REPORT

ISOTOPIC ANALYSES REVEAL GEOGRAPHICAL AND SOCIOECONOMIC PATTERNS IN HISTORICAL DOMESTIC ANIMAL TRADE BETWEEN PREDOMINANTLY WHEAT- AND MAIZE-GROWING AGRICULTURAL REGIONS IN EASTERN NORTH AMERICA

Eric Guiry, Paul Szpak, and Michael P. Richards

Historical zooarchaeologists have made significant contributions to key questions about the social, economic, and nutritional dimensions of domestic animal use in North American colonial contexts; however, techniques commonly employed in faunal analyses do not offer a means of assessing many important aspects of how animals were husbanded and traded. We apply isotopic analyses to faunal remains from archaeological sites to assess the social and economic importance of meat trade and consumption of local and foreign animal products in northeastern North America. Stable carbon and nitrogen isotope analyses of 310 cattle and pigs from 18 rural and urban archaeological sites in Upper Canada (present-day southern Ontario, Canada; ca. A.D. 1790–1890) are compared with livestock from contemporary American sources to quantify the importance of meat from different origins at rural and higher- and lower-status urban contexts. Results show significant differences between urban and rural households in the consumption of local animals and meat products acquired through long-distance trade. A striking pattern in urban contexts provides new evidence for the social significance of meat origins in historical Upper Canada and highlights the potential for isotopic approaches to reveal otherwise-hidden evidence for social and economic roles of animals in North American archaeology.

Les zooarchéologues travaillant sur la période historique ont apporté d'importantes contributions à des questions-clés sur les dimensions sociales, économiques et nutritionnelles de l'utilisation des animaux domestiques dans les sites coloniaux d'Amérique du Nord. Cependant, les techniques couramment utilisées dans les analyses fauniques ne permettent pas d'aborder plusieurs aspects concernant l'élevage et l'échange d'animaux. Nous appliquons des analyses isotopiques sur les restes fauniques provenant de sites archéologiques pour évaluer l'importance sociale et économique du commerce de la viande et de la consommation de produits animaliers d'origine locale et étrangère dans le Nord-Est américain. L'analyse des isotopes stables de carbone et d'azote sur 310 bovins et porcs provenant de 18 sites archéologiques ruraux et urbains dans le Haut-Canada (aujourd'hui le sud de l'Ontario, Canada, entre 1790–1890 A.D.) sont comparées avec le bétail provenant de sources américaines contemporaines afin de quantifier l'importance de la viande de différentes origines dans les sites ruraux et dans les contextes urbains représentant des occupations de statut élevé et moins élevé. Les résultats démontrent que des différences significatives existent entre les maisonnées urbaines et rurales dans la consommation d'animaux d'origine locale et les viandes acquises par le commerce à longue distance. Une différence marquée dans les contextes urbains fournit de nouvelles informations quant à l'importance sociale des origines de la viande dans le Haut-Canada durant la période historique et souligne le potentiel des approches isotopiques pour révéler des informations autrement cachées sur les rôles sociaux et économiques des animaux en archéologie nord-américaine.

Stable isotope analyses of ancient human and animal tissues hold substantial, yet under-recognized potential to provide archaeological insights into historical processes. This potential is particularly significant in the context of the worldwide expansion of European activities and industrialization between A.D. 1500 and 1900 that fostered profound global

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environmental, economic, and social changes that shape our contemporary world. While many historical and post-medieval archaeological studies have used stable isotope analyses of human remains to document changing diet, mobility, and residency patterns during this period (e.g., Beaumont et al. 2013; Katzenberg et al. 2002; Sparks 2012; Ubelaker and Owsley 2003), materials from the animals that were directly involved with, and in some cases the focus of, socio-economic and technological innovations have received comparatively little attention (Guiry et al. 2014, 2015, 2016; Klippel 2001; Reitsema et al. 2013; Tourigny et al. 2016). Isotopic patterns associated with a wide range of past events are recorded in different ways by animal species with divergent behavioral and ecological niches, and this potential breadth of isotopic perspectives can be used to explore past subsistence, mobility, and environmental changes that may not be recorded in human tissues (Guiry 2013; Guiry and Gaulton 2016; Szpak et al. 2012, 2013). The archaeological record is a particularly rich source of faunal remains and is well positioned to provide novel contexts in which to approach both long-standing and emerging questions about shifting historical economic practices, social processes, and human impacts on the environment (Guiry et al. 2012). In this paper, we explore the utility of faunal stable isotope values as a record of large-scale patterns in agriculture and socioeconomic change in recent centuries in eastern North America.

Agricultural adaptability was often key to the success of colonial endeavors, and, therefore, subsistence innovation and flexibility were necessarily a vital interface between Europeans and their New World environments (e.g., Dugmore et al. 2007, 2012). Many of the earliest experiments with European New World colonization occurred along the western margins of the North Atlantic, and these have become the focal point for archaeological and historical research seeking to understand the dynamic interplay between European attempts to transplant their culturally familiar agricultural systems, on the one hand, and adoption of New World resources, on the other (e.g., Anderson 2002; Reitz and Waselkov 2015). In North America, a change in emphasis from traditional European crops, such as wheat, to New World crops, such as maize, is thought to be one of the most economically and environmentally important European agricultural adaptations (Staller et al. 2006), one that underpins significant differences in isotopic composition between European and North American populations to this day (Nardoto et al. 2006; Wagenmakers et al. 1993). However, historical documentation suggests that the earliest European settlers in some areas did not embrace maize agriculture (e.g., McInnis 1984). In particular, settlers of what became York (established 1793, later changed to Toronto in 1834; hereafter Toronto) and its surrounding environs in Upper Canada (established 1791, later changed to Canada West, 1841–1867, and now Ontario, 1867–present) between the 1790s and 1890s developed a wheat-based agriculture regime (e.g., Lewis 1975; McCalla 1978), following a history of at least 1,500 years of maize-dominated cultivation by indigenous peoples in the area (e.g., Crawford 1997; Katzenberg 2006; Katzenberg et al. 1995; Schwarcz et al. 1985).

Here, we undertake the first large-scale isotopic study of historical archaeological domestic animals in North America to explore economic and especially social practices associated with major agricultural shifts between culturally (Indigenous, Canadian, and American) and geographically (Upper Canada and the United States) distinct groups in the eastern Great Lakes basin (Figure 1). We compare bone collagen stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope values from 310 late eighteenth-century and nineteenth-century (1790s to 1890s) pigs and cattle from urban sites associated with different social classes in Toronto as well as sites in its rural environs to test hypotheses about the potential for animal-based dietary and mobility information to verify historical accounts and address new socio-economic questions. We argue that (1) different agricultural systems founded on wheat, particularly in Upper Canada, and maize would leave a geographically patterned isotopic record in the remains of livestock; and (2) this distinction could be used to explore (a) the extent to which maize agriculture was utilized or discarded by settling Europeans in Upper Canada, and (b) the economic (trade) and social (i.e.,

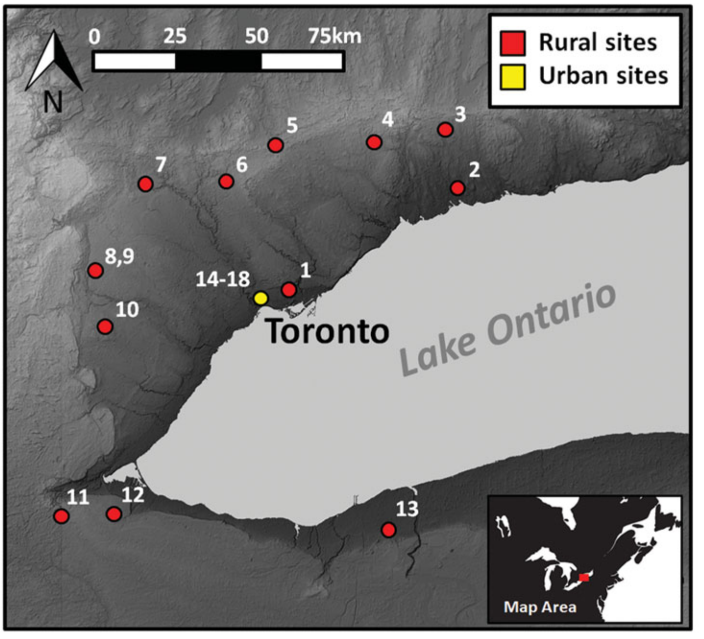

Figure 1. Map showing locations of Upper Canada historical sites considered in this study. Sites are labeled as follows: (1) Ashbridge (AjGt-1), (2) Trull (AlGq-67), (3) CH36 (AlGr-315), (4) Graham (AjGs-370), (5) Lewis (AlGu-365), (6) Edgar (AlGu-196), (7) Hall (AlGw-68), (8) Dolson (AkGx-80), (9) Landmart (AkGw-474), (10) Edwards (AjGw-470), (11) Henry (AhGw-123), (12) Yeager, (13) Loretto (AgGs-326), (14) Bell (AjGu-68), (15) Bishop's Block (AjGu-49), (16) Dollery (AjGu-81), (17) 327–333 Queen St. (AjGu-63), (18) Toronto General Hospital (AjGu-51). (Color online)

values assigned to fresh vs. salt meat) roles of animals and their products during the evolution of North American trading networks.

Isotope Background

Stable isotope analyses are based on the premise that the carbon (C) and nitrogen (N) atoms incorporated to form biological tissues are taken directly from foods eaten by consumers. Some foods have distinctive isotopic compositions, and it is therefore possible to distinguish between certain dietary regimes based on the stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope values of animal tissues, in this case, archaeological bone collagen (for review, see Lee-Thorp 2008). Relatively little change occurs in δ^{13}C values as C atoms are passed up successive trophic levels in a food chain; for this reason, broad differences between plants using C_3 (lower δ^{13}C values) and C_4 (higher δ^{13}C values) photosynthesis can be recorded in the tissues of humans and animals that consume C that is predominantly taken from one or the other (DeNiro and Epstein 1978; O'Leary 1988). In this study, we are interested in exploring the importance of maize, a New World C_4 cultigen, relative to traditional European crops, such as wheat, oats, and barley, as well as locally available natural resources that are predominantly C_3 plants. Other factors, such as consumption of some kinds of aquatic foods, can also produce higher δ^{13}C values (Chisholm et al. 1982), but these are less relevant in our study context, which is focused on a terrestrial temperate region.

The δ^{15}N values of consumer tissues become significantly higher, increasing by 3–4‰, as N is passed between trophic levels (DeNiro and Epstein 1981). This stepwise enrichment of ^{15}N in consumer tissues can be a useful indicator of relative carnivory and of consumption of upper trophic level marine foods (Post 2002). A variety of environmental factors, however, can also create variability in δ^{15}N values (for review, see Szpak 2014) in terrestrial and aquatic ecosystems, and for this reason, baseline information from herbivore δ^{15}N values is necessary for interpreting trophic level.

Research Design

Research Questions

Historical analyses suggest that maize agriculture, though long established in the region by indigenous communities at the time of European settlement (Katzenberg 2006), was not embraced by settlers, who preferred C_3 plants, such as wheat, oats, and peas (McInnis 1982, 1984, 1987). In the same period in the United States, however, maize continued to be widely cultivated and maintained an important role as a source of animal feed, especially for fattening livestock, such as swine and cattle (e.g., Pate 2005; Walsh 1977). While farms in Upper Canada usually raised some livestock, particularly pigs, for market sale to generate income (e.g., Lewis 2001; Lewis and Urquhart 1999; McCalla 1985a, b), their southern counterparts in the United States produced larger quantities for commercial sale, and, with coinciding advances in canal and rail transport systems, much of this surplus was traded north to urban centers like Toronto, in the form of barreled salt pork and beef (Clemen 1923; McCalla 1979; McInnis 1982; Pate 2005; Skaggs 1986; Walsh 1977, 1982). In the temperate terrestrial environment of Upper Canada, δ^{13}C values from domestic herbivores and omnivores should provide a means of identifying animals raised locally (i.e., lower δ^{13}C values from C_3 plant consumption) and animals imported from the United States (i.e., higher δ^{13}C values reflecting some C_4 plant intake). In this context, we compare δ^{13}C and δ^{15}N values from cattle (n = 144) and pigs (n = 124) collected from urban sites (n = 5) in Toronto and rural sites (n = 13) in the region (Figure 1) to assess the extent to which European settlers had either integrated or disused maize as a crop staple. In this context, we also tested two related hypotheses:

(1) If historical analyses (e.g., McInnis 1984) indicating that settlers preferred to cultivate wheat over maize as their agricultural staple are correct, then there will be a lower proportion of C_4-fed animals identified in Upper Canada rural contexts, where animals were locally produced, relative to their urban counterparts in Toronto, where there was more access to imported animal products from the United States.

(2) If there was a historical preference for fresh, as opposed to preserved, meats, then, within urban contexts, C_4-fed animals that were likely imported as salted meat from the United States would be found in lower frequency at higher-status sites relative to lower-status sites due to greater access to market goods for wealthier households.

Sampling Strategy

We focus on cattle and pigs because these species were the most important domesticates for settlers from economic and dietary perspectives (McInnis 1987; Reitz and Waselkov 2015) and were also highly visible and symbolically valued animals within a European social framework (Anderson 2002; Landon 2009). Both species were preferentially fattened on maize (when available) and used to produce barreled salt meat for long-distance trade (Pate 2005; Walsh 1977). Samples were selected based on minimum number of individual estimates per species for archaeologically distinct contexts. For higher-status sites (urban middle and upper class), samples were collected from domestic refuse associated with a series of seven homes at two sites in relatively wealthy neighborhoods (ASI 2012a, b). Lower-status (working- and lower-class) sites are represented by samples from two houses in poorer areas as well as a hospital (ASI 2014a, b; HHI 2011). As a baseline for locally raised livestock, we collected samples from 13 roughly contemporaneous rural agricultural homestead sites distributed mostly within 25 km around the outskirts of Toronto, but including sites over a 200 km section of Lake Ontario's north shore (ASI 2006, 2007a, b, 2012a, b, 2014a, b, 2017 a, b; GAL 2014a, b, c; Latta 2000; TRCA 2005, 2012, 2013). For a comparison with contemporary livestock from the United States, we sourced baseline values from the literature (Reitsema et al. 2015), which come from six urban eighteenth- to nineteenth-century sites in Charleston, South Carolina (n = 27), and we also analyzed bones recovered from salt meat barrels on the steamboat *Heroine* (n = 11), which was wrecked on the Red River in 1838 while transporting cargo from Cincinnati, Ohio, to Fort

Towson, Oklahoma (Crisman et al. 2013). These bones are mainly from intact salt-pork barrels packed by Alfred S. Reeder Packers of Cincinnati in 1837 (Brophy and Crisman 2013) and are representative of a key United States livestock region that produced salt meats that could have been traded north to Upper and Lower Canada via the Miami–Erie canal during the nineteenth century (Clemen 1923; Pate 2005; Skaggs 1986; Walsh 1977, 1982).

Methods

Following a modified Longin protocol (Beaumont et al. 2010; Longin 1971), cleaned animal bone samples (100–400 mg) were soaked in 0.5 M hydrochloric acid (HCl), with periodic solution changes until the sample was demineralized (usually 1–3 weeks). Samples were then rinsed to neutrality in pure water and treated several times with 0.1 M sodium hydroxide (NaOH) in an ultrasonic bath (15-minute intervals) until visible reactions ceased (i.e., the solution remained clear; usually within one hour). Samples were again rinsed to neutrality with pure water and then refluxed in a 10^{-3} M HCl (pH ~3) solution at 75°C for 48 hours. The soluble collagen solution was then further purified using 45−90 μm mesh filters[1] and 30 kDa molecular weight cut-off (MWCO) filters[2] to remove larger particulates and low molecular weight contaminants, respectively (Brown et al. 1988). The solutions containing the > 30 kDa fraction were then frozen for 24 hours and lyophilized for 48 hours.

Stable isotope analyses were performed in duplicate on 0.5 mg samples of collagen using an Elementar vario MICRO cube elemental analyzer coupled to an Isoprime isotope ratio mass spectrometer in continuous flow mode. Carbon and nitrogen isotopic compositions were calibrated relative to VPDB and AIR using a two-point calibration curve anchored by USGS40 and USGS41 (Qi et al. 2003). Measurement accuracy was monitored using a suite of internal check standards with the following long-term δ-values: methionine (MET, δ^{13}C −28.62 ± 0.11 and δ^{15}N −5.03 ± 0.15), bovine liver (NIST 1577c, δ^{13}C −17.52 ± 0.09 and δ^{15}N +8.21 ± 0.33), seal bone collagen (SUBC−1, δ^{13}C −13.74 ± 0.18, δ^{15}N +17.40 ± 0.35), caribou bone collagen (SRM−1, δ^{13}C −19.33 ± 0.13 and δ^{15}N +1.81 ± 0.12), and walrus bone collagen (SRM−2, δ^{13}C −14.72 ± 0.14 and δ^{15}N +15.59 ± 0.10). The average absolute difference between the observed and known δ-values for all of the check standards (reproducibility or accuracy) was 0.04‰ for δ^{13}C and 0.06‰ for δ^{15}N. The repeatability (precision) of the measurements on all of the check and calibration standards was ± 0.13‰ for δ^{13}C and ± 0.14‰ for δ^{15}N. Most samples (292/310) were analyzed in duplicate. Any samples that were not analyzed in duplicate did not produce sufficient collagen for a second analysis. The average difference between duplicate sample pairs was 0.09‰ for δ^{13}C and 0.13‰ for δ^{15}N. The overall analytical error for all analyzed samples was calculated to be ± 0.14‰ for δ^{13}C and ± 0.16‰ for δ^{15}N. Collagen integrity was assessed using elemental C and N concentrations as well as C to N ratios (Ambrose 1990). For statistical analyses, we used a *K*-means cluster analysis (Hartigan and Wong 1979) of δ^{13}C values for pigs from Upper Canada to aggregate C_3- and C_4-fed group members. The cluster analysis was performed using IBM SPSS Statistics for Mac OS X (IBM_Corp 2014). Cattle and pig dietary contributions from C_3 and C_4 plants were estimated using a single-isotope mixing model in the SIAR (Stable Isotope Analyses in R) package (Parnell et al. 2010) in R 3.0.3 for Mac OS X (R Core Development Team 2007). Parameters for C_3 and C_4 input were set at −26.0 ± 2.0‰ and −12.0 ± 1.0‰, respectively. The trophic enrichment factor for collagen was set at +3.7 ± 1.6‰ (Szpak et al. 2012). Carbon concentrations in C_3 and C_4 plants were assumed to be the same.

Results

Stable isotope and elemental concentration data are presented in full (Supplemental Tables 1 and 2) and in summary (Figures 2 and 3). Collagen integrity indicators vary, with most samples (90 percent) producing values in the acceptable range for C/N (2.9–3.6) and elemental C (> 18 percent) and N (> 6 percent) concentrations (Ambrose 1990). Figure 2 shows that cattle at rural sites (n = 81) produced no evidence for C_4 dietary inputs (C_4 contribution:

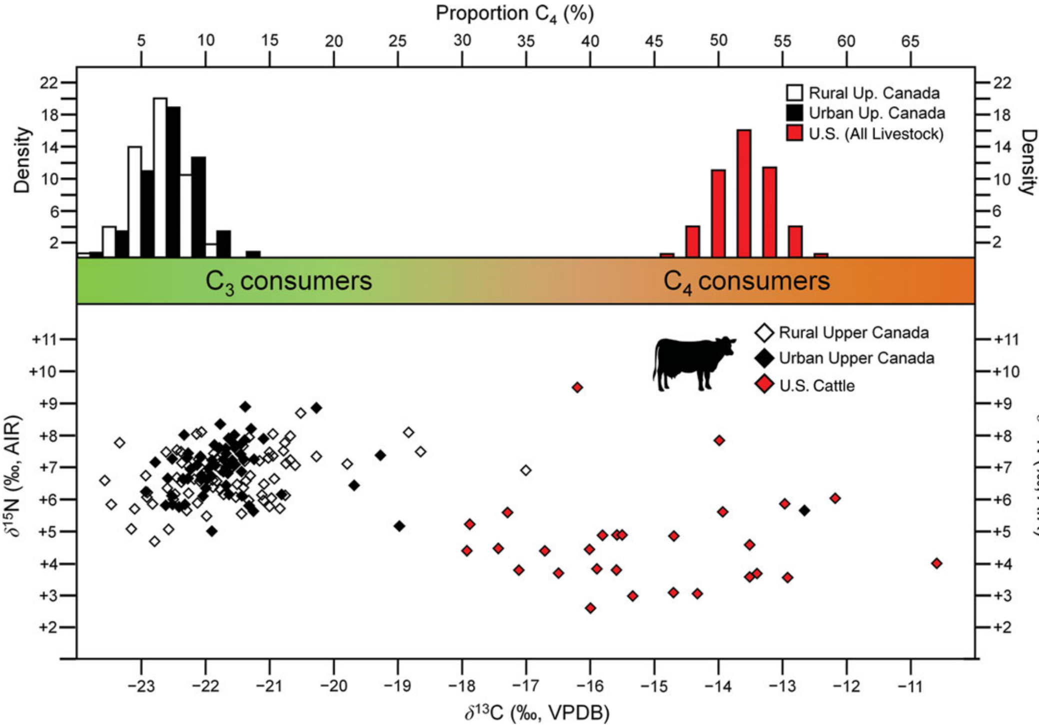

Figure 2. Bottom panel: bivariate plot of δ^{13}C and δ^{15}N values for cattle with comparative eastern U.S. data from published literature (Reitsema et al. 2015). Top panel: SIAR (Parnell et al. 2010) density histograms showing percent dietary contributions from C_4 plants for different urban and rural cattle groups from Upper Canada alongside contemporary livestock (combined pigs and cattle) from United States sites, including animals from the steamboat *Heroine* and from literature (Reitsema et al. 2015). (Color online)

3–10 percent, 95 percent credibility interval) and had uniformly low δ^{13}C values, averaging −21.6 ± 1.1‰, and δ^{15}N values averaging +6.7 ± 0.8‰. Pigs from rural sites ($n = 65$) had similarly low δ^{13}C values, averaging −21.2 ± 0.9‰, and δ^{15}N values averaging +6.9 ± 1.6‰, indicating that they also had no significant maize-based dietary inputs (C_4 contribution: 7–15 percent, 95 percent credibility interval). All pigs from the steamboat *Heroine* (n = 8), on the other hand, show clear evidence for significant C_4 (probably maize) dietary inputs (C_4 contribution: 39–62 percent, 95 percent credibility interval) with higher δ^{13}C values, averaging −14.7 ± 2.9‰, and with δ^{15}N values averaging +6.5 ± 1.1‰. Only two cattle and one horse were analyzed from this site, but, combined with published values of cattle from several historic contexts in Charleston, South Carolina (Reitsema et al. 2015), these also produced δ^{13}C ($n = 30$; average = −15.1 ± 1.7‰) and δ^{15}N ($n = 30$; average = +4.5 ± 1.4‰) values, indicating a high reliance on C_4 plants (C_4 contribution: 48–57 percent, 95 percent credibility interval; Figure 2). This difference between livestock from rural Upper Canada and Cincinnati (the largest pork producer in North America at this time; Pate 2005), with lower and higher δ^{13}C values, respectively, supports the premise that C_4 maize dietary input can be a useful marker for livestock origin in C_3 wheat-dominated Upper Canada.

Relative to rural sites, pigs ($n = 59$) at urban sites produced a much wider range of δ^{13}C values, averaging −20.2 ± 2.5‰ (range = −22.9 to −11.4‰) but had similar δ^{15}N values, averaging +6.9 ± 1.6‰. This variability reflects the presence of a significantly different group of pigs (n = 11; K-means cluster analysis) with higher δ^{13}C values (average = −15.5 ± 2.0‰; range = −18.4 to −11.4‰) that consumed between 46 and 64 percent C_4 foods (95 percent credibility interval; Figure 3), which are primarily localized to a series of higher-status homes (AjGu-49) in a relatively affluent area. Urban cattle (n = 63),

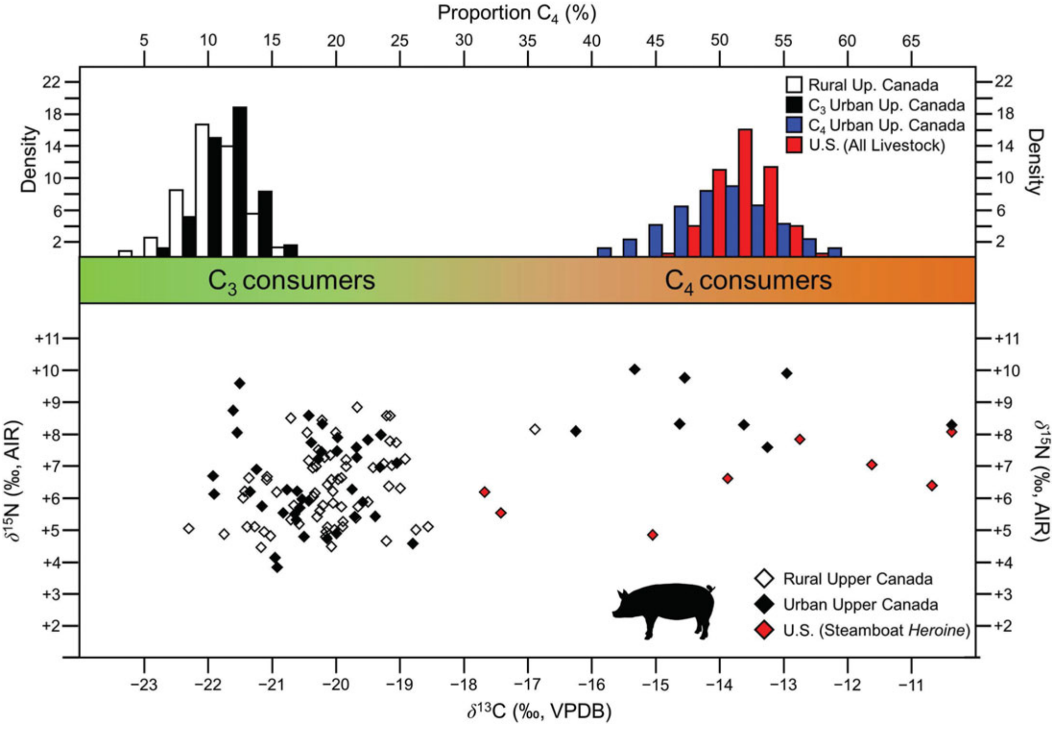

Figure 3. Bottom panel: bivariate plot of $\delta^{13}C$ and $\delta^{15}N$ values for pigs (bottom) analyzed in this study. Top: SIAR (Parnell et al. 2010) density histogram showing percent dietary contributions from C_4 plants for different urban and rural pig groups from Upper Canada alongside contemporary livestock (combined pigs and cattle) from U.S. sites, including animals from the steamboat *Heroine* and from published literature (Reitsema et al. 2015). (Color online)

however, do not follow this trend and, like their rural counterparts, have uniformly low $\delta^{13}C$ values, averaging -21.6 ± 0.9‰, and $\delta^{15}N$ values that are also similar, averaging $+7.0 \pm 0.8$‰.

Discussion

Livestock $\delta^{13}C$ values at rural sites around Toronto ($n = 146$) show an overwhelming dominance of C_3 dietary input and support historical interpretations (McCalla 1978; McInnis 1984) suggesting that European settlers in Upper Canada focused on wheat rather than maize agriculture. In this context, it is worth pointing out that butchery marks as well as element types for samples that did produce $\delta^{13}C$ values indicative of C_4-feeding at rural sites (SUBC 9189 cattle rib and SUBC 9279 pig vertebra) were consistent with common salt meat cuts, suggesting that they most likely represent the occasional purchase of imported commercial meat products from off-site sources, rather than locally raised animals. The near-complete absence of C_4-fed livestock is particularly interesting because it was still possible and perhaps even profitable to cultivate maize on a limited basis as a valuable source of feed for fattening livestock (McInnis 1982).

Given our large sample size (146 rural cattle and pigs) and broad geographical coverage of approximately 200 km around the western margin of Lake Ontario, we believe that this pattern is representative of agricultural practices across these rural and urban regions of Upper Canada. It appears that the lack of emphasis on maize cultivation for fodder was pervasive throughout a large geographical area. This finding provides a unique isotopic context, both temporally and spatially, in eastern North America. An important implication for the absence of C_4 feeding in locally raised animals is that it can allow for clearer interpretations of the presence and archaeological distribution of imported maize-fed animal products in different urban socioeconomic contexts.

Analyses of remains from beef and pork consumed in different social contexts in the urban center of Toronto provide contrasting evidence for the trajectories and origins of meat products from cattle and pigs in nineteenth-century Upper Canada. Nearly all cattle from urban contexts, regardless of the social statuses associated with their respective sites, produced $\delta^{13}C$ values indicative of C_3-based diets and fall comfortably within the range observed for rural animal production sites in the local region. A single individual (SUBC 5048) from a lower-status site produced a higher $\delta^{13}C$ value indicative of C_4-fed animal and indicates that beef from maize-fed cattle did occasionally find its way to the markets of Toronto.

From a social perspective, the isotopic similarity between cattle remains from rural and upper- and lower-status urban households suggests that locally produced beef was accessible and preferable to members of diverse social classes and that the origin of beef products, insofar as is detectable through our isotopic analyses, may not have carried significant social value for people living in nineteenth century Upper Canada. Given the adverse effects that salt-based preservatives can have on beef flavor and texture, we anticipate a historical preference among all social groups for fresh beef when possible. In this context, our results may simply reflect the fact that nineteenth-century cattle production in Upper Canada was sufficient to satisfy both rural and urban needs and, therefore, there was no need to rely on imported meat products as might occur early on during the establishment of colonial centers. From an economic perspective, this finding is significant in that it provides negative archaeological evidence for the mobility of cattle, one of the most important colonial domesticates, between two key regions of European New World activity.

In contrast to cattle, maize-fed pigs made up an appreciable portion of the urban pork assemblage and differed markedly between sites of different social statuses. At lower-status sites, nearly all pork remains had $\delta^{13}C$ values indicative of a C_3-fed diet, suggesting that less wealthy urban people probably consumed pork from locally raised pigs. At higher-status sites, a significant proportion ($>$ 20 percent) of pig remains show high $\delta^{13}C$ values and clearly had diets incorporating a significant amount of C_4 foods, most likely maize. It therefore appears that, while imported pork products did not make up a significant portion of the pigs consumed in all urban areas, they were more frequently consumed by wealthier members of society.

The association of C_4 fed pigs with wealthier sites contradicts our hypothesis and could suggest that they were perceived as a higher-status food item, perhaps because they were likely imported and therefore exotic, or due to a preference for the qualities of pork from pigs finished on maize, which can impart differing flavor profiles and fat content (Calkins and Hodgen 2007). Consumption of salt pork may also, in part, reflect access to pork on a more regular basis. While pigs can be slaughtered year round, it is possible that those who could afford it purchased salted pork for the convenience and ease of regular access.

With respect to the potential for using well-contextualized historical archaeological contexts as a venue for testing isotopic interpretive methods, these results are interesting because they present an example that may be useful for interpreting meat trade and consumption patterns in the deeper past, where historical records are unavailable. For example, bearing in mind issues with the use of analogy in archaeological interpretation (Wylie 2002), the finding that isotopically detectable differences in animal origins may be connected with social status of different communities within a single settlement could provide a useful basis for approaching social status in relation to foods origins, and food trade more generally, in more ancient contexts. This would be particularly useful in contexts where the use of C_3 and C_4 plants varied between different agricultural centers in the ancient world, such as maize-based regions in North America or millet-based regions in Asia.

Conclusion

From a wider angle, the evidence for an overwhelming dominance of C_3-fed domesticates at all historical Euro-Canadian rural sites represents a fundamental shift, both temporally and geographically, in the way incoming settlers engaged with their new agricultural landscape in the eastern Great Lakes Basin. In contrast to indigenous maize-based agricultural regimes of the Iroquoian-speaking peoples on the north shore (Katzenberg 2006), European settlers chose a different path—wheat agriculture. Our isotopic evidence is in line with historical analyses suggesting that wheat came to monopolize agricultural land under European cultivation (McCalla 1978); however, the complete absence of maize in livestock diets at all rural sites provides surprisingly clear insight into the pervasive nature of this shift in agricultural regimes.

The sharp distinction between agricultural practices in Upper Canada, where new, introduced C_3 crops monopolized farm fields, and more southerly regions of eastern North America, where maize agriculture continued to play an important role, provides a new opportunity to explore historical processes linked with animal husbandry and meat consumption. Here we used this relationship to consider broad trends in local as well as international meat trade among groups of differing economic and social statuses in nineteenth-century Toronto and were surprised to find that wealthier individuals consumed more imported salt-meat products, as opposed to fresh meats, than their less wealthy counterparts. This unexpected finding inverted our expectations about how animals and their products were valued socially in the past and serves to highlight the immense potential for testing hypotheses about relationships between humans and animals during the profound socioeconomic developments associated with the rise of the industrial era. In this context, the roles of livestock, which were ubiquitous in urban spaces until the early twentieth century, underwent continued economic, social, and legal evolution, particularly in response to changing transportation infrastructure, globalizing economic markets, and new norms for how people should and could relate to animals (Kheraj 2013; Pate 2005; Ritvo 1994). Given the considerable importance of historical human–animal relations as precursors to present-day ontologies about how humans mediate their relations to animals (Armstrong Oma 2010; Ingold 1994; Knight 2005; Puputti 2008), increased work in this area could be highly productive.

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Supplemental Materials. Supplemental materials are linked to the online version of the paper, accessible via the SAA member login at https://doi.org/10.1017/aaq.2016.34:

Supplemental Table 1. Stable carbon and nitrogen isotope and elemental composition data.

Supplemental Table 2. List of average stable carbon and nitrogen isotope values for animal groups.

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Notes

1. Filters are from Elkay Laboratory Products, Basingstoke, UK.
2. Filters are from Pall Corporation, Port Washington, New York, USA.

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