, a category that includes venison and fish.

CONCLUSIONS

Our study shows that ancestral Huron-Wendat communities living along the north shore of Lake Ontario demonstrated consistency in the degree of reliance on maize as a staple food through the fourteenth, fifteenth and sixteenth centuries AD, then a shift to greater maize consumption in the seventeenth century. The results of this study correct earlier interpretations that postulated vacillations in ingestion of maize. That narrative should be replaced by a picture that shows consistent, pervasive reliance on maize, supplemented by dietary protein that varies by community in ways that are consistent with ecological, seasonal and cultural constraints. Second, we demonstrate a previously undocumented difference between children's and adults' diets. Young children relied on maize to a greater extent than adults, and likely had less access to animal protein.

As archaeologists establish an era in which we work collaboratively with descendant communities, it is important that we examine past statements and correct them when needed. Based on incomplete information that best reflected protein sources, earlier narratives about maize farming practices attributed behaviors to past peoples that appear to have been capricious. Isotopic values from small numbers of samples taken from sometimes imprecisely dated sites showed dramatic temporal and spatial variation, appearing to show some groups ingesting more maize than was healthy, while neighbors ingested much less. The information provided in this study illustrates that at least some of this variability in $\delta^{13}C_{bone\ collagen}$ values could reflect different exploitation of available fish foods. For example, some local communities may have had access to the more ^{13}C

enriched eel and some of the nominally piscivorous taxa, while others may have focused on the less enriched Salmonidae and burbot.

Contrary to earlier studies of smaller samples from Iroquoian sites, the contribution of maize to the diet did not peak prior to the era of European contact; it increased during those disrupted times. In prior isotopic studies, maize seemed always to be present from the thirteenth century onward, but its trajectory made little sense. Indeed, there was no trajectory. The most positive δ^{13}C values were from the early fourteenth century (Moatfield, based on $\delta^{13}C_{enamel}$ and Fairty, based on $\delta^{13}C_{bone\ collagen}$). The current study corrects this perception. It provides temporal and spatial perspective of over 400 years, during which the ancestral Huron-Wendat nation grew in numbers, and went through some challenging times. Throughout the whole period, maize consumption was a stable factor, despite the challenges of generating yields in a northern, temperate climate. The proportion of maize in the overall diet increased only during the tumultuous seventeenth century – a time during which food scarcity could have arisen from myriad disruptions and where maize may have represented a stable, accessible source of food. These may have included restricted access to traditional hunting and fishing locations. Rather than a story of fits and starts, we see reliance on maize as a dietary staple in a society that honed impressive horticultural knowledge and skill over the centuries.

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REFERENCES CITED

AlQahtani, S.J. and H.M. Liversidge

2010 Brief communication: The London Atlas of human tooth development and eruption. *American Journal of Physical Anthropology* 142:481-490.

Ambrose, S.H.

1990 Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis. *Journal of Archaeological Science* 17:431-451.

Biggar, Henry P. (editor) 1922-36 *The Works of Samuel de Champlain*. 6 vols. Champlain Society, Toronto.

Birch, Jennifer

2015 Current research on the historical development of northern Iroquoian societies. *Journal of Archaeological Research* 23(3):263-323.

Birch, Jennifer and R.F. Williamson

2013 *The Mantle Site: An Archaeological History of an Ancestral Wendat Community*. Issues in Eastern Woodlands Archaeology. AltaMira Press, Lanham, Maryland.

Caut, S., E. Angulo and F. Courchamp

2009 Variation in discrimination factors (Δ15N and Δ13C): the effect of diet isotopic values and applications for diet reconstruction. *Journal of Applied Ecology* 46:443-453.

Chisholm, B. S., D. E. Nelson and H. P. Schwarcz

1982 Stable-carbon isotope ratios as a measure of marine versus terrestrial protein in ancient diets. *Science* 216(4550):1131-1132.

DeNiro, M. J. and S. Epstein

1981 Influence of diet on the distribution of nitrogen isotopes in animals. *Geochimica et Cosmochimica Acta* 45(3):341-351.

Ellwood, E.C., M.P. Scott, W.D. Lipe and R.G. Matson

2012 Stone-boiling maize with limestone: experimental results and implications for nutrition among SE Utah preceramic groups. *Journal of Archaeological Science* 40:35-44.

Forrest, C.

2010 The in-house burials at the Late Ontario Iroquoian Draper Site (AlGt-2): a multidirectional approach to interpretation. *Ontario Archaeology* 89-90:97-119.

Fox, W.A.
2000 A true Canadian fish story: archaeological food for thought. *Kewa (Newsletter of the London Chapter of the Ontario Archaeological Society)* 00(7-8):16-23.

France, C.A.M. and D.W. Owsley
2013 Stable carbon and oxygen isotope spacing between bone and tooth collagen and hydroxyapatite in human archaeological remains. *International Journal of Osteoarchaeology* early view.

Gates St-Pierre, C.
2014 Fish & corn: St. Lawrence Iroquoians as fishers and farmers. Paper presented at the International Council for Archaeozoology, San Rafael, Argentina.

Harrison, R. G. and M. A. Katzenberg
2003 Paleodiet studies using stable carbon isotopes from bone apatite and collagen: examples from Southern Ontario and San Nicolas Island, California. *Journal of Anthropological Archaeology* 22(3):227-244.

Hart, J.P. and W.A. Lovis
2013 Reevaluating what we know about the histories of maize in Northeastern North America: a review of current evidence. *Journal of Archaeological Research* 21:175-216.

Hawkins, A.L. and E. Caley
2012 Seasonality, mass capture and exploitation of fish at the Steven Patrick site, a Uren village near Kempenfelt Bay. *Ontario Archaeology* 92:95-122.

Hedges, R.E.M. and L.M. Reynard
2007 Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science* 34:1240-1251.

Heidenreich, C.E.
1971 *Huronia: A History and Geography of the Huron Indians, 1600 - 1650*. McClelland and Stewart Ltd., Toronto, Canada.

Howland, M. R., L. T. Corr, S. M. M. Young, V. Jones, S. Jim, N. J. Van der Merwe, A. D. Mitchell and R. P. Evershed
2003 Expression of the dietary isotope signal in the compound-specific delta(13) values of pig bone lipids and amino acids. *International Journal of Osteoarchaeology* 13(1-2):54-65.

Junker-Andersen, C.
1988 The eel fisheries of the St. Lawrence Iroquoians. *North American Archaeologist* 9:97-121.

Katzenberg, M. A.

2006 Prehistoric maize in southern Ontario: Contributions from stable isotope studies. In *Histories of maize : multidisciplinary approaches to the prehistory, linguistics, biogeography, domestication, and evolution of maize*, edited by J. E. Staller, R. H. Tykot and B. F. Benz, pp. 263-273. Elsevier Academic Press, Amsterdam.

Katzenberg, M.A.

1989 Stable isotope analysis of archaeological faunal remains from southern Ontario. *Journal of Archaeological Science* 16:319-329.

Katzenberg, M.A. and R.G. Harrison

1997 What's in a Bone? Recent advances in archaeological bone chemistry. *Journal of Archaeological Research* 5(3):265-293.

Katzenberg, M.A., H.P. Schwarcz, M. Knyf and F.J. Melbye

1995 Stable isotope evidence for maize horticulture and paleodiet in Southern Ontario, Canada. *American Antiquity* 60(2):335-350.

Kellner, Corina M. and Margaret J. Schoeninger

2007 A simple carbon isotope model for reconstructing prehistoric human diet. *American Journal of Physical Anthropology* 133(4):1112-1127.

Lee-Thorp, J.A.

2008 On isotopes and old bones. *Archaeometry* 50(6):925-950.

Lee-Thorp, J.A., L. Manning and M. Sponheimer

1997 Problems and prospects for carbon isotope analysis of very small samples of fossil tooth enamel. *Bull. Soc. Geol. France* 168(6):767-773.

MacDonald, R.I.

2002 Late Woodland Settlement Trends in South-Central Ontario: A Study of Ecological Relationships and Culture Change, Department of Anthropology, McGill University, Montreal.

Makarewicz, C.A. and J. Sealy

2015 Dietary reconstruction, mobility, and the analysis of ancient skeletal tissues: Expanding the prospects of stable isotope research in archaeology. *Journal of Archaeological Science* 56:146-158.

Matson, R.G.

2015 The nutritional context of the Pueblo III depopulation of the northern San Juan: too much maize? *Journal of Archaeological Science Reports* in press(xx-xx).

Morris, Zoe Hensley

2015 Reconstructing subsistence practices of Southwestern Ontario Woodland peoples (AD 900-1600) using stable isotopic analyses of faunal material, Department of Anthropology, University of Western Ontario, London, Ontario.

Needs-Howarth, S.

1999 Native fishing in the Great Lakes - A multidisciplinary approach to zooarchaeological remains from precontact Iroquoian villages near Lake Simcoe, Ontario, Rijksuniversiteit, Groningen, the Netherlands.

Needs-Howarth, S. and S.C. Thomas

1998 Seasonal variation in fishing strategies at two Iroquoian village sites near Lake Simcoe, Ontario. *Environmental Archaeology* 3:109-120.

Needs-Howarth, S. and R.F. Willamson

2010 Feeding and clothing the masses: The role of white-tailed deer in community planning in sixteenth century Ontario. Paper presented at the 11th Conference of the International Council for Archaeozoology, Paris, France.

O'Connell, T.C., C.J. Kneale, N. Tasevska and G.G.C. Kuhnle

2012 A Diet-Body Offset in Human Nitrogen Isotopic Values: A Controlled Dietary Study. *American Journal of Physical Anthropology* 149:426-434.

Pfeiffer, S. and S. Fairgrieve

1994 Evidence from ossuaries: the effect of contact on the health of Iroquoians. In *In the Wake of Contact: Biological Responses to Conquest*, edited by C. S. Larsen and G. Milner, pp. 47-61. A.R. Liss, New York.

Pfeiffer, S. and L. Lesage

2014 The Repatriation of Wendat Ancestors / Le rapatriement des ancêtres Wendat, 2013. *Canadian Journal of Archaeology* 38:1-22.

Pfeiffer, S., R.F. Willamson, J.C. Sealy, D. G. Smith and M. H. Snow

2014 Stable Dietary Isotopes and mtDNA from Woodland period southern Ontario people: results from a tooth sampling protocol. *Journal of Archaeological Science* 42:334-345.

Pfeiffer, S., R.F. Williamson, J.C. Sealy and C. Forrest

2013 Environmental isotopes indicate interactions among Iroquoians. “Trading Spaces: The Archaeology of Interaction, Migration and Exchange” University of Calgary, Alberta, Canada, November 7-9, 2013. Paper presented at the Chacmool: Trading Spaces: The Archaeology of Interaction, Migration and Exchange University of Calgary, Calgary, Alberta.

Robertson, D. A.
2004 The Hutchinson site: A place to prepare for the final journey. *Ontario Archaeology* 77/78:95-120.

Robertson, D.A., S.G. Monckton and R.F. Williamson
1995 The Wiacek site revisited: The results of the 1990 excavations. *Ontario Archaeology* 60:40-91.

Salazar-Garcia, D.C., M.P. Richards, O. Nehlich and A.G. Henry
2014 Dental calculus is not equivalent to bone collagen for isotope analysis: a comparison between carbon and nitrogen stable isotope analysis of bulk dental calculus, bone and dentine collagen from same individuals from the Medieval site of El Raval (Alicante, Spain). *Journal of Archaeological Science* 47:70-77.

Saunders, S.R. and F.J. Melbye
1990 Subadult Mortality and Skeletal Indicators of Health in Late Woodland Ontario Iroquois. *Canadian Journal of Archaeology* 14:61-74.

Schoeninger, M. J. and M. J. Deniro
1984 Nitrogen and carbon isotopic composition of bone-collagen from marine and terrestrial animals. *Geochimica Et Cosmochimica Acta* 48(4):625-639.

Schwarcz, H.P., J. Melbye, M.A. Katzenburg and M. Knyf
1985 Stable Isotopes in Human Skeletons of Southern Ontario: reconstructing Paleodiet. *Journal of Archaeological Science* 12:187-206.

Scott, W.B. (editor) 1967 *Freshwater fishes of eastern Canada*. second edition ed. University of Toronto Press, Toronto.

Szpak, P.
2011 Fish bone chemistry and ultrastructure: implications for taphonomy and stable isotope analysis. *Journal of Archaeological Science* 38(12):3358-3372.

Thwaites, R.G.
1896-1901 *The Jesuit Relations and Allied Documents*. 73 vols. Burrows Brothers Company, Cleveland, OH.

Tooker, Elizabeth
1964 *An Ethnography of the Huron Indians, 1615-1649*. Smithsonian Institution, Bureau of American Ethnology Bulletin 190. U.S. Government Printing Office, Washington, D.C.

Trigger, B.G.

1976 *The Children of Aataentsic: A History of the Huron People to 1660*. 2 vols. McGill-Queen's University Press, Montreal.

van der Merwe, N. J., S. Pfeiffer, R.F. Williamson and S.C. Thomas
2003 Isotopic analysis and the diet of the Moatfield community. In *Bones of the Ancestors: The Archaeology and Osteobiography of the Moatfield Ossuary*, edited by R. F. Willamson and S. Pfeiffer, pp. 205-222. Canadian Museum of Civilization, Ottawa, Ontario.

van der Merwe, N.J. and J.C. Vogel
1978 13C Content of human collagen as a measure of prehistoric diet in woodland North America. *Nature* 276(21):815-816.

van der Merwe, N.J., R.F. Williamson, S. Pfeiffer, S.C. Thomas and K.O. Allegretto
2003 The Moatfield Ossuary: Isotopic dietary analysis of an Iroquoian community, using dental tissue. *Journal of Anthropological Archaeology*:245-261.

Van Klinken, G. J.
1999 Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* 26(6):687-695.

Warinner, Christina and Noreen Tuross
2009 Alkaline cooking and stable isotope tissue-diet spacing in swine: archaeological implications. *Journal of Archaeological Science* 36:1690-1697.

Warrick, G.A.
2008 *A Population History of the Huron-Petun, A.D. 500-1650*. Cambridge University Press, Cambridge, U.K.

Williamson, R.F.
2014 The Archaeological History of the Wendat to A.D. 1651: An Overview. *Ontario Archaeology* 94:3-64.

Williamson, R.F. and S.K. Pfeiffer (editors)
2003 *Bones of the Ancestors: The Archaeology and Osteobiography of the Moatfield Site.* Canadian Museum of Civilization, Ottawa.

Williamson, R.F. and D.A. Steiss
2003 A history of Iroquoian multiple burial practice. In *Bones of the Ancestors: The Archaeology and Osteobiography of the Moatfield Ossuary*, edited by R. F. Williamson and S. Pfeiffer, pp. 89-132. Mercury Series Archaeology Paper 163. Canadian Museum of Civilization, Ottawa, Ontario.

Williamson, R.F., S.Cox Thomas and R.I. MacDonald

2003 The archaeology of the Moatfield village site. In *Bones of the Ancestors: The Archaeology and Osteobiography of the Moatfield Site*, edited by R. F. Williamson and S. Pfeiffer, pp. 19-88. vol. Mercury Series Paper 163. Archaeological Survey of Canada Ottawa, Canada.

Wright, J.

2004 Ouatit's People: The Cosmological Significance of Dogs in Wendat Society. In *A Passion for the Past: Papers in Honour of James F. Pendergast*, edited by J. V. Wright and J.-L. Pilon, pp. 305-320. vol. Mercury Series Archaeology Paper 164. Canadian Museum of Civilization, Gatineau, Quebec.

Wrong, G.M. (editor) 1939 *The Long Journey to the Country of the Hurons, by Gabriel Sagard (1632)*. Champlain Society, Toronto.

Figure Captions:

Figure 1: Map of the study area with sites identified by time period. The earliest sites are near the shore of Lake Ontario and more recent sites are farther north.

Figure 2: Boxplots of human $\delta^{13}C_{enamel}$ (dotted white) and $\delta^{13}C_{dentine}$ (white) (‰) for groups, organized by century. Each box represents median and quartiles; box length= interquartile range, whiskers indicate min and max values. Outliers are represented by circles. Outliers are outside the interquartile range by 1.5 times or more.

Figure 3: Boxplots of human $\delta^{13}C_{enamel}$ values (‰) for each of the sixteen sites in this study, organized in approximate chronological order. Each box represents median and quartiles; box length= interquartile range, whiskers indicate min and max values. Outliers are represented by circles and stars. Outliers are outside the interquartile range by 1.5 times or more, with starred values more extreme than circled values.

Figure 4: Boxplots of human $\delta^{15}N_{dentine}$ (‰) organized by century. Each box represents median and quartiles; box length= interquartile range, whiskers indicate min and max values. Outliers are represented by circles.

Figure 5: Boxplots of human $\delta^{15}N_{dentine}$ (‰) for each of the sixteen sites in this study, organized in approximate chronological order. Each box represents median and quartiles; box length= interquartile range, whiskers indicate min and max values. Outliers are represented by circles and stars.

Figure 6: Individual $\delta^{13}C$ (‰, horizontal axis) and $\delta^{15}N$ (‰, vertical axis) values from archaeological fish bone collagen, and a single data point for white-tailed deer (*Odocoileus virginianus*), as per published values (N=114, see Table 3). The vertical shaded line indicates the estimated $\delta^{13}C_{diet}$ (based on the ancestral Wendat average for $\delta^{13}C_{dentine}$ minus an offset of 5‰); the horizontal shaded lines indicate the estimated $\delta^{15}N_{diet}$ (based on ancestral Wendat average for $\delta^{15}N_{dentine}$ minus offsets of 3‰ and 6‰). In the absence of consensus about what the offset may be, we assume that $\delta^{15}N$ in deer and fish collagen from bone or dentine is not significantly different from the $\delta^{15}N$ of edible flesh.

Table 1: Sites from which human enamel, dentine and bone were derived in this study.

	Site name	Context	Date (A.D.)	Date Lab #	Sources
	14th Century				
1	Staines Rd	Disturbed ossuary	1030-1270*	Beta-156359	(Pfeiffer, et al. 2014; Williamson and Steiss 2003)
2	Moatfield AkGu-65	ossuary	1160-1290*	GX-26251	(Pfeiffer, et al. 2014; Williamson, et al. 2003)
3	Hutchinson AkGt-34	special purpose	Early 14th		(Pfeiffer, et al. 2014; D. A. Robertson 2004)
4	Fairty AlGt-3	ossuary	1365-1385*	Beta-397304	(Williamson 2014)
	15th Century				
5	Uxbridge BbGs-3	ossuary	1415-1455*	Beta-403922	This study
6	Teston Road AlGv-2	ossuary	1450-1500		(Pfeiffer, et al. 2014)
7	Bosomworth BaGv-1	cemetery	1450-1640*	Beta-316502	This study
8	Hidden Spring AlGu-368	occupation	Mid 15th		(Pfeiffer, et al. 2014)
9	Damiani AlGv-231	village	Late15th		(Pfeiffer, et al. 2014)
	16th Century				
10	Mantle AlGt-334	village & cemetery	1487-1527**; 1446-1530*	Beta-217158; 217159	(Birch and Williamson 2013)
11	McKenzie-Woodbridge AkGv-2	village	early 16th		
12	Milne BcHb-28	cemetery	mid 16?		
13	Kleinburg AlGv-1	ossuary	1580-1610		
	17th Century				
14	Warminster BdBv-1	ossuary	1610-1620		
15	Maurice BeHa-1	ossuary	1630-1650		
16	Christian Is BeHb-3	ossuary	1649-1651		

*calibrated 2sigma; **calibrated 1 sigma.

Table 2: Summary statistics for $\delta^{13}C$ and $\delta^{15}N$ values for human enamel, dentine and bone from the 16 sites, organized by time period: In each bin, rows are means and standard deviations (‰).

Era	Site Name	Tooth N	Bone N	$\delta^{13}C$			$\delta^{15}N$	
				Enamel	Dentine	Bone	Dentin	Bone
14th C								
	Moatfield[1]	43	10	-4.19	-11.31	-12.16	12.69	12.18
				1.55	1.45	1.39	0.86	0.52
	Fairty	15	6	-3.76	-10.75	-10.58	11.68	11.63
				1.72	1.10	0.49	0.52	0.43
	Hutchinson[2]	5	1	-3.74	-11.48		13.0	
				1.85	1.19	-12.2	0.74	10.45
	Staines Rd[2]	15	4	-3.97	-11.1	-12.4	11.9	12.25
				1.39	1.21	0.71	0.59	0.38
MEAN		78	21	-4.03	-11.17	-11.76	12.3	11.95
				1.55	1.33	1.26	0.87	0.61
15th C								
	Damiani[2]	1	0	-2.9	-9.7		12.0	
	Hidden Spring[2]	4	2	-3.55	-11.18	-13.15	12.15	11.85
				1.09	0.58	0.21	0.39	0.07
	Bosomworth	3	0	-3.83	-10.87		12.27	
				1.11	1.32		0.15	
	Teston Rd[2]	10	6	-3.72	-11.0	-12.15	11.1	11.3
				1.21	0.68	0.28	0.71	0.39
	Uxbridge	16	7	-3.07	-10.91	-11.61	11.36	13.49
				1.34	0.94	1.0	0.72	1.65
MEAN		34	15	-3.38	-10.9	-12.03	11.5	12.39
				1.2	0.85	0.85	0.75	1.54
16th C								
	Mantle[2]	15	0	-3.9	-10.6		10.6	
				1.4	1.3		0.6	
	Milne	3	1	-3.17	-10.27	-11.2	12.27	
				1.62	0.55		0.35	15.2
	McKenzie-Woodbridge[2]	4	1	-2.72	-10.9		10.7	
				0.72	0.94	-13.7	1.36	12.7
	Kleinburg	16	9	-3.21	-10.23	-11.88	11.78	12.14
				0.8	0.69	0.93	0.38	0.40
MEAN		38	11	-3.41	-10.44	-11.98	11.24	12.47
				1.14	0.98	1.02	0.87	1.0
17th C								
	Maurice	8	2	-2.10	-10.46	-12.7	12.70	13.7
				0.83	0.73	0.71	1.16	0.57
	Warminster	6	3	-2.22	-10.47	-11.90	11.93	11.85
				0.85	0.92	0.63	0.53	0.53
	Christian Island	3	1	-2.07	-8.97		12.33	
				0.25	0.74	-10.8	0.12	11.4
MEAN		17	6	-2.14	-10.19	-11.97	12.34	12.4
				0.74	0.97	0.9	0.87	1.11
TOTAL								
MEAN		167	53	-3.57	-10.86	-11.91	11.9	12.24
				1.45	1.18	1.05	0.98	1.07

[1] (N.J. van der Merwe, Williamson, et al. 2003)

[2] (Pfeiffer, et al. 2014); values for two deciduous teeth from Damiani (UCT 13706) and Hidden Spring (UCT 13702) included in the previously published data set have been omitted here.

Table 3: Isotopic values for *Odocoileus virginianus* (white-tailed deer) samples from archaeological sites in the study region.

	mean±S.D. ‰ (range)	n	references
$\delta^{13}C_{\text{bone collagen}}$	-22.6±1.4 (-24.9 to -20.2)	114	Katzenberg 1989, 2006; Morris 2015
$\delta^{13}C_{\text{dentine collagen}}$	-22.3±0.9 (-25.9 to -20.5)	55	This study
$\delta^{15}N_{\text{bone collagen}}$	5.4±0.9 (2.8 to 8.6)	114	Katzenberg 1989, 2006; Morris 2015
$\delta^{15}N_{\text{dentine collagen}}$	6.2±1.0 (3.5 to 9.0)	55	This study
$\delta^{13}C_{\text{enamel}}$	-15.0±1.2 (-18.3 to -11.9)	55	This study

Résumé : Suite à l'apparition du maïs (*Zea mays*) dans le Nord-est de l'Amérique du Nord, les populations iroquoiennes du nord ont accru leurs effectifs et élargi leur territoire, une situation qui peut-être induite par popularité envahissante de l'utilisation du maïs. Les valeurs isotopiques de collagène osseux ont été incompatibles avec cette hypothèse supposant des fluctuations temporelles et régionales fondées sur la dépendance de cet aliment de base. Suite à la suggestion de Katzenberg que la consommation de maïs devrait être mesurée à partir de l'apatite plutôt qu'à partir des protéines de tissus biologiques, et avec la permission de la Nation huronne-wendat de Wendake, au Québec, nous avons mesuré δ13Cémail, δ13Cdentine et δ15Ndentine de 167 dents ainsi que δ13Ccollagène et δ15Ncollagène à partir de 53 échantillons d'os adhérant à ces dents, lesquelles ont été obtenues avant la réinhumation de leurs squelettes ancestraux. Les valeurs d'émail se rapportent à l'alimentation de la petite enfance (environ 1,5 à 4 ans) tandis que les valeurs de la dentine reflètent plutôt l'enfance tardive. Les dents proviennent de 16 sites du territoire ancestral des hurons-wendat soit où se trouve maintenant le sud de l'Ontario. Les valeurs des isotopes démontrent une dépendance constante du maïs du début du 14ème au 16ème siècle, avec une plus grande dépendance au 17 ème siècle, soit la période de contact avec les Européens et où surviennent des changements sociétaux significatifs. Nous démontrons une différence entre les régimes alimentaires des enfants et des adultes, où les jeunes enfants consomment plus de maïs et moins de protéines animales que les adultes. Nous n'observons aucune évidence isotopique que le cerf de Virginie (*Odocoileus virginianus*) exploite les champs de maïs. Nous démontrons plutôt que les chasseurs exploitent cette ressource dans des régions plus éloignées. Vingt-et-une nouvelles valeurs ont été regroupées à des données antérieures pour fournir une meilleure évaluation des modèles d'isotopes stables de C et N dans différentes espèces de poissons exploités. L'anguille d'Amérique (*Anguilla rostrata*) démontre une grande variabilité. Les sources de protéines alimentaires chez l'humaines étaient variables comparativement à la stabilité du maïs, ce dernier semble avoir été une source fiable d'énergie sous forme de glucides pendant quatre siècles.

Figure 1

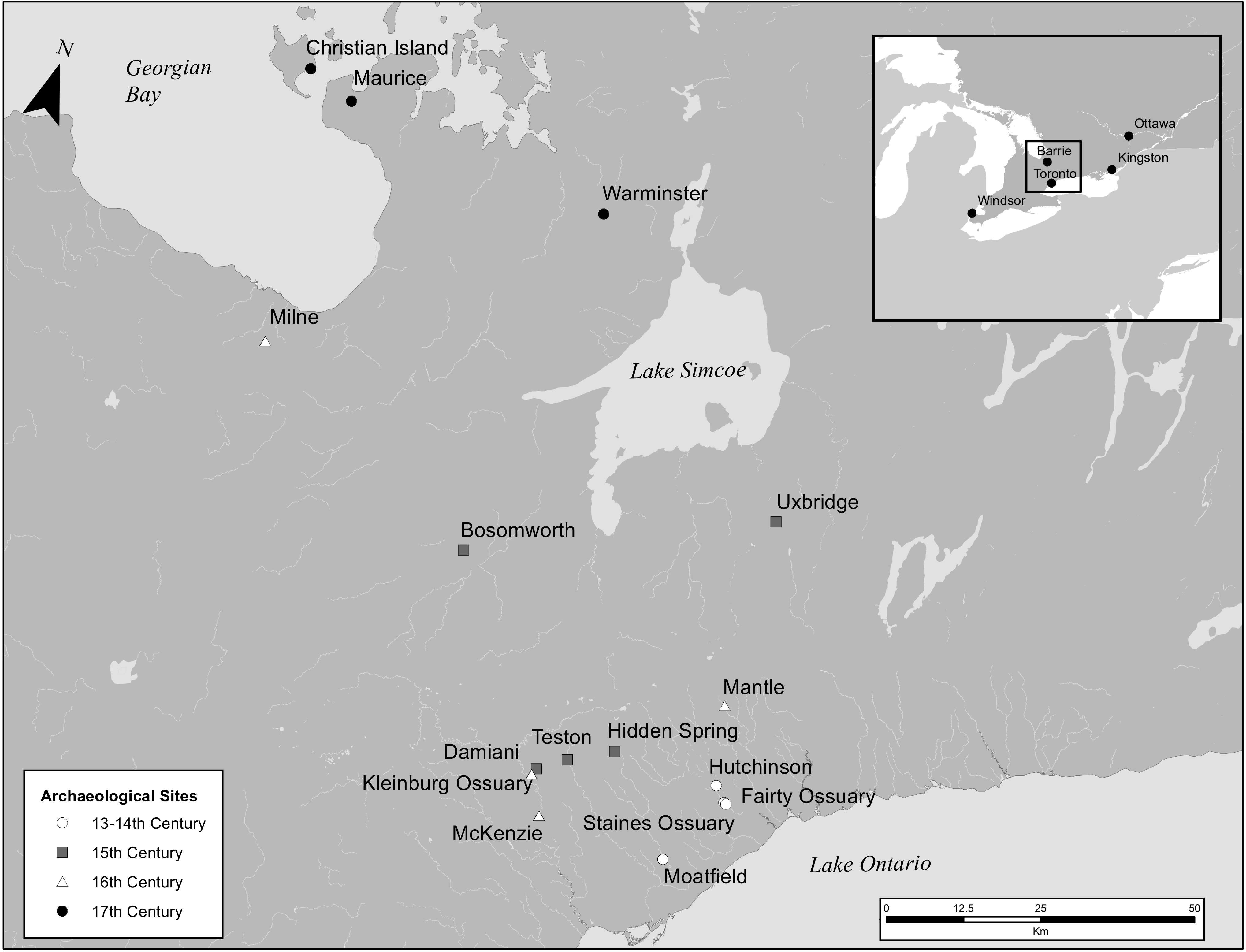

N
Georgian Bay
Christian Island
Maurice
Warminster
Milne
Lake Simcoe
Uxbridge
Bosomworth
Mantle
Hidden Spring
Teston
Damiani
Kleinburg Ossuary
Hutchinson
Fairty Ossuary
McKenzie
Staines Ossuary
Moatfield
Lake Ontario
Ottawa
Barrie
Kingston
Toronto
Windsor
Archaeological Sites
○ 13-14th Century
■ 15th Century
△ 16th Century
● 17th Century
0
12.5
25
50
Km

Figure 2

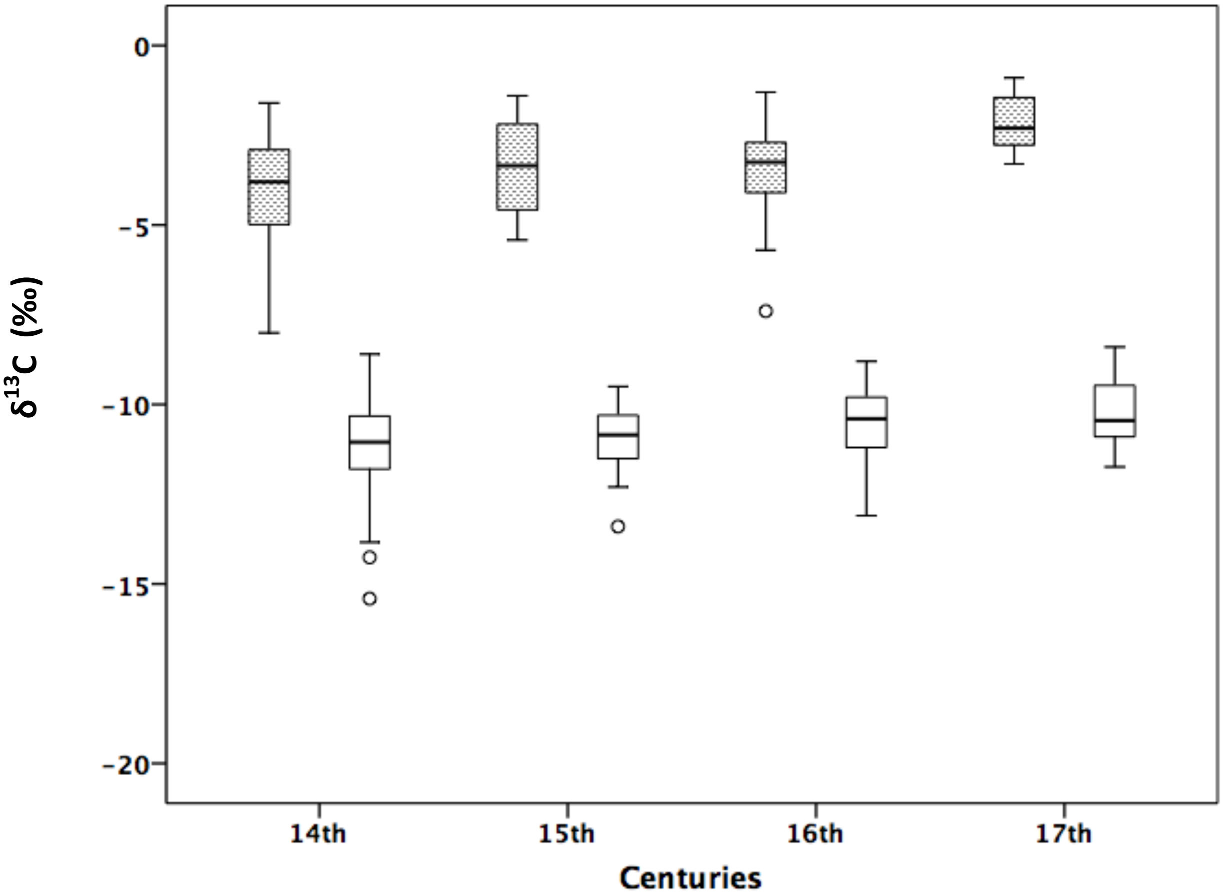
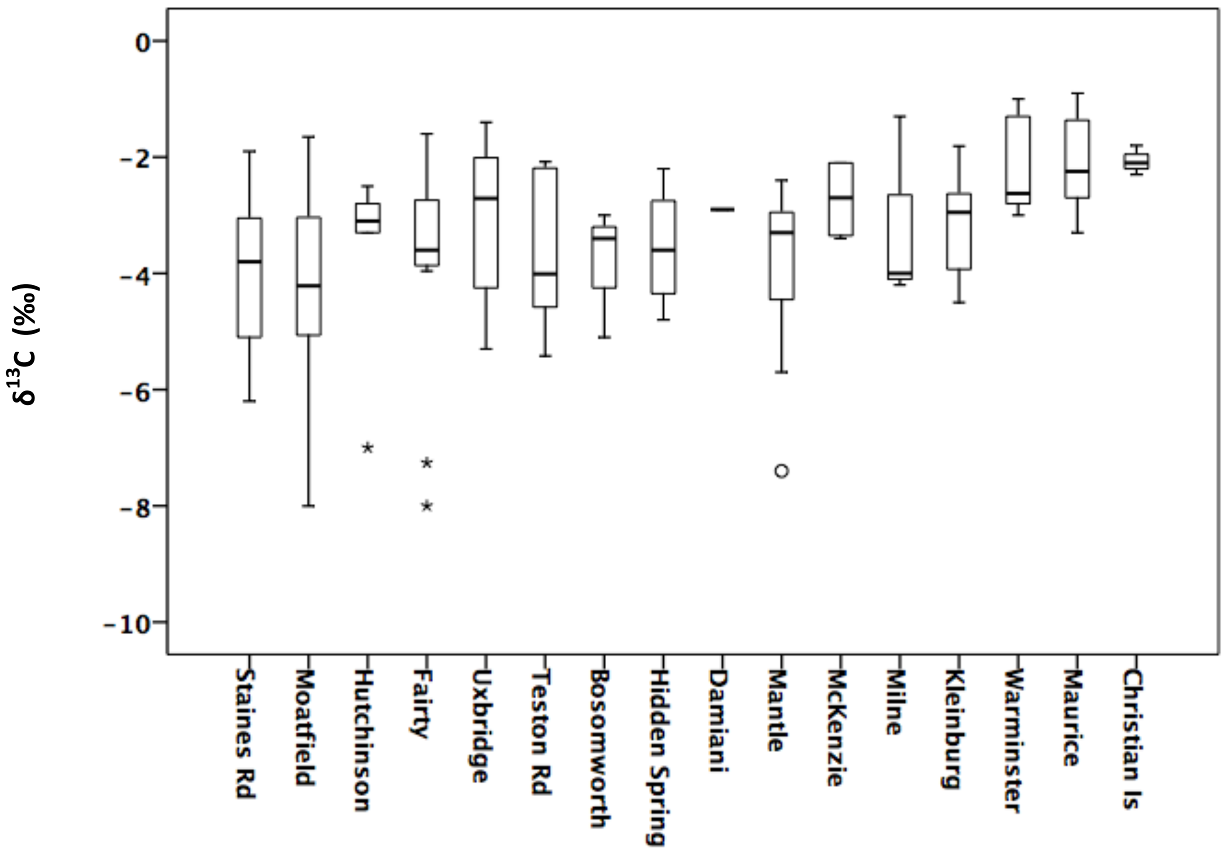


Figure 3



$\delta^{13}C$ (‰)
0
-2
-4
-6
-8
-10
Staines Rd
Moatfield
Hutchinson
Fairty
Uxbridge
Teston Rd
Bosomworth
Hidden Spring
Damiani
Mantle
McKenzie
Milne
Kleinburg
Warminster
Maurice
Christian Is

Figure 4

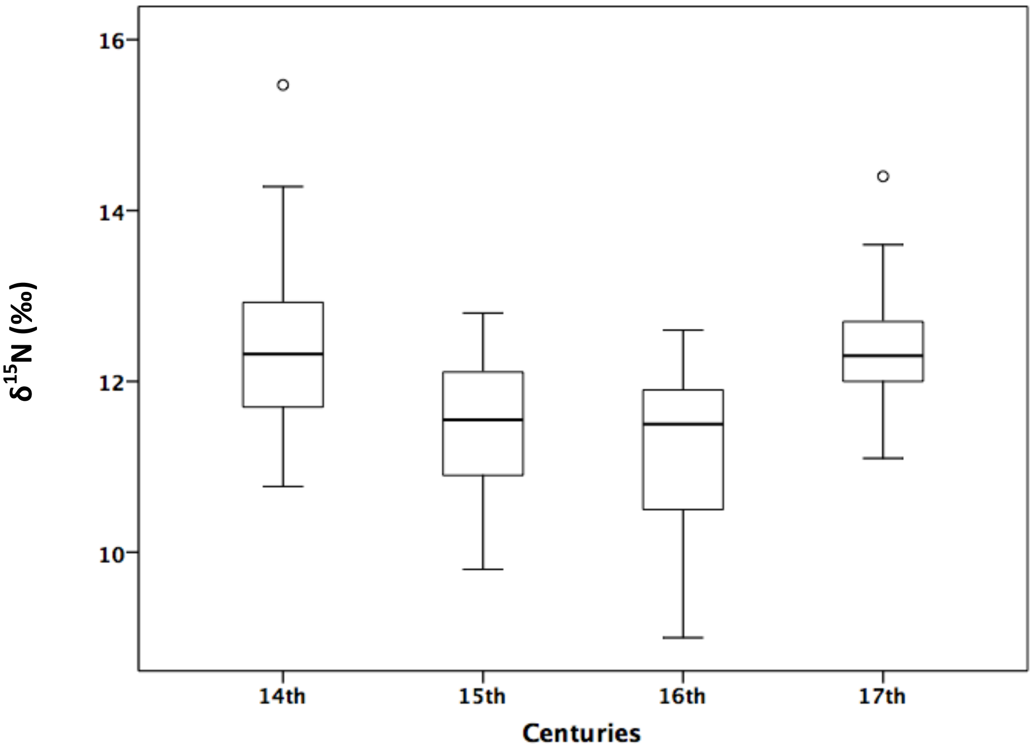
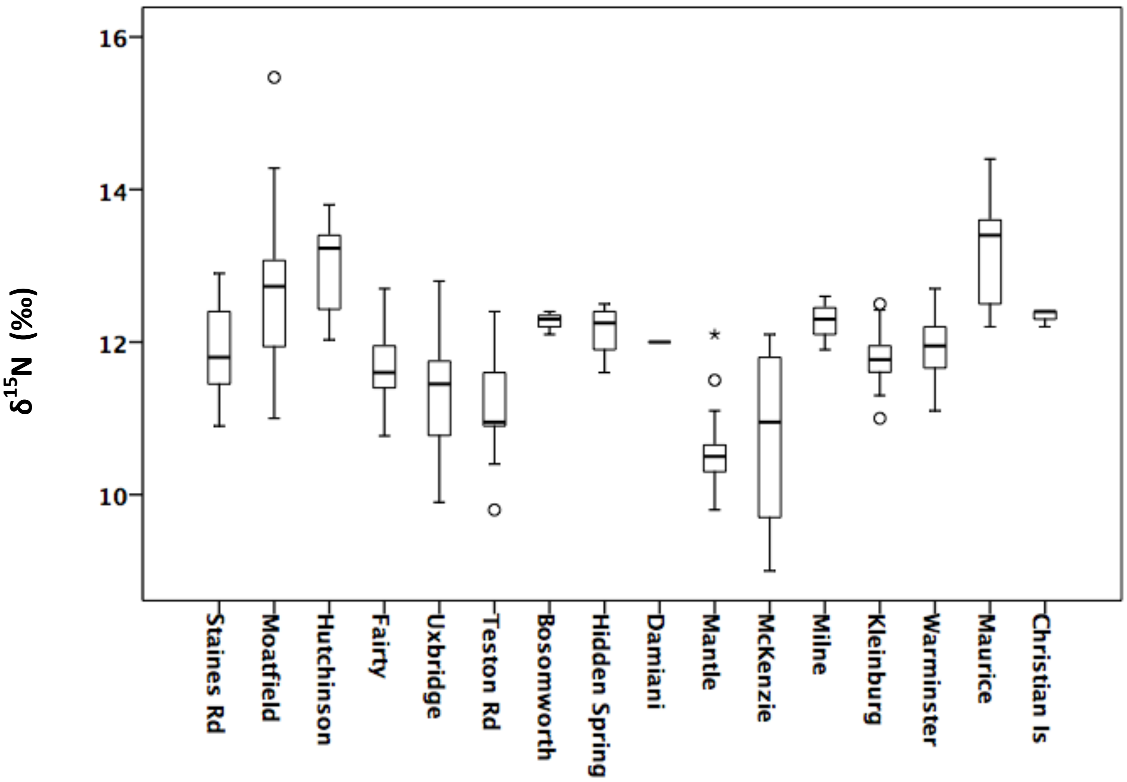
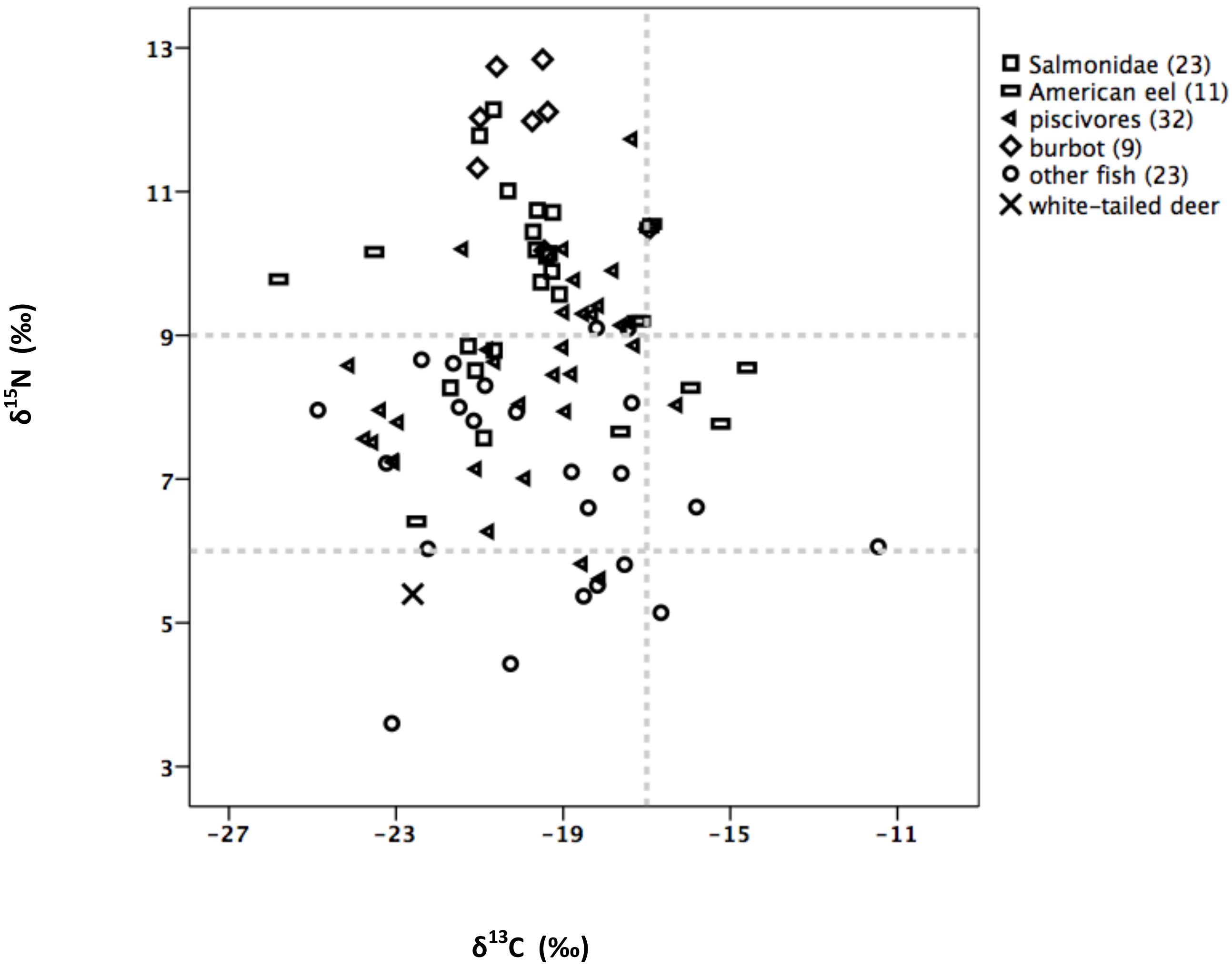


Figure 5



δ15N (‰)
16
14
12
10
Staines Rd
Moatfield
Hutchinson
Fairty
Uxbridge
Teston Rd
Bosomworth
Hidden Spring
Damiani
Mantle
McKenzie
Milne
Kleinburg
Warminster
Maurice
Christian Is

Figure 6


δ15N (‰)
13
11
9
7
5
3
-27
-23
-19
-15
-11
δ13C (‰)
□ Salmonidae (23)
▭ American eel (11)
◀ piscivores (32)
◇ burbot (9)
○ other fish (23)
✕ white-tailed deer

Supplementary Table 1. Isotope values and collagen quality indicators for tooth enamel, dentin and bone samples new to this study. Sites are listed in chronological order, as per Table 2 in the text. All teeth are lower first molars, unless otherwise indicated. Values for dentin from UCT numbers followed by brackets [3] include values that were created from the means of three horizontally oriented samples of tissue from mid-root to the apex.

Site Name & Borden #	Identifier /Tooth, if not M_1	UCT No.	$\delta^{13}C$			$\delta^{15}N$		wt %C		wt % N		C/N	C/N
		Tooth/ Bone	**Enamel**	**Dentine**	**Bone**	**Dentine**	**Bone**	**Dentine**	**Bone**	**Dentine**	**Bone**	**Dentine**	**Bone**
Fairty AlGt-3	cranmand0022 (43)	14138	-2.9	-9.8		12.7		43.0		15.1		3.3	
Fairty AlGt-3	cranmand0010 (817)	14139	-1.6	-10.2		11.4		43.1		15.6		3.2	
Fairty AlGt-3	cranmand0024 (318)	[1]14140	-3.5	-10.7		11.4		42.9		15.3		3.3	
Fairty AlGt-3	cranmand0006 (739)	14141	-3.6	-10.8	-10.6	10.8	10.9	43.8	41.4	15.7	14.7	3.2	3.3
Fairty AlGt-3	cranmand0041 (126)	14142	-8.0	-8.6	-10.5	12	11.9	42.7	43.4	15.3	15.4	3.3	3.3
Fairty AlGt-3	cranmand0027 (301)	14143	-2.4	-11.8		12		43.1		15.6		3.2	
Fairty AlGt-3	cranmand0023 (47)	14144	-3.7	-11.2	-11.4	11.6	12.1	42.7	38.2	15.3	13.3	3.3	3.3
Fairty AlGt-3	cranmand0053 (54)	14145	-2.6	-10.6	-14.2	11.6	10.9	43.3		15.7		3.2	
Fairty AlGt-3	cranmand0038 (52)	14146	-2.5	-10	-10.2	11.8	11.9	45.3	42.3	16.5	15.2	3.2	3.3
Fairty AlGt-3	cranmand0014 (738)	14147	-3.8	-13.4		11.9		39.5		12.6		3.7	
Fairty AlGt-3	cranmand0149 (479)	16045 [3]	-7.3	-10.7		11.6		43.6		14.7		3.5	
				-11.4		11.4		44.2		14.9		3.5	
				-11.5		11.5		43.7		14.8		3.5	
Fairty AlGt-3	cranmand0157 (25)	16046 [3]	-3.9	-10.7	-10	12.3	11.5	41.8	41.1	14.2	13.8	3.4	3.5
				-11.3		12.4		41.5		14.2		3.4	
				-11.5		12.4		41.7		14.4		3.4	
Fairty AlGt-3	cranmand0156 (153)	16047 [3]	-3.8	-10.3	-10.8	11.3	11.5	41.9	40.7	15.3	13.9	3.2	3.4
				-11.2		11.3		37.7		15.3		3.3	
				-11.1		11.0		42.1		15.2		3.2	
Fairty AlGt-3	cranmand0062 (102)	16048 [3]	-4.0	-12.2		10.3		41.91		14.4		3.4	
				-10.9		10.5		41.35		14.0		3.4	
				-10.7		11.6		41.61		14.3		3.4	
Fairty AlGt-3	cranmand0034 (MUI2)	16049 [3]	-2.9	-9.5		11.5		42.9		15.3		3.3	
				-9.5		11.6		43.2		15.4		3.3	
				-9.7		11.8		43.4		15.4		3.3	
Bosomworth BaGv-1	cranmand0003 (BwC2) /Canine	14188	-5.1	-9.7		12.1		45.4		16.5		3.2	
Bosomworth BaGv-1	cranmand0004 (BwH2) /PM_1	14189	-3.4	-12.3		12.4		45.0		16.5		3.2	
Bosomworth BaGv-1	cranmand0001 (BwE2) /M_2	14190	-3	-10.6		12.3		45.3		16.5		3.2	
Uxbridge BbGs-3	cranmand0168 (U3L9S8 162)	[1]14173	-2.9	-11.3	-13.2	9.9	13.8	45.2	39.9	16.6	13.8	3.2	3.4
Uxbridge BbGs-3	cranmand0164 (U2L9S8 369)	14174	-2.3	-10.6		11.1		45.2		16.3		3.2	

Uxbridge BbGs-3	cranmand0085 (U2L9S6 232)	14175	-1.5	-9.9	-11.9	11.7	14.1	44.9	40.6	16.3	14.1	3.2	3.4
Uxbridge BbGs-3	cranmand0063 (U2L5S4 166)	14176	-4.9	-10.8		11.2		45.2		16.0		3.3	
Uxbridge BbGs-3	cranmand0004 (L19S1 87)	14177	-5.3	-10.3		12.2		43.0		15.3		3.3	
Uxbridge BbGs-3	cranmand 0114 (U2L11S5 260)	14178	-3.4	-11.8		11.5		42.7		15.4		3.2	
Uxbridge BbGs-3	cranmand 0125 (U1L12S3 81)	14179	-4.9	-13.4		12.8		42.1		15.1		3.3	
Uxbridge BbGs-3	cranmand0037 (U3L10S1 389)	14180	-3.6	-11.7		11.5		45.0		15.9		3.3	
Uxbridge BbGs-3	cranmand0027 (U3L11S8 406)	14181	-5.1	-10.9		11.8		45.5		16.2		3.3	
Uxbridge BbGs-3	cranmand0007 (L20S3 95)	14182	-1.4	-11.1	-10.4	11.7	15.1	42.4	42.0	15.2	15.1	3.3	3.3
Uxbridge BbGs-3	cranmand0040 (U3 L10 S7 397)	16050 [3]	-1.9	-9.9	-12	10.3	12.1	42.7	37.0	15.6	12.7	3.2	3.4
				-9.6		10.8		42.2		15.4		3.2	
				-9.0		11.1		43.3		15.7		3.2	
Uxbridge BbGs-3	cranmand0109 (U2 L8 S4)	16052 [3]	-1.9	-11.6		11.6		38.3		12.7		3.5	
				-12.0		10.2		39.5		13.6		3.4	
				-11.6		10.6		39.1		13.6		3.3	
Uxbridge BbGs-3	cranmand0069 (U2 L5 S4 A6)	16054 [3]	-2.1	-10.5	-11.8	10.6	11.9	44.4	42.1	15.8	14.7	3.2	3.3
				-10.4		10.6		64.7		23.2		3.2	
				-11.2		11.0		44.3		15.9		3.3	
Uxbridge BbGs-3	cranmand0129 (U1 F2 S2 ind. 2 A79)	16057 [3]	-2.5	-9.6		11.6		38.7		13.9		3.2	
				-10.0		12.3		43.7		15.8		3.2	
				-10.9		12.4		43.0		15.5		3.3	
Uxbridge BbGs-3	cranmand0106 (U2 L8 S4 211)	16058 [3]	-2.2	-10.1	-10.3	11.4	11.6	42.9	34.4	15.0	11.5	3.3	3.5
				-10.7		11.5		38.6		13.4		3.4	
				-9.3		11.3		43.2		14.8		3.4	
Uxbridge BbGs-3	cranmand0022 (East wall 106)	16059 [3]	-3.2	-9.3	-11.7	10.3	15.8	43.9	29.6	15.8	10.8	3.2	3.2
				-10.1		10.5		40.8		14.8		3.2	
				-11.0		10.7		37.8		13.5		3.3	
Milne BcHb-28	cranmand0003 (mm-22 #6) /M_2	14153	-4.2	-10.9		11.9		42.3		14.9		3.3	
Milne BcHb-28	cranmand0001 (mm-4) /M_3	14154	-1.3	-9.9		12.3		42.8		15.3		3.3	
Milne BcHb-28	cranmand0002 (mm-19)	14152	-4.0	-10	-11.2	12.6	15.2	43.0	43.5	15.3	15.2	3.3	3.3

Kleinburg AlGv-1	#2030	14163	-3.3	-11.5	-13	12	12.2	43.1	42.2	15.1	14.6	3.3	3.4
Kleinburg AlGv-1	#190	14164	-2.4	-8.9	-11	11.6	12.3	43.1	42.3	15.4	15.0	3.3	3.3
Kleinburg AlGv-1	18:14 05	14165	-2.9	-10.4	-12.3	12.5	12.7	43.5	43.5	15.5	15.3	3.2	3.3
Kleinburg AlGv-1	#35	14166	-4.1	-9		11.4		42.3		15.3		3.2	
Kleinburg AlGv-1	#213	14167	-4.5	-11.4	-12.5	11.9	11.7	45.5	41.8	16.7	14.8	3.2	3.3
Kleinburg AlGv-1	#2073	14168	-4.3	-10.4	-10.1	11	12.3	45.2	42.7	16.5	15.3	3.2	3.2
Kleinburg AlGv-1	#195	14169	-2.7	-9.8		11.9		45.4		16.6		3.2	
Kleinburg AlGv-1	#31	14170	-3.0	-10.5	-12.2	11.3	11.7	45.6	21.6	16.6	7.8	3.2	3.2
Kleinburg AlGv-1	#2070	14171	-2.5	-10.1		11.8		42.4		15.1		3.3	
Kleinburg AlGv-1	#2130	14172	-3.6	-10.4	-12	12.1	11.9	43.3	31.1	15.6	10.8	3.2	3.3
Kleinburg AlGv-1		16029 [3]	-4.3	-10.2		11.6		40.7		14.8		3.3	
				-10.0		11.5		41.7		14.9		3.3	
				-10.5		11.9		41.8		15.1		3.2	
Kleinburg AlGv-1		16031 [3]	-2.8	-10.2		11.7		37.2		13.6		3.3	
				-9.5		11.3		39.7		14.4		3.2	
				-10.8		11.8		39.7		14.4		3.3	
Kleinburg AlGv-1		16032 [3]	-1.8	-9.2	-11.2	12.4	12.7	42.7	40.3	15.5	14.2	3.2	3.3
				-9.2		12.3		43.5		15.8		3.2	
				-10.5		12.5		43.2		15.5		3.3	
Kleinburg AlGv-1		16033 [3]	-3.8	-10.1		11.9		43.1		15.3		3.3	
				-10.2		11.7		43.5		15.4		3.3	
				-10.5		11.6		43.9		15.5		3.3	
Kleinburg AlGv-1		16036 [3]	-2.8	-10.6	-12.6	11.5	11.7	43.51	32.7	15.6	11.8	3.2	3.2
				-10.6		11.8		44.5		15.7		3.3	
				-10.5		11.9		45.0		15.8		3.3	
Kleinburg AlGv-1		16039 [3]	-2.6	-10.6		11.3		42.4		15.1		3.3	
				-10.1		12.1		42.0		15.2		3.2	
				-9.4		12.1		43.8		15.8		3.2	

Maurice BeHa-1	cranmand0004 (W8 N4 1292)	14183	-0.9	-11.2	-12.2	13.4	14.1	45.1	43.2	16.5	14.4	3.2	3.5
Maurice BeHa-1	cranmand0049 (W10 N4 1121)	14184	-2.6	-10.9	-13.2	13.6	13.3	41.6	42.8	14.5	14.9	3.4	3.4
Maurice BeHa-1	cranmand0046 (W8 N4 2003)	14185	-1.6	-9.3		12.5		42.7		15.4		3.2	
Maurice BeHa-1	cranmand0047 (W8 N4 2004)	14186	-2.8	-10.4		12.2		42.9		15.5		3.2	
Maurice BeHa-1	cranmand0052 (W10 N4 1129)	14187	-3.3	-10.7		14.4		42.8		15.5		3.2	
Maurice BeHa-1	W10_N4_L13	16024	-2.2										
Maurice BeHa-1	cranmand0041 (W10 N4 1133)	16025 [3]	-2.3	-11.7		10.8		48.8		17.1		3.3	
				-11.6		10.9		46.2		15.8		3.4	
				-10.0		11.7		43.5		15.5		3.3	
Maurice BeHa-1	cranmand0054 (W10 N6 712)	16026 [3]	-1.1	-9.6		11.3		52.3		18.6		3.3	
				-9.8		11.7		40.5		14.3		3.3	
				-9.5		12.0		33.1		11.7		3.3	
Warminster BdBv-1	cranmand0006 (90)	14155	-2.8	-10.9		12.2		43.1		14.6		3.4	
Warminster BdBv-1	cranmand0001 (91)	14156	-1	-8.9	-11.5	11.1	12	42.5	43.1	14.4	14.3	3.4	3.5
Warminster BdBv-1	cranmand0021 (114)	14157	-3	-10.5	-12.6	12.7	12.3	43.1	41.9	15.5	14.2	3.2	3.4
Warminster BdBv-1	no provenience	14158 [3]	-1.3	-10.6		11.7						3.3	
				-10.6		11.7		42.5			14.5	3.4	
				-11.2		12.4		42.5			14.1	3.5	
Warminster BdBv-1	no provenience	14159 [3]	-2.5	-11.4		12.2		43.1		14.6		3.3	
				-10.1		12.2		42.5		15.0		3.4	
				-9.6		11.8		42.3		15.1	15.0	3.3	
Warminster BdBv-1	cranmand0013 (115)	16021 [3]	-2.8	-11.6	-11.5	11.8	11.3	42.3	41.3	15.0	14.2	3.3	2.9
				-12.1		11.8		41.9		14.4		3.4	
				-11.5		11.4		42.5		14.4		3.4	
Christian Is BeHb-3	cranmand 0001(TPIF8B3)/M3	14160	-2.3	-9.8		12.2		42.2		15.2		3.3	
Christian Is BeHb-3	cranmand 002(68W1, 70WIB20)/M_2	14161	-1.8	-8.7		12.4		42.1		15.3		3.2	
Christian Is BeHb-3	maxillary, no provenience/M_2	14162	-2.1	-8.4	-10.8	12.4	11.4	42.4	45.1	15.4	15.7	3.2	3.4

[1] subsequently used for ^{14}C date.

TABLE Suppl. 2: Carbon and nitrogen isotope values from bone collagen of likely food fish; individual values.

Grouping	**Taxon (common name)**	**$\delta^{13}C$ ‰**	**$\delta^{15}N$ ‰**	**C:N**	**%C**	**%N**	**Site (Borden number)**	**Source***	**Catalogue #**
Catadromous	*Anguilla rostrata* (American eel)	−15.2	7.8	3.2	41.4	14.9	Joseph Picard (AlGs-376)	This study	UCT15997/ ASI11923
	Anguilla rostrata (American eel)	−23.5	10.2	3.3	38.7	13.8	Joseph Picard (AlGs-376)	This study	UCT15998/ ASI2080
	Anguilla rostrata (American eel)	−14.6	8.6	3.2	42.3	15.7	Joseph Picard (AlGs-376)	This study	UCT15999/ ASI9477
	Anguilla rostrata (American eel)	−17.2	9.2	3.2	42.4	15.6	Joseph Picard (AlGs-376)	This study	UCT16000/ ASI11021
	Anguilla rostrata (American eel)	−25.8	9.8	3.2	41.7	15.2	Joseph Picard (AlGs-376)	This study	UCT16001/ ASI9138
	Anguilla rostrata (American eel)	−22.5	6.4	3.2	41.6	15.0	Joseph Picard (AlGs-376)	This study	UCT16002/ ASI12246
	Anguilla rostrata (American eel)	−15.9	8.3	3.2	39.0	14.1	Joseph Picard (AlGs-376)	This study	UCT16086/ ASI11021
	Anguilla rostrata (American eel)	−17.1	9.2				Moatfield	(van der Merwe et al. 2003)*	61
	Anguilla rostrata (American eel)	−16.9	10.5				Moatfield		4003
	Anguilla rostrata (American eel)	−16.9	10.5				Moatfield		4006
	Anguilla rostrata (American eel)	−16.2	8.1				Grandview		
Salmonidae	Salmonidae (2)	−19.4	10.1				Wallace	(Katzenberg 2006)	
	Salmo salar (Atlantic salmon)	−19.7	10.4				Moatfield		11
	Salmo salar (Atlantic salmon)	−19.2	10.7				Moatfield		21
	Salmo salar (Atlantic salmon)	−19.6	10.2				Moatfield		4020
	Salmo salar (Atlantic salmon)	−19.1	9.6				Grandview		
	Salmo salar (Atlantic salmon)	−19.6	10.7				Grandview		
	Salmo salar (Atlantic salmon)	−19.3	9.9				Grandview		
	Salmo salar (Atlantic salmon)	−19.3	10.1				Grandview		
	Salvelinus namaycush (Lake trout)	−19.5	9.7				Moatfield		1458
	Salvelinus namaycush (Lake trout)	−20.7	12.1				Moatfield		1477
	Salvelinus namaycush (Lake trout)	−20.3	11.0				Moatfield		4018
	Salvelinus namaycush (Lake trout)	−21.0	11.8				Grandview		
	Coregonus clupeaformis (Lake whitefish)	−20.6	8.8				Grandview		

	Coregonus clupeaformis (Lake whitefish)	−21.7	8.3				Moatfield		
	Coregonus clupeaformis (Lake whitefish)	−21.3	8.8				Moatfield		
	Coregonus clupeaformis (Lake whitefish)	−20.9	7.6				Moatfield		
	Coregonus clupeaformis (Lake whitefish)	−21.1	8.5				Moatfield		
Nominally piscivorous	*Amia calva* (Bowfin)	−23.4	8.0				Moatfield		
	Amia calva (Bowfin)	−23.7	7.6				Moatfield		
	Ameiurus nebulosus (Brown bullhead)	−21.1	7.1				Moatfield		
	Ameiurus nebulosus (Brown bullhead)	−23.0	7.2				Moatfield		
	Ameiurus nebulosus (Brown bullhead)	−18.5	5.8				Moatfield		
	Ameiurus nebulosus (Brown bullhead)	−19.9	7.0				Moatfield		
	Ameiurus nebulosus (Brown bullhead)	−20.8	6.3				Moatfield		
	Ameiurus nebulosus (Brown bullhead)	−18.1	5.6				Moatfield		
	Esox americanus (Grass pickerel)	−23.6	7.5				Parsons		
	Esox americanus (Grass pickerel)	−22.9	7.8				Parsons		
	Esox lucius (Northern pike)	−20.8	8.8				Kelly-Campbell	(Katzenberg 2006)	
	Esox lucius (Northern pike)	−18.2	9.4				Moatfield		
	Esox lucius (Northern pike)	−20.6	8.6				Moatfield		
	Esox lucius (Northern pike)	−18.3	9.3				Moatfield		
	Esox lucius (Northern pike)	−18.7	9.8				Moatfield		
	Micropterus dolomieu (Smallmouth bass)	−17.3	8.9				Moatfield		
	Micropterus dolomieu (Smallmouth bass)	−17.6	9.1				Moatfield		
	Micropterus salmoides (Largemouth bass)	−18.8	8.5	3.41	25.3	8.6	Joseph Picard (AlGs-376)	This study	UCT16005/ ASI7827
	Micropterus salmoides (Largemouth bass)	−20.0	8.0	3.35	39.4	13.7	Joseph Picard (AlGs-376)	This study	UCT16007/ ASI11929
	Micropterus salmoides (Largemouth bass)	−19.2	8.4	3.29	44.8	15.9	Joseph Picard (AlGs-376)	This study	UCT16008/ ASI10123
	Micropterus salmoides (Largemouth bass)	−23.1	7.2	3.26	42.3	15.1	Joseph Picard (AlGs-376)	This study	UCT16009/ ASI2195
	Micropterus salmoides (Largemouth bass)	−18.9	7.9	3.29	42.1	14.9	Joseph Picard (AlGs-376)	This study	UCT16010/ ASI10303
	Perca flavescens (Yellow perch)	−19.0	10.2				Ball	(Katzenberg 2006)	
	Perca flavescens (Yellow perch)	−21.4	10.2				Draper	(Katzenberg 2006)	
	Perca flavescens (Yellow perch)	−17.8	9.9				Kelly-Campbell	(Katzenberg 2006)	
	Perca flavescens (Yellow perch)	−19.0	8.8				Moatfield		

	Perca flavescens (Yellow perch)	−24.1	8.6				Moatfield		
	Perca flavescens (Yellow perch)	−19.0	9.3				Moatfield		
	Perca flavescens (Yellow perch)	−17.4	9.2				Moatfield		
	Perca flavescens (Yellow perch)	−18.5	9.3				Moatfield		
	Stizostedion sp. (Walleye or sauger)	−17.4	11.7				Moatfield		
	Sander vitreus (Walleye)	−16.3	8.0	3.24	39.7	14.3	Joseph Picard (AlGs-376)	This study	UCT16003/ ASI12073
Oily liver	*Lota lota* (Burbot)	−21.0	12.0				Parsons		
	Lota lota (Burbot)	−19.4	12.1	3.48	16.2	5.4	Joseph Picard (AlGs-376)	This study	UCT16011/ ASI2219
	Lota lota (Burbot)	−20.2	14.0	3.43	36.5	12.4	Joseph Picard (AlGs-376)	This study	UCT16013/ ASI12195
	Lota lota (Burbot)	−21.1	11.3	3.44	31.3	10.6	Joseph Picard (AlGs-376)	This study	UCT16014/ ASI7875
	Lota lota (Burbot)	−16.9	10.5	3.31	35.3	12.4	Joseph Picard (AlGs-376)	This study	UCT16015/ ASI1718
	Lota lota (Burbot)	−20.6	12.7	3.51	36.2	12.1	Joseph Picard (AlGs-376)	This study	UCT16016/ ASI2174
	Lota lota (Burbot)	−19.4	10.2	3.28	36.9	13.1	Joseph Picard (AlGs-376)	This study	UCT16018/ ASI5593
	Lota lota (Burbot)	−19.5	12.8	3.35	37.6	13.1	Joseph Picard (AlGs-376)	This study	UCT16019/ ASI12415
	Lota lota (Burbot)	−19.7	12.0	3.42	38.4	13.1	Joseph Picard (AlGs-376)	This study	UCT16085/ ASI5593
Non-piscivorous fish	*Catostomus* sp. (Sucker)	−18.8	7.1				Ball	(Katzenberg 2006)	
	Catostomus sp. (Sucker)	−18.4	6.6				Draper	(Katzenberg 2006)	
	Catostomus sp. (Sucker)	−23.1	3.6				Kelly-Campbell	(Katzenberg 2006)	
	Catostomus catostomus (Longnose sucker)	−17.5	5.8				Parsons		
	Catostomus commersoni (White sucker)	−22.2	6.0				Moatfield		
	Catostomus commersoni (White sucker)	−18.5	5.4				Moatfield		
	Catostomus commersoni (White sucker)	−18.2	5.5				Moatfield		
	Catostomus commersoni (White sucker)	−16.7	5.1				Moatfield		
	Ictalurus cf. *punctatus* (probable Channel catfish)	−17.4	8.1				Parsons		

	Ictalurus cf. *punctatus* (probable Channel catfish)	−17.4	9.1				Parsons		
	(Sunfish)	−18.2	9.1				Ball	(Katzenberg 2006)	
	Ambloplites rupestris (Rock bass)	−24.9	8.0				Parsons		
	Ambloplites rupestris (Rock bass)	−20.9	8.3				Moatfield		
	Ambloplites rupestris (Rock bass)	−21.6	8.6				Moatfield		
	Ambloplites rupestris (Rock bass)	−21.1	7.8				Moatfield		
	Ambloplites rupestris (Rock bass)	−22.4	8.7				Moatfield		
	Lepomis gibbosus (Pumpkinseed)	−15.8	6.6				Moatfield		
	Lepomis gibbosus (Pumpkinseed)	−23.2	7.2				Moatfield		
	Lepomis gibbosus (Pumpkinseed)	−17.6	7.1				Moatfield		
	Lepomis gibbosus (Pumpkinseed)	−20.3	4.4				Moatfield		
	Pomoxis cf. *nigromaculatus* (crappy, probably Black crappy)	−20.1	7.9				Moatfield		
	Pomoxis cf. *nigromaculatus* (crappy, probably Black crappy)	−21.5	8.0				Moatfield		
	Aplodinotus grunniens (Freshwater drum)	−11.5	6.1				Parsons		

* Unless otherwise indicated, values are from van der Merwe, et al., 2003.

Katzenberg MA. 2006. Prehistoric maize in southern Ontario: Contributions from stable isotope studies. In: Staller JE, Tykot RH, and Benz BF, editors. Histories of maize : multidisciplinary approaches to the prehistory, linguistics, biogeography, domestication, and evolution of maize. Amsterdam: Elsevier Academic Press. p 263-273.

van der Merwe NJ, Pfeiffer S, Williamson RF, and Thomas SC. 2003. Isotopic analysis and the diet of the Moatfield community. In: Willamson RF, and Pfeiffer S, editors. Bones of the Ancestors: The Archaeology and Osteobiography of the Moatfield Ossuary. Ottawa, Ontario: Canadian Museum of Civilization. p 205-222.