Title

Tracing historical animal husbandry, meat trade, and food provisioning: A multi-isotopic approach to the analysis of shipwreck faunal remains from the *William Salthouse*, Port Phillip, Australia.

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Abstract

Salted meats were an important food-stuff throughout recent centuries, not only as a protein source during long distance voyages but also in New World colonies. They were often used in conjunction with locally husbanded animals in areas where it was possible to raise European livestock. Isotope analysis can potentially be used to determine the sources and relative contributions of imported vs. local meats. This paper explores the stable carbon, nitrogen, and sulfur isotope values of bone collagen from barreled salt pork and beef products (n=18) recovered from the wrecksite of the *William Salthouse*, a British ship that sank in 1841 while undertaking the first ever attempt at trade between Canada and Australia. Results show a pronounced heterogeneity in animal life histories and highlight a need for better understanding of variation in animal husbandry practices in major livestock production centers during the historical period.

Key Words

Stable isotope analysis, Diet, Historical archaeology, Shipwreck, Maritime Archaeology, Animal husbandry, Meat trade

1. Introduction

Stable isotope analyses of human and faunal bone can help in understanding past diet and mobility in prehistory and are now routinely applied in a variety of archaeological research areas (Lee Thorp 2008). Stable isotopic techniques are as yet, however, underutilized in recent historical and maritime archaeology. This is particularly the case for research on human-animal relations, a field of study that is growing rapidly in prehistoric archaeology (e.g. Birch et al. 2013). Recent discussion has highlighted the fact that many novel forms of human-animal relations were caught up in parallel social and economic processes of change throughout the historical period and could be detectable using stable isotope analyses (Guiry et al. 2012b). This is because shifting practices in historical animal husbandry and trade should have produced new and distinctive patterns in animal diet and movement.

A trend in the developing literature has been a focus on the use of stable isotope analyses to understand aspects of food provisioning at colonial sites via animal husbandry and/or long distance trade of livestock and animal products aboard seagoing vessels (Guiry et al. 2012a, 2014; Klippel 2001; Varney 2003). While this work has been successful, it has proceeded despite a limited knowledge of the nature of stable isotopic variation that might be expected in traded animal products. Future studies of human-animal relations at historical sites could be aided by an understanding of the potential dietary variability amongst animals raised in particular livestock producing regions and shipped to various colonies around the globe. Such an understanding may be obtained through analyses of the remains of animals that had been drawn into this shipping trade network that have known geographical and temporal origins based on historical records. An ideal source of such remains would be the faunal collections deriving from salt meat barrels recovered from shipwreck sites. Ships might be thought of as a temporary nexus for animal cargo that may be sourced from multiple locations near the point of departure and destined for dissemination to, and use at, potentially diverse sites of consumption upon completion of their seafaring journey. Recent research (Migaud 2011) which compiled information on such collections suggests that there are, in fact, a large number (over 30) of such potential sites to work with.

This paper presents the first study of stable carbon, nitrogen, and sulfur isotope values from faunal remains (n=18) recovered from a historical shipwreck, the *William Salthouse*. Carrying a large commercial supply of barreled salt pork, beef, and fish from Montréal, Canada, the *William Salthouse* sank in 1841 while entering Port Phillip Bay near Melbourne, Australia (Staniforth 2000). Results are discussed in the context of previous historical faunal stable isotope work and demonstrate that animals transported in a single load of cargo could have relatively heterogeneous diets and probably had multiple origins. Findings illustrate the value of applying stable sulfur in conjunction with carbon and nitrogen isotope analyses and highlight the potential for conducting similar studies on other shipwreck faunal collections.

2. Historical Context

In 1841, the *William Salthouse*, a British trading vessel, was sailing between two very different colonial centers, Montréal, Canada and Melbourne, Australia when it made a fatal maneuver. During its final approach the ship collided with a submerged rock and eventually scuttled on a sand bar near the entrance of Port Phillip Bay (Staniforth 1997; Figure 1).

Periodic shortages of foodstuffs and other goods in the fledgling settlement of Melbourne during the late 1830s and 1840s meant that high profits could be made by ship owners willing to dispatch vessels to this new colony in Australia (Staniforth 2000). Though acting illegally, in contravention of the British Navigations Act, this may have been the incentive behind Green and Company of Liverpool's decision to divert one of their vessels, the *William Salthouse* (under consignment to R.F. Maitland and Company), to transport goods valued at 12,000 pounds sterling from Montréal to Melbourne.

The wrecksite of the *William Salthouse* was rediscovered in 1982 and underwent underwater excavations in 1983 and 1991 by the Maritime Archaeology Unit (MAU) of the Victoria Archaeology Survey (now Heritage Victoria; Staniforth and Vickery 1984). A number of research projects have been undertaken on the material culture recovered from the site (Staniforth 2007) including the analyses of the casks (Staniforth 1987), salt meat faunal remains (English 1990, 1991), and bottles (Morgan 1990; Peters 1996).

The ship's cargo included at least 1086 'casks' of various sizes of which 375 contained salt pork and 176 contained salt beef. Branded, cut, and/or stenciled markings on the lids of salt beef and pork barrels (Figure 2) indicate that their contents were of 'prime' or 'prime mess' quality and were inspected between December 1840 and April of 1841 by inspectors in Montréal (Staniforth 2000). This does not, however, necessarily mean that the pigs and cattle processed and packaged into these barrels were raised in the immediate vicinity. The inspection dates inscribed upon salt pork barrel lids suggest that these goods were part of stock received by R.F. Maitland and Company during late May and early June of 1841 and imply that they were already months old when taken on as cargo by the *William Salthouse*.

Recent archival research by one author (MS) has shed further light on the potential range of origins of the salt pork cargo aboard the ship. Shortly before the voyage, R.F. Maitland and Company took consignment of two shipments of salt pork from the barge *Oswego* (May 29th, 90 barrels; June 2nd, 67 barrels), one from the barge *Kingston* (June 5th, 15 barrels), and one from the barge *Victoria* (June 10th, 64 barrels) (Staniforth 2000). These shipments were transported via the Lachine canal indicating that they were probably sourced from pig husbandry operations to the west of Montréal. The completion of the Welland (in

1829), Rideau (in 1832) and Miami & Erie (which opened the way from Toledo to Cincinnati in 1840) canals also meant that salt meat products could have been relatively easily transported from further west and south than ever before. In fact, new archival research suggests that pork products reaching Montréal may have come from as far away as Cincinnati (Ohio), which at the time was also sometimes known as "Porkopolis" as it was the chief hog packing city in the USA (McGlone and Pond 2003:6; Pate 2005:65. see also Brophy and Crisman 2014). This journey would have required more than 1000 miles of travel by the existing river, canal, and lock systems.

“Pigs and pork products played a pivotal role during European settlement of the Great Lakes region and other farming areas to the south (e.g. James 1997:28; Pate 2005). The popularity of pig husbandry stemmed mainly from their capacity to eat virtually anything, from hunting and livestock offal to domestic and agricultural waste, as well as behavioral flexibility which also allows these animals to forage for their own food during leaner times (James 1997:28). With the growth in feedlots for livestock adjacent to industrial sources of edible food waste (e.g. distilleries) in the early 19th C., pigs could also be raised in relatively large numbers with more homogenous diets (Pate 2005). These assets made pork a key source of protein and a valuable trade item that could be produced in either small or large husbandry operations. Archaeologically, however, this versatility means that the husbandry practices employed in raising a particular animal that has been traded can be difficult to predict.”

3. Stable Isotope Theory

Stable isotope based paleodietary reconstructions are built on the premises that different foodstuffs can have distinctive isotopic compositions and that humans and animals are biologically constructed from molecules derived from the foods they have eaten.

Numerous reviews of stable isotope theory for archaeology exist (see Lee-Thorp 2008; Nehlich et al. 2011; Richards et al. 2003) but it is worth reiterating some of the key tenets related to bone collagen, the analyte in this study, and stable carbon, nitrogen, and sulfur isotope ecology.

Collagen is the primary protein component of bone. Relative to other bodily tissues, bones remodel or 'turnover' at a slower pace and, for this reason, the isotopic values in bone collagen record a relatively long-term (up to 20 years or more in humans; Hedges et al. 2007; Wild 2000) average of dietary information. In addition, where dietary protein intake is nutritionally sufficient the stable isotope values of bone collagen will primarily reflect the protein component of diet (Ambrose and Norr 1993; Jim et al. 2004; Tieszen and Fagre 1993).

Stable carbon ($^{13}C/^{12}C$; $\delta^{13}C$) and nitrogen ($^{15}N/^{14}N$; $\delta^{15}N$) isotope ratios are expressed as per mil (‰) values relative to the VPDB and AIR standards. Plants (and their animal consumers) with C_4 and C_3 photosynthetic pathways in terrestrial ecosystems produce isotopically heavier and lighter $\delta^{13}C$ values, respectively (DeNiro and Epstein 1978; Schwarz and Schoeninger 1991). C_3 plants dominate the flora of temperate regions such as Northern Europe (Van Klinken et al. 2000) while most archaeologically relevant C_4 plants are tropical grasses such as maize (corn), sugar cane, and millet (Tieszen 1991). In addition to photosynthetic pathways, plant $\delta^{13}C$ values can also be influenced by environmental and physiological factors such as forest canopy density (Vogel 1978), irradiance (Ehleringer et al. 1986), temperature (Tieszen 1991), aridity and water stress (Farquhar and Richards 1984), altitude (Körner et al. 1988), and salinity (e.g., Guy et al. 1980). Plants in marine environments obtain some of their carbon from dissolved bicarbonates, which have $\delta^{13}C$ values elevated by roughly 7‰ over atmospheric carbon sources (Chisholm et al.1982).

Stable nitrogen isotope values increase by 3-5‰ with each step up a food web allowing for the differentiation of herbivorous, omnivorous, and carnivorous diets (DeNiro and Epstein 1981; Hedges and Reynard 2007). Forming the base of the trophic web, most autotrophs take biologically available nitrogen in soil which can have variable $\delta^{15}N$ values (for a review see Szpak 2014) in response to factors such as water stress (Heaton and Vogel 1986), salinity (Heaton 1987), soil ammonia volotization (Mizutani et al 1985), altitude (Mariotti et al 1980), and the nature and quantity of local bacterial activity (Van Klinken et al. 2000). As the number of trophic level steps in marine and freshwater ecosystems can be significantly greater than in terrestrial ecosystems, $\delta^{15}N$ values can also provide a means of distinguishing between terrestrial and aquatic diets (Schoeninger et al.1983).

Stable sulfur isotope ratios ($^{34}S/^{32}S$; $\delta^{34}S$) in bone collagen reflect dietary methionine sources (Eastoe 1955). Methionine is an essential amino acid with $\delta^{34}S$ values that primarily derive from the soluble sulfur (in soil, bedrock, and local water) taken up by plants at the base of a food web (Brady and Weil 2000). For this reason, $\delta^{34}S$ values have been used as a record of geographical information about where an individual sourced foods during growth and turn over of their bone collagen (e.g. Bollongino et al. 2013; Richards et al. 2001; 2003).

4. Previous Isotopic Research

During the historical period at many New World permanent and seasonal sites it was common for settlers or visitors to rely at least partially on imported animal products (e.g. Landon 2009; Lawrence and Tucker 2002; Noël 2010; Simons and Maitri 2006; Tourigny 2009). Previous research on animal trade and husbandry in New World contexts has been able to effectively exploit isotopic variation produced by pronounced shifts in human-animal relations during this period (Ellerbrook 2012; Guiry et al 2012a, 2014; Klipple 2001; Varney 2003). A trend binding most of these studies is that they rely on $\delta^{13}C$ and $\delta^{15}N$ data, which are normally reserved for reconstructing dietary intake and do not necessarily record evidence for geographical sources of meat products. In these cases, however, they could be used for determining imported foodstuffs because the imported animal products were fed food that had different carbon and nitrogen isotope signatures than would be expected for local livestock and wild game. These imported animals therefore had dietary signatures that were anomalous within their respective environmental, cultural, or economic contexts that, in conjunction with the historical written and archaeological records, allowed for the identification of instances of long distance animal trade.

This previous emphasis on the use of $\delta^{13}C$ and $\delta^{15}N$ data for detecting whether or not animals were imported or locally raised at New World colonial sites may seem surprising given the existence of techniques that are more explicitly oriented towards reconstructing human and animal mobility and migration such as $\delta^{34}S$ and stable oxygen ($\delta^{18}O$; e.g. White et al. 1998) and radiogenic strontium ($^{87}Sr/^{86}Sr$; see Bentley 2006) isotope analyses. There are probably a number of factors behind this phenomenon such as the relatively low cost (compared to other isotope measurements) of $\delta^{13}C$ and $\delta^{15}N$ analysis and the fact that animal remains are often analyzed only as a baseline for human dietary reconstructions. Another issue could be that the tissue (enamel from teeth) generally used for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analyses may occur less frequently in the remains of salt meat products. On the other hand, $\delta^{34}S$ analysis is becoming more accessible and can be applied to bone collagen. This study is the first to assess the applicability of $\delta^{34}S$ analyses for reconstructing animal mobility patterns in an historical context.

5. Methods

Though a significant number of casks have been preserved on the *William Salthouse* wrecksite, relatively small-scale excavations have produced a limited faunal collection from which we sampled 18 specimens. Sample selection proceeded based on available contextual information and minimum number of individual counts per barrel and aimed to acquire bone samples from as many individual animals as possible. Sampled bones were free of residual soft tissues and fat. Original notes from English's (1990, 1991) faunal analyses were unavailable. For this reason, in some cases it was not always possible to ensure that specimens selected derive from separate animals based on archaeological contextual details alone. However, when isotopic differences between specimens are considered alongside contextual information, it appears that all specimens derive from separate individuals originating from at least nine different barrels.

Collagen extraction followed well-established procedures (Nehlich and Richards 2009; Richards and Hedges 1999) and took place at La Trobe University in Melbourne, Australia. Samples of bone weighing between 150 and 300 mg were abraded to remove surface contamination and then demineralized in 0.5M hydrochloric acid at 4°C. The resulting collagen pseudomorphes were gelatinized on a heating block at 70°C in a pH3 solution for 48hrs. Gelatin residues were purified using 5-8μm Eeze filters (and for sulfur analyses, 30kDa ultrafilters) before freezing and lyophilisation in a freeze dryer.

Stable carbon and nitrogen isotope measurements took place in the CREAIT stable isotope laboratory at Memorial University of Newfoundland. One milligram subsamples of collagen were analyzed using a Carlo Erba NA 1500 Series II elemental analyzer coupled via continuous flow to a Thermo Delta V Plus isotope ratio mass spectrometer. Based on replicate analyses of Elemental Microanalysis Standard B2155 (casein protein; n = 4) the instrumental error (1σ) for $\delta^{13}C$ and $\delta^{15}N$ measurements in this run was ±0.05 ‰ and ±0.12 ‰, respectively. Stable sulfur isotopes were measured in the University of British Columbia's Department of Anthropology Stable Isotope Laboratory. Four milligram samples of ultrafiltered collagen were combusted with ~1mg of V_2O_5 on an Elementar vario MICRO cube elemental analyzer coupled to an Isoprime 100 isotope ratio mass spectrometer following procedures outlined by Nehlich and Richards (2009). This achievement of the analysis of sulfur isotopes from smaller amounts of bone collagen than previously (10 mg with conventional elemental analyzers with gas chromatographic separation) is due to the Temperature Programmed Desorption (TPD) column in the MICRO cube elemental analyzer (Elementar Analysesysteme GmbH, Hanau, Germany), which allows for the separation of combusted gases without any influence of their weight percentages in the sample. Additionally the SO and SO_2 gases can be released from the column at once and produce a more focused peak with a small baseline and no tailing. Based on replicate analyses (n=4) of international sulfur standards, IVA Casein Protein and NIST 1577b bovine liver, the standard deviation for $\delta^{34}S$ measurements was ±0.3 ‰ for this run. Measurements on an internal mammalian bone collagen standard (n=3) produced a standard deviation (1σ) of ±0.4 ‰.

Collagen integrity was assessed using collagen yield and elemental ratio and concentration criteria. Briefly, stable isotope values are considered valid when they derived from bone with a collagen yield above 2%, atomic C:N ratios that are between 2.9 and 3.6, and elemental concentrations above 18% and 6% for carbon and nitrogen respectively (DeNiro 1985; VanKlinken 1999), and between 0.15% and 0.35% for sulfur (Nehlich and Richards 2009).

6. Results

Stable isotope values and collagen quality data from pigs and cattle are given in Table 1 and Figures 3a, 3b, and 3c. All samples produced collagen with acceptable yields, atomic C:N values, and elemental carbon and nitrogen concentrations. One pig sample, LTU 31, produced a higher S% value and should be interpreted with caution. Pigs (n=16) produced average $\delta^{13}C$ and $\delta^{15}N$ values of -21.4±1.9 ‰ and 5.9±1.0 ‰, respectively. When LTU 26 (a probable partially C_4 fed animal with $\delta^{13}C$ and $\delta^{15}N$ values of -15.8 ‰ and 6.4 ‰, respectively) is removed, these values have a range of 3.9 ‰ for $\delta^{13}C$ and 3.8 ‰ for $\delta^{15}N$ and are consistent with a predominantly C_3 oriented diet with varying quantities of plant and animal protein intake. The two cattle produced indistinguishable $\delta^{13}C$ values of -21.9 ‰ and $\delta^{15}N$ values of 3.7 ‰ and 3.9 ‰ indicating that they were pastured and foddered on C_3 plants.

Animals produced a wide range of $\delta^{34}S$ values between 4.5 ‰ and 13.2 ‰ (average 8.8 ±2.8 ‰). Excluding two samples with the highest values (~13 ‰), all pigs cluster into one of two significantly different groups (One Way ANOVA, Post Hoc Bonferroni test, $P < 0.05$) with average $\delta^{34}S$ values of 9.9±0.8 ‰ (n=9; Figure 3b and 3c, light green diamonds) and 4.7±0.3 ‰ (n=4; Figure 3b and 3c, blue diamonds). Two cattle specimens produced $\delta^{34}S$ values of 8.8 and 7.2 ‰.

7. Discussion

Stable carbon isotope evidence shows that pork and beef products loaded aboard the *William Salthouse* derive mostly from pigs and cattle that were fed diets based on C_3 and, to some extent, C_4 derived proteins. LTU 26 is an exception amongst the group and clearly consumed significant amounts of C_4 based foods, probably deriving from maize. The large range in pig $\delta^{15}N$ values, spanning at least one and possibly two trophic levels, suggests that these pigs were husbanded in areas with very different $\delta^{15}N$ baseline values and/or that feeding practices were probably variable within or between regions with some animals having a more herbivorous diet while others consuming larger amounts of animal foods.

Based on the nature of this faunal assemblage we can assume that these pigs were husbanded more or less contemporaneously or within the time span of a year or two (probably between 1839 and 1841). For this reason, variation in the stable isotope composition of pig diets probably reflects differences between separate pig husbandry operations. In this data set, for instance, such differences in animal husbandry practices are most stark in the relative quantity for C_3 and C_4 plants incorporated in pig diets. This is significant in the context of a shipwreck faunal assemblage for two reasons. First, it shows that animals from a small window of time and relatively confined geographical region could have diverse dietary life histories. The implication here is that the variation in animal husbandry seen in animal products from a site may have little to do with changes in animal husbandry practices over time. Second it demonstrates that ships became a muster point for animals produced in different husbandry regimes. This means that, at sites on the receiving end of shipping based supply chains, one can expect a greater degree of variability in pork stable isotope values which could be transferred to their human consumers.

These findings have wider implications for interpreting stable isotope dietary information from pig and salt pork remains in colonial and other historical contexts. For example, it is interesting to consider these data in relation to the growing corpus of historical stable isotope values from pig remains excavated in other colonial contexts (Guiry et al. 2012a, b, 2014, Ellerbrook 2012; Varney 2003). For instance, the remains of pork products from the 17th to 19th C. sites of Dos de Cheval and Ferryland in Newfoundland, Canada, which are thought to represent pigs raised in Europe over a multi century timescale, have a much more restricted range of $\delta^{13}C$ values (Guiry 2012b). Indeed, data presented here shows a wider range for pig $\delta^{13}C$ signatures (even without the outlier, LTU 26) than all combined values known from archaeological pork remains from Europe's major livestock producing and victualing regions during both the Medieval and Post Medieval periods (Figure 4 and Table 2; n=31, $\delta^{13}C$ range = 1.8 ‰, mean = -21.5±0.5 ‰ and $\delta^{15}N$ range =5.8 ‰, mean = 7.7±1.3 ‰). This makes sense given the relatively restricted temperate environmental and climatic conditions in major livestock husbandry areas of Northern Europe - mainly favoring the growth of C_3 plants - which became provisioning stops for colonial seafarers on route to New World destinations (e.g. Manion 2000, 2001). This stands in contrast to the situation in North America where the greater land area, a large range of climatic conditions, and well-known use of C_4 cultigens such as maize as an animal fodder could produce greater heterogeneity in animal stable isotope values. The implication here is that we now have positive evidence to support the expectation that salt meat provisions deriving from North American sources will produce a wider array of isotope values (particularly $\delta^{13}C$) in comparison with those of major livestock producing regions in Europe, which were commonly drawn upon for salt meat provisions by colonial supply ships.

There is also analytic value in further exploring these data in relation to 19th C. faunal data from Melbourne, Australia, the intended destination of salt pork cargo aboard the *William Salthouse*. Such a comparison allows for some consideration of the would-be (hypothetical) question, 'how might such data be interpreted *if* they were derived from salt pork remains that, rather than spoiling aboard the ill-fated the *William Salthouse*, had completed their voyage and been consumed and discarded in Melbourne?' Figure 5 shows the stable isotope data from salt pork remains recovered from the *William Salthouse* in the context of previously published values from pigs (n=9) as well as local omnivores (rats [n=7] and dogs [n=4]) and herbivores (ovicaprids [n=4] and cattle [n=4]) from an urban 19th C. faunal assemblage recovered from Commonwealth Block site in Melbourne's city center (Guiry et al. 2014). While pig remains from the Commonwealth Block site could derive from imported animals, their stable isotope values (n=9; average $\delta^{13}C$ of -19.7±1.5 ‰ and $\delta^{15}N$ of 9.7±2.0 ‰) are consistent with the modern and archaeological isotopic baseline, showing a C_3 dominated diet (with some C_4 inputs) as well as variable but always elevated $\delta^{15}N$ values. Salt pork remains from the *William Salthouse* have $\delta^{13}C$ and $\delta^{15}N$ values which are, for the most part, much lower than pigs, and even herbivores, from the Commonwealth Block site respects (significantly so for $\delta^{15}N$; One Way ANOVA, Post Hoc Bonferroni test, $P < 0.05$) and would be relatively easily distinguishable as non-local animals. On the other hand, when considered together, pig stable isotope values from both sites form a continuum and if certain salt pork bones from the *William Salthouse*, such as LTU40, had been collected and analyzed from the Commonwealth Block site it would not be possible to differentiate them from local animals based only on $\delta^{13}C$ and $\delta^{15}N$ data. This comparison highlights the potential problems with using dietary stable isotope information only to interpret geographical origin of faunal remains.

Stable sulfur isotopes add a complementary line of evidence to our analyses of pork products from the wrecksite of the *William Salthouse*, allowing us to consider whether varying pig husbandry practices were maintained in different regions. While $\delta^{34}S$ values cannot be used to assess the specific origins of these pigs in the absence of archaeological baseline data from their potential regions of husbandry, they can still be used to show a minimum estimate of the husbandry locations as well as to examine dietary variation between them.

Stable sulfur isotope data indicate that these pigs were raised in at least two areas with distinctive $\delta^{34}S$ baselines (4.7±0.3 ‰ [n=4] and 9.9±0.8 ‰ [n=9], respectively) and possibly three. Assuming that animal feed was not imported from other regions (either terrestrial or aquatic), this means that animal products taken on as cargo by the *William Salthouse* were probably obtained from farms in multiple regions. This fits well with the available historical information indicating that R.F. Maitland and Company had accepted salt meat shipments from at least three barges (see above) on route from multiple origins west of the Lachine canal just prior to the provisioning of the *William Salthouse*.

We might expect that some of the dietary variation evident in pig $\delta^{13}C$ and $\delta^{15}N$ values would reflect animals raised in different regions with differing isotopic baselines or distinctive husbandry practices. In that context, it is surprising to note that both of the main groups of pigs, as defined by clustering $\delta^{34}S$ values (Figure 3a white vs. grey diamonds), produced a similar range of $\delta^{13}C$ and $\delta^{15}N$ values suggesting that pig husbandry practices in both regions could have been equally diverse - based mostly on C_3 food chains with varying quantities of animal protein intake spanning one trophic level. In the possible third group of $\delta^{34}S$ values are two specimens, LTU 26 and 31 (Figure 3b and 3c, black diamonds), with similar $\delta^{15}N$ values and very high and low $\delta^{13}C$ values, respectively. If these animals were husbanded in the same region it would demonstrate an extreme intraregional difference in pig feeding practices. It is also possible that these animals originate from different regions with a similar $\delta^{34}S$ baseline.

8. Conclusion

Though this dataset is derived from only one site, it demonstrates that shipwreck faunal assemblages are a valuable resource for stable isotopic reconstructions aimed at understanding variability in the life histories of animals and human-animal relations in different parts of the world, both at and between the point of animal husbandry (exporter) and consumption of animal products (importer).

Results provide an interesting historical snapshot indicating that: 1) historical pig husbandry practices in northeastern North America varied in the types of foods used as fodder; 2) that animal products loaded aboard a single ship bound for long distance trade could derive from animals with a relatively wide range of dietary life histories and origins; and 3) that stable isotope based reconstruction of animal trade and husbandry at colonial sites that sourced some of their meat products from North American suppliers may be more complex relative to other livestock production regions, such as Europe.

Beyond archaeological subsistence reconstructions, it should be pointed out that similar stable isotope based work on historical animal husbandry and human mobility could also have more direct applications to understandings of deeper cultural processes. For instance, recent historical analyses (e.g. Anderson 2009; Silverman 2002) have put increasing emphasis on understanding the ways in which indigenous peoples and colonial settlers and visitors interacted with and raised animals in the New World during the historical period as a means of uncovering important evidence for shifting inter- and intra-cultural norms and identities. In this context, future stable isotope analyses of faunal remains from shipwrecks, representing animals of relatively well-known origins and temporality, might contribute to wider debates on human experience in colonial times.

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Figure Captions

Figure 1. Maps showing the route and final resting place of the *William Salthouse* (modified from Google Earth).

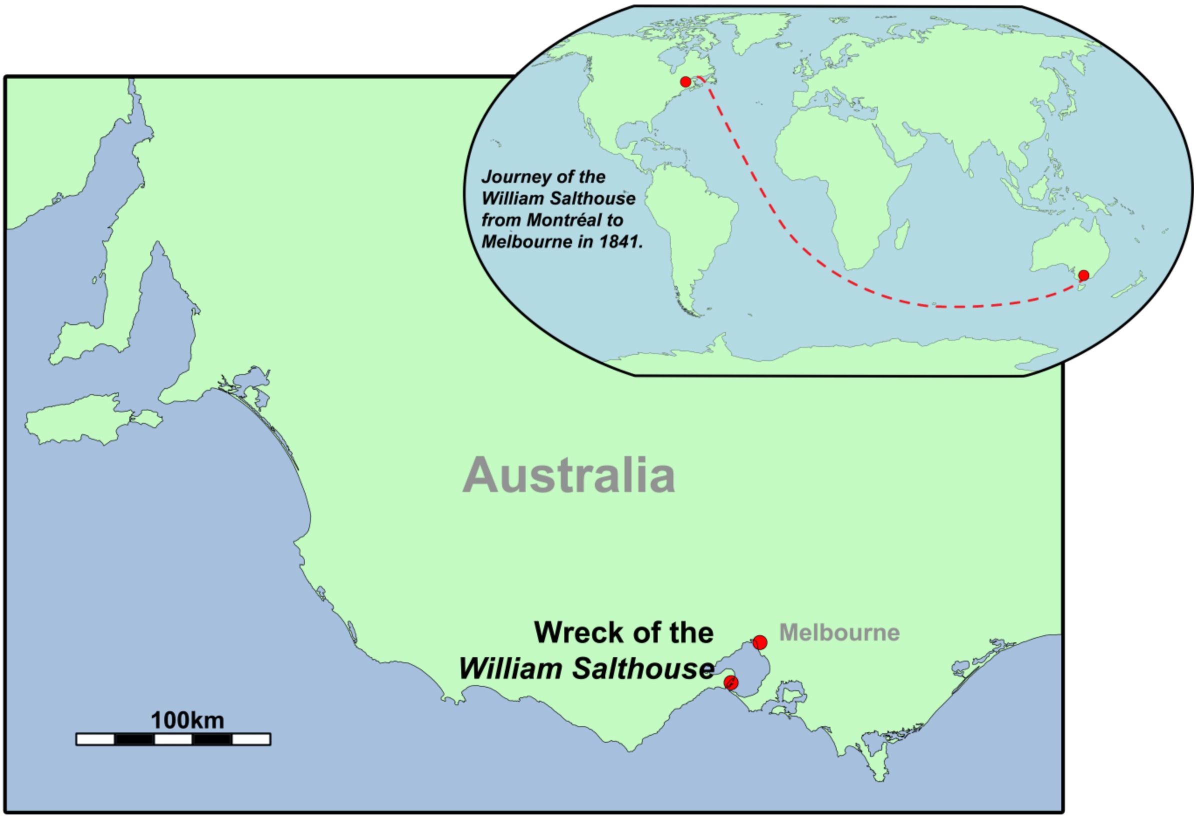


Figure 2. Inspection markings on a cask head from a barrel of salt beef excavated at the *William Salthouse Shipwreck* site in Port Phillip, Australia. Drawing by Jeff Hewitt (Staniforth 1987; reproduced with permission).

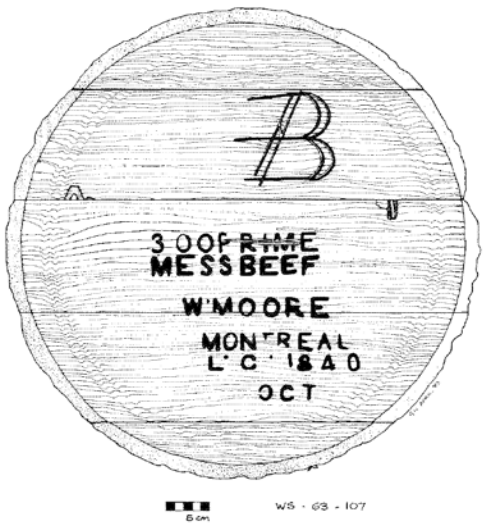
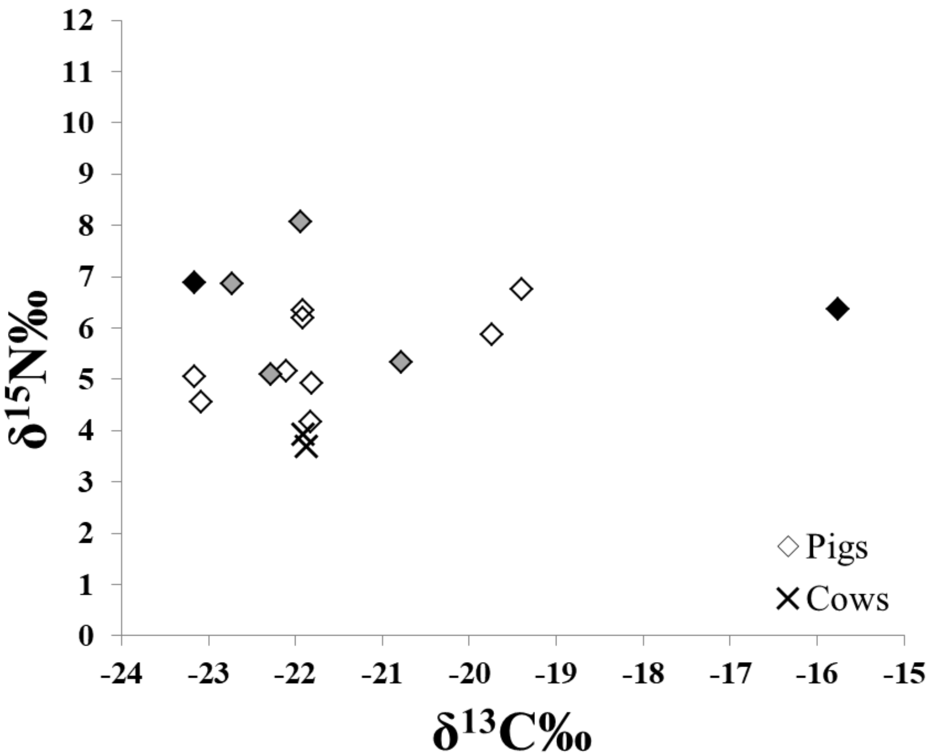
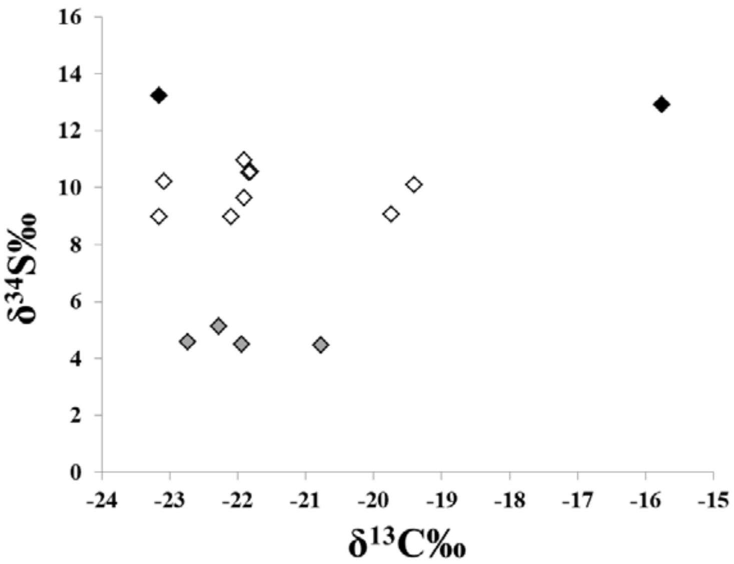


Figure 3a. Stable carbon and nitrogen isotope values from *William Salthouse* pigs (diamonds; color corresponds with stable sulfur isotope groupings) and cattle (triangles) remains.



Figures 3b and 3c. Stable sulfur and carbon (3b) and nitrogen (3c) isotope values from *William Salthouse* pigs (color corresponds with stable sulfur isotope groupings).



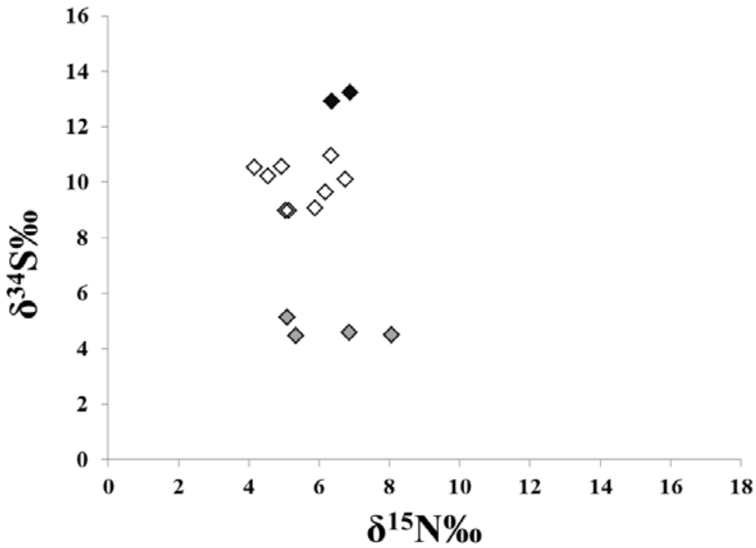


Figure 4. Stable carbon and nitrogen isotope values of pigs from the *William Salthouse* and those from historical and medieval pigs husbanded in major livestock production and victualing regions in Europe. European salt pork values are taken from pigs raised in Europe and imported to Newfoundland, Canada as shown in Guiry and colleagues (2012; 5 and 15 individuals from Ferryland and Dos de Cheval respectively; includes an additional 11 new unpublished values from the latter site). Post Medieval and Medieval European pigs derive from a number of sites in England and France as shown in Table 2.

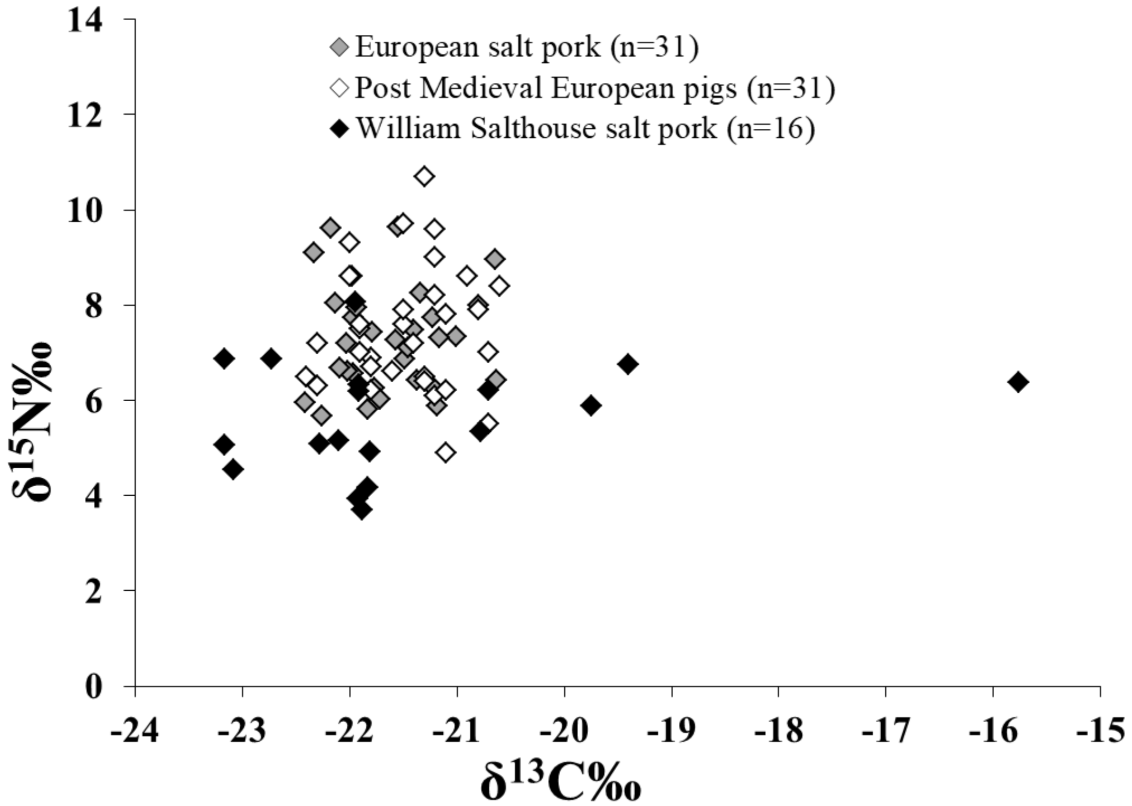


Figure 5. Stable carbon and nitrogen isotope values of salt pork remains from the *William Salthouse* and those from select historical fauna remains from meals consumed in the 19th C. at the Commonwealth Block site in Melbourne, Australia (Guiry et al. In Press). For contextualization, comparative data from other fauna from the Commonwealth Block site are shown, including omnivores (rats [n=7] and dogs [n=4]) that inhabited the site as well as select herbivorous livestock (ovicaprids [n=4] and cattle [n=4] with 'local' stable isotope signatures.

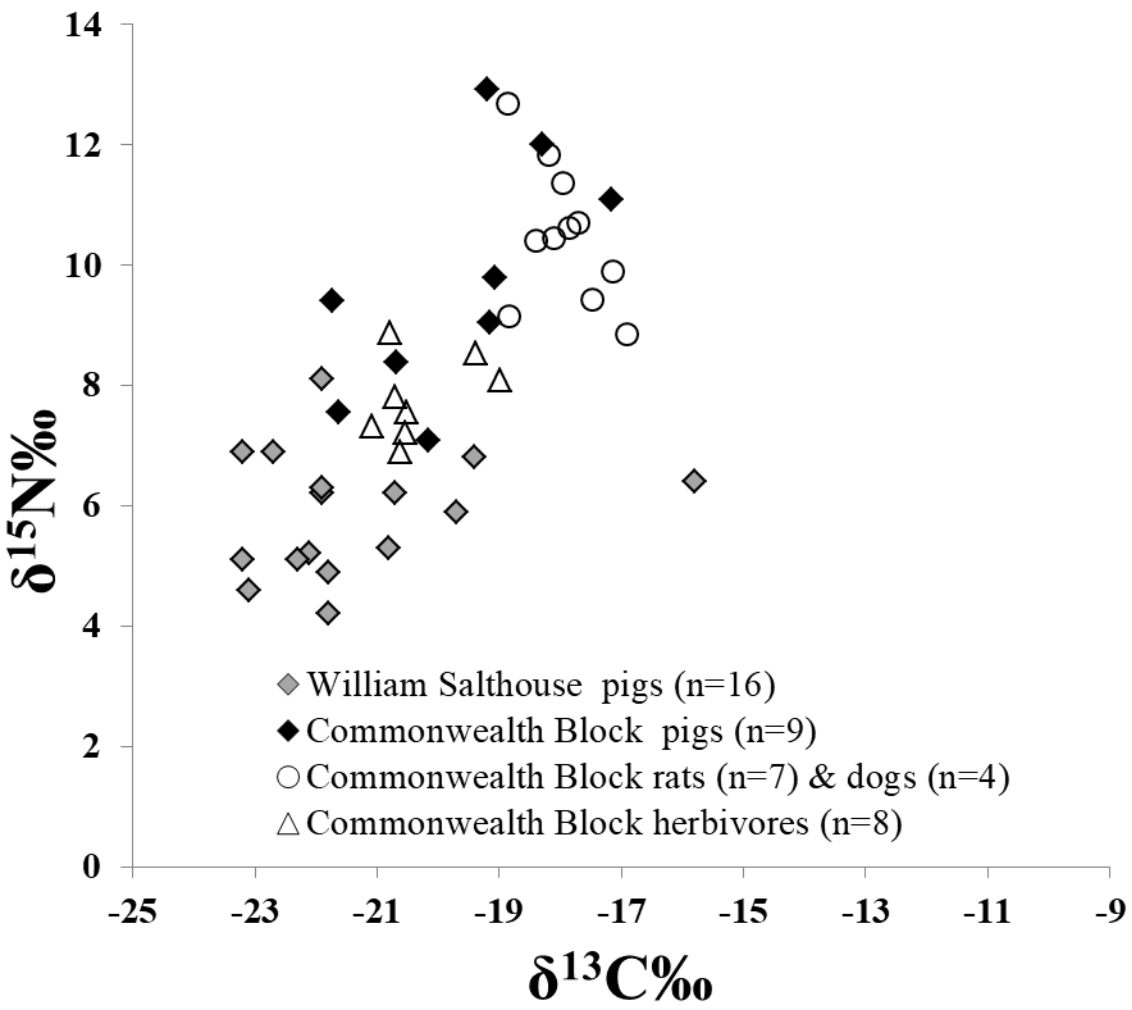


Table Captions

Table 1. Stable carbon, nitrogen, and sulfur isotope data from pigs and cattle loaded aboard the *William Salthouse* in the form of salt meat. Asterisks indicate stable carbon and nitrogen isotope values averaged from duplicate analyses.

Lab No.	Species	Bone	Side	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$	%col	%N	%C	%S	C:N
LTU 26	Pig	Os Coxa		-15.8	6.4	12.9	18.7	44.1	16	0.28	3.2
LTU 27	Pig	Os Coxa		-19.4	6.8	10.1	20.5	42.9	15.5	0.32	3.2
LTU 28	Pig	Mandible		-23.1	4.6	10.2	13.4	43.9	15.1	0.30	3.4
LTU 29	Pig	Mandible	L	-19.7	5.9	9.1	13.1	45.1	16.2	0.25	3.2
LTU 30*	Pig	Mandible	L	-21.9	6.2	9.6	10.8	43.4	15.5	0.27	3.3
LTU 31	Pig	Skull		-23.2	6.9	13.2	5.9	44.8	15	0.41	3.5
LTU 32	Cow	Vertebra	L	-21.9	3.7	8.6	22.6	43.5	15.7	0.27	3.2
LTU 33	Pig	Ulna	L	-21.8	4.2	10.5	19	44	16.1	0.26	3.2
LTU 34	Pig	Mandible	L	-21.9	6.3	11	18.1	43.7	15.6	0.26	3.3
LTU 35	Pig	Mandible	L	-21.8	4.9	10.6	18.9	41.2	14.9	0.27	3.2
LTU 36	Pig	Mandible	L	-22.1	5.2	9	16.6	40.6	14.4	0.27	3.3
LTU 37	Pig	Skull		-23.2	5.1	9	2.4	42.7	14.7	0.22	3.4
LTU 38	Pig	Scapula		-20.7	6.2	NA	11.6	36.7	13	NA	3.3
LTU 39	Pig	Tibia	R	-22.3	5.1	5.1	23.4	42.9	15.2	0.25	3.3
LTU 40	Pig	Tibia	R	-21.9	8.1	4.5	19.5	41.9	14.7	0.28	3.3
LTU 41	Pig	Mandible	L	-22.7	6.9	4.6	9.5	33.6	11.5	0.23	3.4
LTU 42	Cow	Femur		-21.9	3.9	7.2	20.2	42.9	15.3	0.25	3.3
LTU 43	Pig	Mandible	L	-20.8	5.3	4.5	12.5	43.2	15.1	0.26	3.4

Table 2. Temporal and contextual information for British and French pig data from post A.D. 1000 as shown in Figure 4. St. Giles and Wharram Percy data are from Müldner and Richards (2005); Fisher Gate and Tanner Row data are from Müldner and Richards (2007); Besançon data are taken from Bocherens and colleagues (1991); and Mary Rose data are taken from Tripp and colleagues (2006).

Site	**Time Period**	**Number of Pigs**
St. Giles (UK)	12^{th}-15^{th} C.	4
Wharram Percy (UK)	Later Medieval	6
Fisher Gate (UK)	10^{th}-12^{th} C. High Medieval	5
Fisher Gate (UK)	13^{th}-16^{th} C. Later Medieval	7
Fisher Gate (UK)	1538-late 16^{th} C. Post-medieval	1
Tanner Row (UK)	10^{th}-12^{th} C. High Medieval	4
Tanner Row (UK)	13^{th}-16^{th} C. Later Medieval	2
Besançon (France)	14^{th} C.	1
Mary Rose (UK)	1545	1

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