A Land of Plenty? Colonial Diet in Rural New Zealand

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ABSTRACT:

Colonial New Zealand was built on the ideal of creating better lives for settlers. Emigrants came looking to escape the shackles of the class-system and poor conditions in Industrial Revolution period Britain. Colonial propaganda claimed that most emigrants achieved their aims, but the lives the colonists actually experienced upon reaching New Zealand remain relatively unexplored from a biosocial perspective. In this paper we present a pilot study of stable isotope results of bone collagen from seven adults interred in the St. John's Cemetery (SJM), Milton, New Zealand (*ca.* AD 1860–1900). We interpret the diet at Milton and broadly compare our isotopic results with contemporaneous samples from Britain. We show that, like

contemporary Britain, the diet of our studied individuals was focused on C_3 crops and terrestrial meat sources. Despite higher δ^{15}N values in contemporary UK populations (which can simplistically be interpreted as indicative of higher meat intake), consideration of different local baselines makes it likely that this New Zealand population had relatively similar levels of meat intake. Interestingly marine resources did not form an important part of the Milton diet, despite the site's proximity to the ocean, hinting at the possible stigmatisation of local resources and the development of a European New Zealand (pākehā) food identity.

Keywords: carbon; nitrogen; stable isotopes; colonialism, pākehā.

Introduction

The 19th century was a time of increasing globalization as various colonial powers expanded across the world and the movement of peoples and ideas became increasingly common (Ballantyne 2012). Colonial migration not only involved movements of people themselves, but also the transplanting of food resources and attempts to recreate 'home' or 'improve' the environments they colonised. New Zealand was involved in this movement, with European colonisation beginning with sporadic settlement by sealers, whalers and timber merchants in the late 1700s, and continuing with mission settlements from the early 1800s (Anderson 1998; O'Malley 2012). Formal acquisition of New Zealand as a colony was conducted under the auspices of the Treaty of Waitangi (1840), which facilitated large-scale colonisation spearheaded by the New Zealand Company (Burns 1989). In some areas, settlement was preceded by formal land sales (e.g., the Otago Purchase 1844). The discovery of gold in Otago in the 1860s further catalysed settlement, with an influx of European and Chinese migrants arriving to make their fortunes on the goldfields (Butler Earp 1853; Salmon 1963).

These colonists entered a country already settled by a culturally-continuous indigenous people, the Māori, whose ties to the land and its resources went well beyond what could be conceived of by foreigners. Māori consider themselves the people of the land, a part of the New Zealand landscape and guardians of its resources (Hill 2012). Colonial ideology, however, considered the displacement or assimilation of Māori into European (or pākehā) culture, and the reworking of the New Zealand environment to be essential to their mission of taming the wasteland and generally 'improving' the environment (Ballantyne 2012). Transplanting resources and bringing in a colonial food identity was an important part of this 'improvement'. The abolition of indigenous lifeways, including dietary habits was, to the European settlers, evidence that they were achieving their aims.

Colonial propaganda describes New Zealand as a land of plenty, a place where settlers could go to improve their fortunes, and escape the increasingly industrialised and class-based society of the United Kingdom (Butler Earp 1849; Fox 1851; Sargent 2001; Durrer 2006). New Zealand was advertised as a land of rolling pastures, where meat was readily available (Vogel 1875; Veart 2008) and the working man had every opportunity to advance (Labourers Union Chronicle 1873; Hill 2017). Historical records, however, generally give a state-sponsored narrative of the settlement process (Ballantyne 2012). Letters written home and published were often solicited by the New Zealand Company to give favourable impressions of resource availability (New Zealand Company 1841; Durrer 2006). The diaries written at the time were generally by literate, upper-class settlers, potentially giving a biased account of the New Zealand experience (e.g. Barker 1871; Martin 1884).

Our challenge is therefore to study the lives of the 'silent' early settlers who have left few or no written records but formed the majority of the settler population in the mid-nineteenth century. Elsewhere in the world, the dietary effects of human movement and initial colonisation have been successfully assessed directly by using isotopic analysis of human tissues (Cox et al. 2010; Pate and Anson 2012). Analysis of stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotopes in human bone collagen can give insight into the diet of an individual during life. Used together these isotopes can show whether terrestrial or marine resources were being used, the photosynthetic pathway of plants being exploited (C_3 versus C_4), and the trophic level of foods consumed - often related to the amount of meat in the diet (Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Ambrose and Norr 1993).

In historic period studies (e.g. Trickett 2006; Beaumont et al. 2013; Britton et al. 2018) the biological record of diet in the skeleton can be compared to written records, resulting in a more nuanced picture of past lifeways. For instance, Beaumont et al. (2013) have used dietary isotope data to identify the dietary regime characteristic of Irish migrants in nineteenth-century Lukin Street cemetery, London. In pre-European New Zealand, dietary isotope analysis has been used to infer mobility and diversity of subsistence practices of Māori individuals buried in the oldest cemetery discovered in the country, Wairau Bar (*c.* AD 1300) (Kinaston et al. 2013). However, the study of European skeletal remains dating to the early colonial period in New Zealand has been very limited (for exceptions see Trotter and McCulloch 1989; Best et al. 2006; Petchey et al. 2018a) and no isotopic studies have been undertaken in this context. Recently, the first research-driven excavation of colonial remains have been undertaken (Petchey et al. 2017; Petchey et al. 2018b) and isotopic evaluation of diet in a New Zealand colonial context is part of this wider project. In this study, we examine whether colonists achieved their aim of developing a 'better Britain', using diet as one measure to assess quality of life by conducting carbon and nitrogen isotope analysis of human bone collagen as a proxy for adult diet in the early colonial site of St. John's, Milton (New Zealand) (Figure 1).

[insert figure 1 hereabouts]

Ship records show that European staple crops such as wheat and oats, and domestic meat resources such as sheep, pigs and cows were brought with the settlers (Holland 2013; Peden and Holland 2013). Emigrants were advised to bring European cookbooks and attempted to recreate European food habits in the new colony (Wakefield 1848). For this reason, we would expect the colonial New Zealand diet to reflect the contemporary diet of Britain and Ireland. This was primarily focused on C_3 crops – bread was the dietary staple in England (Drummond and Wilbraham 1957; Burnett 1989) and potatoes were the staple crop of Ireland (Clarkson and Crawford 2001). Terrestrial meat from domestic animals was also a component of the diet in the United Kingdom and Ireland, but eaten sparingly particularly by lower classes due its prohibitive price (Drummond and Wilbraham 1957). Both marine and freshwater fish, however, were an important source of protein for those of lower socio-economic status. Their significance as a dietary component was particularly commented on among the urban poor - Mayhew (1851:62) stated that *"the rooms of the very neediest of our needy metropolitan population always smell of fish"*. In areas further from the coast, marine fish were lessroutinely consumed, as they were not readily available inland prior to the advent of railway transport in the 1850s (Holland and Olsen 2017). The primary aim of our study is therefore to characterise the colonial diet in Milton and test the hypothesis that it will reflect the traditional dietary components of the United Kingdom and Ireland using carbon and nitrogen isotopic analysis of bone collagen. If a European food identity was maintained we would expect carbon isotope values to reflect the C_3 plant-dominated diet typical of Britain, with nitrogen isotope values highlighting the importance of terrestrial (likely domestic) meat sources i.e. farmed animals.

The extent to which indigenous resources were incorporated into the New Zealand European diet is also of interest in this colonial context. Agriculture was considered an important part of the 'civilising influence' of the European settler, allowing them to 'improve' the land and assimilate the New Zealand indigenous people (Māori) into European lifeways (Beattie and Stenhouse 2007; Ballantyne 2010). Model gardens were created to show Māori how to cultivate European crops and Māori proved to be initially much more successful gardeners than Europeans, because of their intrinsic knowledge of New Zealand environmental conditions and long horticultural history (Leach 2010). However, European settlers generally considered their subsistence strategies and resources superior to those of the Māori (Veart 2008; Holland 2013).

In other colonial settlements there is evidence that settlement was followed by the development of a colonial food identity. Usually this involved the transplanting of resources from 'home' and their preference over indigenous food types (Eden 2001; Earle 2010), sometimes despite considerable economic expense for the settlers (see Guiry et al. 2018).

However, in most colonial contexts there is also heavy reliance on wild and domestic indigenous animal resources, which became incorporated into colonial cookery and are retained in local food traditions to the present day (Reitz and Waselkov, 2015). In New Zealand, colonial records suggest that New Zealand wild game animals were hunted and incorporated into European-style recipes (Veart 2008; Leach 2010) and early settlers in nearby Dunedin were quick to exploit native birds and freshwater fish in lieu of protein from their own limited domesticated animal stock (Gillies 1878; West 2017). Despite this, some resources were potentially stigmatised, including marine fish, which was associated not just with Māori, but also with poverty in Britain and Ireland (Galletly 2010). In this study, we examine whether diet in Milton reflects incorporation of indigenous resources, a mixed colonial food identity or simply emulates that of the settlers' home countries. We would expect a European style diet to be focused on terrestrial crops and animals, whereas incorporation of resources traditionally used by Māori in the area might involve increased use of freshwater fish, game birds and marine resources.

Ultimately, colonial advertising suggests that the move to New Zealand should be associated with a shift to better quality and more nutritious food. In particular, the ready availability of meat from domestic animals farmed in the new colony was highlighted as one of the attractions of New Zealand (Vogel 1875). The British Enclosure Acts of the 1700s had denied the rural poor access to their traditional method of animal pasturing (Rogers 1908; Turner 1984; Daunton 1995) and the Poor Laws of the late 1700s – early 1800s had kept wages artificially low, reducing many of the labouring rural class to paupers (Burnett 1989). Low wages and the burgeoning populations of urban centers during the Industrial Revolution also meant urban food availability was restricted and many of the urban poor suffered from malnutrition as result (Spencer 2000). In the early 1800s, contemporary accounts describe how the labouring British family could not afford fresh meat at all (Davies 1795; Fisher 1904). The price of bread and flour took up the majority of wages, and only around 6 % of income could be spent on cured meats such as bacon (Richardson 1976). The promise of fresh meat, and access to more food in general, proved an important lure for potential emigrants to New Zealand (Burnett, 1989:27). The abundance of meat is generally accepted as a factor which set New Zealand colonial diet apart from that of Britain and Ireland at this time period (Carter and Maynard 2001; Bell and Neill 2014). To test this assumption, we compare diet in Milton with isotopic evidence of diet from individuals interred in contemporary cemetery sites in Great Britain and Ireland.

The sample size for this study is small, making it a pilot investigation of diet in a colonial context. However, settler motivations for emigration focused on personal advancement and looking at a small number of individuals may still reveal important dietary nuances. The Wakefield 'class settlements' (including Dunedin and its surrounding settlements such as Milton) were predicated on replicating the class system of Britain (Burns 1989). However, the gold rushes of the 1860s saw an influx of young men committed to classlessness (Olssen 1977). New Zealand became viewed as a place where one's situation in life could be improved and the class system of Britain escaped. Indeed, in 1848 Constantine Dillon, an early settler in Nelson, described the inexorable progress of egalitarianism in the New Zealand colony *"This is a glorious country for a labouring man!!! No starvation, no fear, no poor law union, high wages, short hours, infinite grazing land for his cows"* (Dillon 1954:65). At this time in rural colonial New Zealand, schools were attended by children from different backgrounds and adults mixed at rural clubs and societies (Olssen 1977). At the very least we would expect class differences to be less pronounced than in Britain. In this study we use diet as a proxy for potential class differences by examining whether unequal access to resources existed in the small colonial settlement of Milton. We hypothesise that if wealth differences existed in Milton this may be reflected in heterogenous dietary isotope values and particularly differences in nitrogen isotope values that reflect differential access to higher quality foods (i.e. meat). A more egalitarian society, on the other hand might be reflected in more homogenous isotopic values and few isotopic differences between the people of Milton.

Materials and Methods

Materials

All individuals analyzed were disinterred from the colonial cemetery site of St John's, Milton (Petchey et al. 2017). Milton was part of the rural hinterland of the Otago Settlement, a joint venture between the New Zealand Company and the Lay Association of the Free Church of Scotland, which purchased 144,600 acres of land in coastal Otago in 1844. The intention was to establish a Wakefield class settlement, where the community would have two main classes, a land-owning capitalist class, and a wage-earning working class. The first emigrant ships arrived in Dunedin in 1848 and European colonists slowly spread out from there onto the surrounding plains (Figure 1). Farming began on the Tokomairiro Plains in the early 1850s, with a small community being established at Fairfax (now part of Milton) (Sumpter and Lewis 1949). Rural development in the Otago interior was slow until the mass influx of miners during the Otago gold rushes of 1861–1862. During the goldrushes, Milton became a center from which supplies could be bought by the miners but also suffered from the loss of men to the goldfields during the rushes (Sumpter and Lewis 1949). As well as being the center of a farming community, Milton also had a number of important industries, including flourmills (1857), brick and pipe works (1869), the pottery works (1873) and the Bruce Woollen Mills (1897). The railway through Milton opened in 1875, providing easy access to Dunedin for both passengers and freight. Therefore, by the late nineteenth century Milton had grown into a well-established rural service town, located on both the main north-south road and one of the major routes into the Central Otago goldfields.

St John's Cemetery (SJM), Milton was established shortly after colonial settlement of the Tokomairiro plains (in the 1850s), and fell out of use in the early 1900s (Sumpter and Lewis, 1949). Most interments date to between 1860–1890, and as such adults in the cemetery are likely to be the first European settlers to the area. 'Lost' parts of the cemetery were excavated in 2016 as a collaboration between the University of Otago and the descendant community in the form of the Tokomairiro 60 Project (Petchey et al. 2017). The total sample consists of 11 adults and 16 non-adults. Bone preservation was variable. Some burials had well-preserved bone with whole skeletal elements present, other burials had clearly been affected by waterflow in the burial environment, with bone completely absent represented instead by just shadows in the soil. Only burials with preserved bone are included in this study. Other tissues besides bone were also present in some graves, including hair, finger- and toe-nails and brain tissue. The non-adults were represented primarily by dental remains, hair and nails. In addition, some graves also contained the legible remains of coffin plates, allowing identification of the individuals (Figure 2). Out of respect for descendants of these individuals we do not use their names in this paper, but have been granted permission by known direct descendants, the community groups with guardianship over the cemetery and the Anglican diocese to share and use relevant historical details to support or add to isotopic interpretations.

[Figure 2 here]

Bone samples were taken from all adults in the sample for collagen extraction and subsequent isotopic analysis. Rib fragments were used preferentially, but one individual (B4) had poorly preserved ribs and the petrous portion of the temporal was sampled instead to maximise the potential for high collagen yield. We recognise that these different bones turnover at different rates (Fahy et al. 2017), with ribs representing one of the shortest timespans of all bones, and even in individuals over 50 they turn over within around 20 years. Long bones/ bones of the skull generally turning over more slowly and reflecting diet over a time period of over 20 years (as per Hedges et al. 2007). Isotopic results will therefore represent a different time period for each individual, but the majority of adults buried in the St John's cemetery had resided in New Zealand for over 15 years at time of death (Findlay., 2016). Therefore all bones analysed should have collagen isotopic signals that are dominated by colonial diet. Two of the individuals who did not have ribs available for sampling are named individuals who historical records tell us had resided in New Zealand for almost 20 years at time of death. We therefore anticipate that their collagen should have a primarily 'colonial' isotopic signal, with perhaps some collagen remaining from life at 'home'.

Non-adults were excluded in this study to avoid interpretive complications arising from breastfeeding. Table 1 presents demographic information alongside other relevant data for each of the individuals analyzed. As mentioned above, bone preservation at the site was variable and only seven adults yielded collagen.

[Table 1 here]

Baseline data

Human collagen isotope values are interpreted with reference to modern food web data compiled from previous isotope studies in New Zealand (Hicks 1997; Leach et al. 2003; Rogers 2008; Bong et al. 2010; Horacek and Min 2010; Supplementary Table 1). There are no native New Zealand C_4 plants, but as maize was grown in the North Island during this time period (Rhodes and Eagles 2012) and sugar was imported from elsewhere in the British Empire (West 2017), we use C_4 data from the USA for reference (DeNiro and Hastorf 1985).

This study is focused on a cemetery site, with no associated contemporary faunal samples that could be used as an isotopic baseline. Indeed, because excavation of historic period sites is rarely undertaken in New Zealand there are not even well-contextualised contemporary samples from elsewhere in the country that could be used as a proxy for colonial Otago values. We stress that use of modern baseline data to interpret historic period isotopic results is far from ideal. There are multiple factors which may have altered typical foodweb values in Otago between first colonisation and today. For example, deforestation processes particularly via burning, use of fertilisers and generation of higher δ^{15}N run-off from agricultural land has the potential to raise δ^{15}N values in both soils and river systems (e.g. Guiry et al. 2018; Brugam et al. 2017), potentially leading to a modern foodweb with higher baseline values than that of the colonial period where processes of land clearance and agriculture were in their infancy.

We also acknowledge that early colonial agricultural practices may have differed from those of today, and involved foddering on different food sources. In New Zealand there are no endemic C_4 food sources on which to fodder animals, and thus we expect that both modern and historic period foddering will have been with C_3 resources and not have affected $\delta^{13}C$ values. Colonists may have consumed preserved, imported meats with variable $\delta^{15}N$ and $\delta^{13}C$ values (as per Guiry et al. 2015), but Otago was considered to be broadly self-sufficient during this time period and we expect imported meat consumption to be minimal, particularly in a rural settlement more than a day's ride from the nearest port (Dunedin).

In using modern foodweb data we accept that there will be elements of uncertainty introduced to the study. Limited comparisons between prehistoric and modern faunal samples conducted in New Zealand species have indicated that in some niches differences in mean isotopic values may not be large. Holdaway et al. (2013), for example, showed mean differences in prehistoric and modern brown teal $\delta^{15}N$ values to be <0.5 ‰ but $\delta^{13}C$ was much more variable (up to 2‰ in some samples). Comparison of local snapper values between AD 1400 and the present in our study region has shown only limited changes in $\delta^{13}C$ values (Neil et al. 2014), but without study of $\delta^{15}N$ values. With these caveats in mind, we believe that use of a modern baseline is better than complete lack of a baseline. There are previously published archaeofaunal isotope data from New Zealand (Kinaston et al. 2013) but these came from a preindustrial context in a climatically and culturally different area of New Zealand. To avoid further complication of the baseline data these were not included in the current study. SJM is a site deriving from the Industrial Revolution period, where industrial activity had already begun to affect global atmospheric carbon reservoirs (Francey et al. 1999). We therefore corrected modern foodweb data to 1880s atmospheric CO_2 values in order to minimise differences in δ^{13}C between the present day and the study period. The comparative food web data from these sources is shown in Figure 3, illustrating how isotopic values vary between food sources. Note, however, that some of the economically important New Zealand freshwater fish species like tuna (eel) and kanakana (lamprey) spend part of their lives in marine environments and so it is possible that their values may overlap with marine values depending on when in their lifecycle they were caught. Flow rates of rivers can also affect algal δ^{13}C values (Finlay et al., 1999) and slow-moving systems generally have higher δ^{13}C values. This makes it possible that in some cases wetland δ^{13}C values might overlap with marine δ^{13}C values. Finally in terms of foodweb considerations, in New Zealand most terrestrial plants, including European crop varieties (e.g., oats, rye, wheat, potatoes, vegetables), are C_3 plants, and C_4 crop contribution (e.g., maize, sugarcane and millet) to the diet in rural Otago is likely to have been minimal.

Human collagen data from St. John's is compared with previously published isotopic values from contemporary sites in Great Britain and Ireland (Table 2; Supplementary Table 2) to examine whether New Zealand diet differed from that of 'home'. These comparative data derive from a variety of contexts, ranging from relatively higher status, to mixed and lower status, including an Irish Famine sample. Many of those who came to New Zealand were fleeing urban overcrowding, or famine conditions in Ireland, making these lower-class British and Irish cemetery sites useful comparative samples for addressing this question. However, we acknowledge that a lack of contemporary baseline data for these sites makes our comparisons exploratory only. We use post-medieval foodweb data from inland Northern England sites (Müldner et al. 2005; 2007; Fisher and Thomas 2012) as the closest available proxy for nineteenth century England. There are no published contemporary baseline datasets for southern England or Ireland, making comparison with these sites more difficult.

[Table 2 here]

Methods

Bone Sample Preparation

Bone fragments weighing approximately 200 mg were sampled using a diamond cutting wheel and dental drill. Collagen was extracted from bone fragments using a modified Longin (1971) method. Bone was placed into 0.5 M HCl at 4°C that was regularly changed until fully demineralised. Demineralised bone was rinsed in DI water, filtered with Ezee filters and gelatinised in pH 3 HCl at 70°C for 24–48 hr. It was then centrifuged, decanted, then lyophilised.

Isotopic Analysis

Isotopic analysis was undertaken at the Stable Isotope Biogeochemistry Lab (SIBL), Durham University using a Costech Elemental Analyzer (ECS 4010) coupled to a Thermo Delta V Advantage isotope ratio mass spectrometer. Carbon isotope ratios are corrected for ^{17}O contribution reported in standard delta notation (δ) relative to international standards (VPDB and AIR ~ atmospheric nitrogen). Isotopic accuracy was established using repeat measurements of in-house standards, which were calibrated against international standards (e.g., USGS 40, USGS 24, IAEA 600, IAEA CH3, IAEA CH6, IAEA N1, IAEA N2). Precision (*u(Rw)*) was determined to be ± 0.1 ‰ for replicate analyses of the international standards and typically < 0.2 ‰ on replicate sample analysis. Accuracy or systematic error (*u(bias)*) was determined to be ± 0.12‰ for both $\delta^{13}C$ and $\delta^{15}N$ on the basis of the difference between the observed and known δ values of the check standards and the long-term standard deviations of these check standards. Using the equations detailed by Szpak et al. (2017), the total analytical uncertainty was estimated to be ± 0.16‰ for $\delta^{13}C$ and ± 0.22‰ for $\delta^{15}N$. Total % carbon and nitrogen data were also obtained using an internal standard (glutamic acid, 40.82 % C, 9.52 % N).

Results Processing

Collagen quality was assessed using established parameters (DeNiro 1985), and was considered to be of good quality if $C:N_{atomic}$ = 2.9–3.6, C (wt %) = 30–50, and N (wt %) = 10–16.

Collagen isotopic values were visualized relative to food web data by plotting using R statistical software (R Core Team 2013). Although the Milton samples derive from a period where industrialization was well underway in Europe, there are systematic differences of around 0.8 ‰ in atmospheric carbon isotope values between the late 1800s and today in the Southern hemisphere (Francey et al. 1999). Values from modern food web data were corrected for this offset. In plotting human and food web values together, human values were corrected for the diet–collagen offset (O'Connell et al. 2012). We consider this offset as 4.8 ± 0.5 ‰ ($\Delta^{13}C$, as per Ambrose and Norr 1993; Tieszen and Fagre 1993; Howland et al. 2003, Jim et al. 2004; Warriner and Tuross 2009; Froehle et al. 2010) and 3.5 ± 0.5 ‰ ($\Delta^{15}N$, as per summary in Hedges & Reynard 2007). When plotting data against foodwebs we use 95% confidence ellipses, rather than the traditional error bars or boxes, to convey the distribution of datapoints in a more statistically meaningful way (Grove & Pearson, 2014).

Results

Table 3 presents the $\delta^{13}C$ and $\delta^{15}N$ values, information on collagen quality and mean isotopic values for the Milton individuals.

[Table 3 here]

Figure 3 shows the human $\delta^{13}C$ and $\delta^{15}N$ values, corrected for diet-tissue offset, relative to the available food web data. Milton values fall clearly in the range of a C_3 terrestrial dominated diet, containing both C_3 plants, and some input from both terrestrial meat sources and freshwater fish and game. B29 has a notably higher $\delta^{15}N$ value than others in the SJM sample, likely due to greater consumption of freshwater fish resources.

[Figure 3 hereabouts]

This diet is similar to that of contemporary British samples, presented in Figure 4 with the Northern English contemporary baseline. All sites used as a comparison have a C_3 – terrestrial dominated diet. However, sites such as those of London (Lukin St, Chelsea and Spitalfields) have more input from freshwater and marine fish resources than the more inland, midland English sites of St. Martin's and Coventry.

[Figure 4 hereabouts]

Discussion

General Comments Regarding Colonial Diet at St. John's, Milton

As expected, the diet of the SJM individuals was focused on C_3 terrestrial resources. As discussed above, historical records stress the importance of wheat, oats, barley and root crops such as potatoes in colonial agriculture (Lynch 1990; Peden and Holland 2013). These C_3 resources were likely the staples of the diet, with C_3 grass-foddered livestock the main sources of terrestrial meat. C_4 crops, while used, seem to have played a minimal role in the diet, suggesting that maize and sugar were used sparingly and had minimal caloric contribution to the diet.

Terrestrial meat resources, including both domestic animals and freshwater fish and game (such as ducks) were clearly important dietary components for all individuals. Earliest settler accounts describe using native freshwater resources heavily during initial colonization of new farmland (Harman 2014), while agricultural flocks were still being established and could not be heavily consumed. It is likely that that bone turnover times of 10 years or more mean that this earliest settlement diet is still partially reflected in the bones of the adult settlers.

The Official Handbook of New Zealand, designed to prepare emigrants for life in the colony, confidently stated that *"the labouring classes use a much more generous diet. The cheapness of meat especially surprises the newly arrived immigrant"* (Vogel 1875:259). Historical accounts show the cattle in Otago numbered over 8,000 in 1855, in addition to the 77,474 sheep mostly on the runs in the north of the Otago province (Otago Gazette, 1855). Contemporary farmers boasted that the Otago region was mostly self-sufficient in terms of food, with only sugar and tea needing to be imported to Dunedin (Pillans 1849). Colonists were likely to have expected a good proportion of meat in their diet. The newspapers of the time tell a different story to that of the colonial propaganda. Angry letters from the people of Milton claiming that meat was "*excessively dear*" (Bruce Herald 1880) with *"no obvious reason why it should be so"* (Otago Witness 1869) are not uncommon. One, perhaps overly dramatic, Otago colonist went so far as to quote London's Punch magazine claiming *"so scant my fare, my bones are bare; I shiver with the cold; Small strength within my shrunken skin, now meat so dear is sold"* (Otago Witness 1868).

Our results, combined with these historical records suggest that the people of Milton certainly had sufficient meat in their diet, but that their domestic animals may not have provided as much meat as they had anticipated. Instead, waterfowl and freshwater fish may have made up for a perceived meat deficit.

Equal Access for all?

New Zealand was also billed as a land of egalitarianism, where the class-system of Britain was left behind in favour of a laborers' paradise where all could progress equally (Fairburn 1989; Hill 2017). If we consider δ^{15}N values to broadly indicate meat consumption levels, most individuals in the Milton sample enjoyed similar amounts of meat. However, B29 is a clear outlier, with much higher values than the rest of the SJM cohort.

When all meat and fish sources are considered, Burial 29 clearly has a more meat- and fish-based diet than any other individual at Milton. Although Burial 29 is an unidentified female, with no historical information associated, she is also unusual in terms of material culture, as her coffin furniture (handles etc.) was far more ornate and of higher quality metal than the others found at Milton. This hints that she was perhaps a wealthier individual, which may explain her higher consumption of meat.

Burials 21 and 23 have the lowest δ^{15}N values and therefore potentially the lowest contribution of meat to their diet. This may superficially be interpreted as lesser access to meat resources for certain individuals in Milton. We note that these two individuals are the individuals for whom we sampled long bones rather than ribs. Long bone collagen turnover is a much longer process than for highly trabecular bones such as ribs (Hedges et al., 2007), and therefore these lower values may partially reflect dietary signals from a lower δ^{15}N diet prior to emigration. We aim to build on this pilot study with further analyses of dentine collagen, which is laid down in childhood, and hair which is forming close to time of death. This will give a clearer view on 'home' versus colonial diet.

We also acknowledge that our sample is potentially biased because we have only sampled unmarked graves. It is therefore likely that we have not examined the wealthiest members of this society, who are more likely to have had headstones. Perhaps unequal access to resources in Milton was more pronounced than our analysis suggests

Did Emigrants Improve Their Lot in Life?

Comparison of SJM values to contemporary samples from Britain shows clear differences, particularly in terms of δ^{15}N, with most individuals from contemporary Britain having higher δ^{15}N values, potentially indicating higher levels of meat consumption. However, if local baseline values are considered this interpretation does not hold. British baseline δ^{15}N values in both post-medieval (Müldner et al., 2005; Müldner et al., 2007; Fisher and Thomas, 2012) and modern (Heaton et al., 2007) systems have terrestrial baseline δ^{15}N values roughly 1‰ higher than the New Zealand baseline values used in this study. This elevated baseline is a relic of centuries of agricultural activity in Britain, with agricultural run-off, fertilization, forest clearance and tillage all contributing to higher δ^{15}N values in soils (Guiry et al., 2018; Brugam et al., 2017; Bogaard et al. 2007).

Consequently, δ^{15}N values in individuals living and eating in Britain are likely to be higher than New Zealand values even when similar amounts of meat were consumed. Figure 4 highlights the similarity in likely dietary components between the English sites and SJM. We believe that despite superficially higher δ^{15}N values in UK sites, terrestrial meat consumption is likely to have been of similar levels to Milton.

Individuals from London sites have higher δ^{15}N values than expected even when considering this higher δ^{15}N baseline (Lukin St, Spitalfields and Chelsea on Fig. 4). These high London values have previously been remarked upon by Beaumont et al. (2013), and may be partly due to the practice of saltmarsh grazing in the area (Britton et al.,2008). However, historical records also emphasize the regular consumption of marine fish and shellfish by the poor in the city (Ackroyd 2001; Picard 2005), and it seems likely that both of these factors result in the higher δ^{15}N values seen in London populations. Burial 29 is the only SJM individual whose δ^{15}N values indicate possible marine food input into the diet. The other Milton individuals do not appear to have been consuming marine fish to any great extent, contributing to their relatively lower δ^{15}N values compared with London populations.

This comparison illustrates the importance of local baseline knowledge. Historical cemetery populations generally do not have associated faunal remains, and thus dietary isotopic results are generally published without reference to a contemporary baseline (see Guiry et al., 2014 for a notable exception to this). This gap in the literature makes comparative studies, such as ours, difficult.

Evidence of Colonial or New Zealand Pākehā Food Identities

We expected that diet might reflect the reinforcement of a European food identity, with the desire to preserve culinary traditions leading to perseverance even in the face of economic disadvantage (as per Guiry et al., 2018). However, both archaeological and isotopic research elsewhere in the world has suggested that 18th and 19th century colonisation events, regardless of the population doing the colonising, are generally followed by the introduction of wild resources into the colonists' culinary repertoire (e.g. Reitz and Waselkov 2015; Hodgetts 2006). In North America this has been observed as resulting in a mixed diet, involving the synthesis of European and indigenous food sources. This ability to adapt local food economies was likely crucial to the success of the colonies, especially in the early years when European-style farming was still in its infancy (Hodgetts 2006).

Our results are consistent with this pattern. While the colonists may have held ideals of creating a new England (Sargeant 2001), with a farmed animal-based diet, their dietary isotopes and historical records show that their meat intake was bolstered by a significant proportion of freshwater fish and game, likely sourced from the wetlands around Milton. In other coastal colonial sites this use of local resources has included large quantities of marine resources (Reitz and Waselkov 2012; Pate and Anson 2012). Milton lies just 20 km from the coast so we might also expect to see this here. There are contemporary records of local Māori selling marine fish in nearby Dunedin and Kaitangata (West 2017), and the European fishing industry was also in full swing by the 1870s (Thomson 1877). However, the first fishmongers in Milton itself did not open until 1885 (Sumpter and Lewis 1949), some years after the death of these individuals. Lack of seafood in the early colonial Milton diet may relate to lack of supply chain to this rural settlement, or settler lack of expertise in fishing local waters (as described in West 2017). Alternatively, it could represent a cultural preference for other food types within a New Zealand pākehā food identity.

Many of the settlers to Milton came from the London area (Tokomairiro Project 60 2016), where marine fish was consumed regularly, particularly by the poor and Irish immigrants (Trickett 2006; Beaumont et al. 2013). However, our results show that this tradition was not carried forward into Milton society. The isotopic results from Milton may reflect a stigma associated with the consumption of marine fish in New Zealand as being associated with Māori lifestyle or poverty (Galletly 2010; Holland 2013). This stigma did not extend to the more expensive imported marine fish of familiar European species, for example herring and mackerel (Johnson 2004; Galletly 2010). Purchasing these imported fish was a luxury, however, and was likely beyond the means of the working-class inhabitants of Milton, with the possible exception of Burial 29 (who has the highest $\delta^{15}N$).

Potential Issues with isotopic reconstruction of diet in an NZ context

All dietary reconstructions are reliant on the accuracy of baseline foodweb data to create good models. As discussed throughout this article, contemporary foodweb data for this time and place is scarce. Decisions made regarding baseline affected the source values used and using food web data from colonial middens may result in different interpretations of diet. Sampling from New Zealand colonial middens should be a priority for informing future work, and we hope that this article serves to show historical archaeologists the value of preserving faunal material for isotopic studies. Generally, dietary modelling benefits from use of dental $\delta^{13}C_{apatite}$ values alongside $\delta^{13}C_{collagen}$. This gives insight into whole diet as well as protein input (Ambrose and Norr 1993). However, in this instance we know that colonial movement and dietary change likely occurred between formation of the dental enamel and bone collagen, and bone apatite values are likely affected by diagenetic change of bones in the burial environment. We therefore cannot add $\delta^{13}C_{apatite}$ values to our models.

Conclusion

This study presents the first isotopic data from a European New Zealand colonial setting. All the individuals analyzed showed a reliance on C_3 crops and terrestrial meat sources. Comparison with contemporary populations at 'home' in England, suggests that the diet of the individuals interred in the SJM cemetery was similar to that of their contemporaries, but with less input from marine resources than anticipated. This lack of seafood in the diet may be symptomatic of a group of settlers lacking in the expertise to exploit marine resources. Alternatively, it may signify an aversion to a resource that early European settlers may have considered to be associated with the indigenous Māori populations or settlers of a lower-class.

We recognise that the SJM cemetery sample is not a large one and these results are presented as a pilot study. We intend to conduct further work on the other surviving tissues (teeth, hair, and nails) to further elucidate diet at SJM. However, more isotopic work also needs to be conducted on other New Zealand colonial cemetery sites and faunal samples before the trends identified here can be considered New Zealand-wide phenomena, or even regional characteristics. This study has laid the foundation for future studies examining New Zealand colonial experience in detail and revealing biological aspects of everyday people's lives which have been lost to history.

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Figure Captions

FIGURE

1. The location of Milton (*grey circle*) shown with reference to the major cities of New Zealand (black circles). Inset shows plains used as agricultural land after colonisation.

2. Burial 6 with inset showing legible writing on coffin plate which, once cleaned, identified the individual (photo by author, 2016).

3. SJM dietary isotope data (*white circles*), corrected for diet-tissue offset and presented against published values for New Zealand food resources (with 95% confidence ellipses). Values used are reported in full in Supplementary Table 1.

4. Comparative UK population isotope data, corrected for diet-tissue offset and plotted against foodweb data from northern English post-medieval contexts (Fisher & Thomas, 2012; Müldner & Richards, 2005). This data is the closest published proxy for nineteenth century UK foodwebs.

Tables and Figures

TABLE 1

DEMOGRAPHIC, PATHOLOGICAL AND ARCHAEOLOGICAL INFORMATION FOR ALL SJM ADULTS. INDIVIDUALS IN ITALICS DID NOT YIELD GOOD COLLAGEN AND SO WERE NOT ANALYZED FURTHER IN THIS STUDY.

Individual	**Age**	**Sex**	**Identified individual?**[*]	**Relevant historical information**	**Pathology**	**Coffin furniture**
SJM B4	Mid (44 years)	M	Y	Town doctor, originally from Germany. Resident in NZ for 14 years prior to death.		Not ornate. Poor quality iron
SJM B6	Mid (36 years)	F	Y	Wife of the doctor (B4). Resident in NZ for 21 years prior to death.	Maxillary sinusitis	
SJM B7	Old	M?	N	None		Ornate, good quality iron
SJM B10	Old	F	N	None		Ornate, poorer quality iron
SJM B11	Mid	M	N	None	Severe perimortem trauma of femur, antemortem fractures of ribs, possible fracture of left elbow	
SJM B13	Mid?	M	N	None	Three healed rib fractures, possible antemortem trauma to right femur	
SJM B21	Mid (42 years)	M	Y	Ex-goldminer, possibly became the town butcher. Death from tuberculosis after	Osteological evidence for tuberculosis in pelvis and skull	Not ornate. Poor quality iron

				prolonged period as invalid. Resident in NZ for 12 years prior to death.		
SJM B22	Adult	F	N			
SJM B23	Unknown	F?	N	None		
SJM B29	Unknown	F	N	None	Rib and limb bone pathology suggestive of residual rickets.	High quality iron, ornate

*= These individuals were identified by the preservation of writing on the coffin plates which comprise the name, year of death and age at death. The death certificates were obtained for all these individuals and cause of death is known.

TABLE 2
COMPARATIVE SITE LOCATIONS, SAMPLE NUMBERS, TIME PERIOD REPRESENTED AND PUBLISHED SOURCES USED IN THIS STUDY.

Comparative site	Location	Time period represented	Number in sample	Inferred status of sample group	Source
St. Luke's	Chelsea, London, England	1750-1890	31	Upper class	Trickett (2006)
St. Mary and Holy Trinity	Coventry, England	1776-1890	13	Lower class	
St. Martin's-in-the-Bull Ring	Birmingham, England	1720-1890	18	Upper class	Richards (2006)
Spitalfields	London, England	1800 - 1850	57	Mixed status	Nitsch et al. (2010)
Lukin Street Cemetery	London, England	1843-1854	66	Lower class	Beaumont et al. (2013)
Kilkenny Workhouse	Kilkenny, Ireland	1847-1861	14	Lower class famine sample	

TABLE 3
ISOTOPIC RESULTS FROM THE SJM SAMPLE. THREE INDIVIDUALS (B7, B13 AND B22) WERE EXCLUDED FROM THE ANALYSIS DUE TO LOW COLLAGEN YIELDS.

Individual	Bone sampled	$\delta^{13}C$ (‰, VPDB)	Wt %C	$\delta^{15}N$(‰, Air)	Wt %N	C:N
B4	Temporal	-20.0	30.2	11.1	10.6	3.3
B6	Lumbar vertebra	-19.8	30.0	10.9	10.1	3.5
B7	R. femur	*Yield < 1%, no data*				
B10	Rib	-20.5	41.8	10.0	13.8	3.5
B11	Rib	-19.0	39.8	11.0	13.5	3.5
B13	Rib	*Yield < 1%, no data*				
B21	R. ulna	-19.2	35.7	10.2	12.5	3.3
B22	R. Femur	*Yield < 1%, no data*				
B23	L. Femur	-20.1	41.2	9.9	14.9	3.2
B29	Thoracic vertebra	-18.8	32.5	12.8	11.2	3.4
Mean		**-19.6**		**10.8**		

FIGURE 1

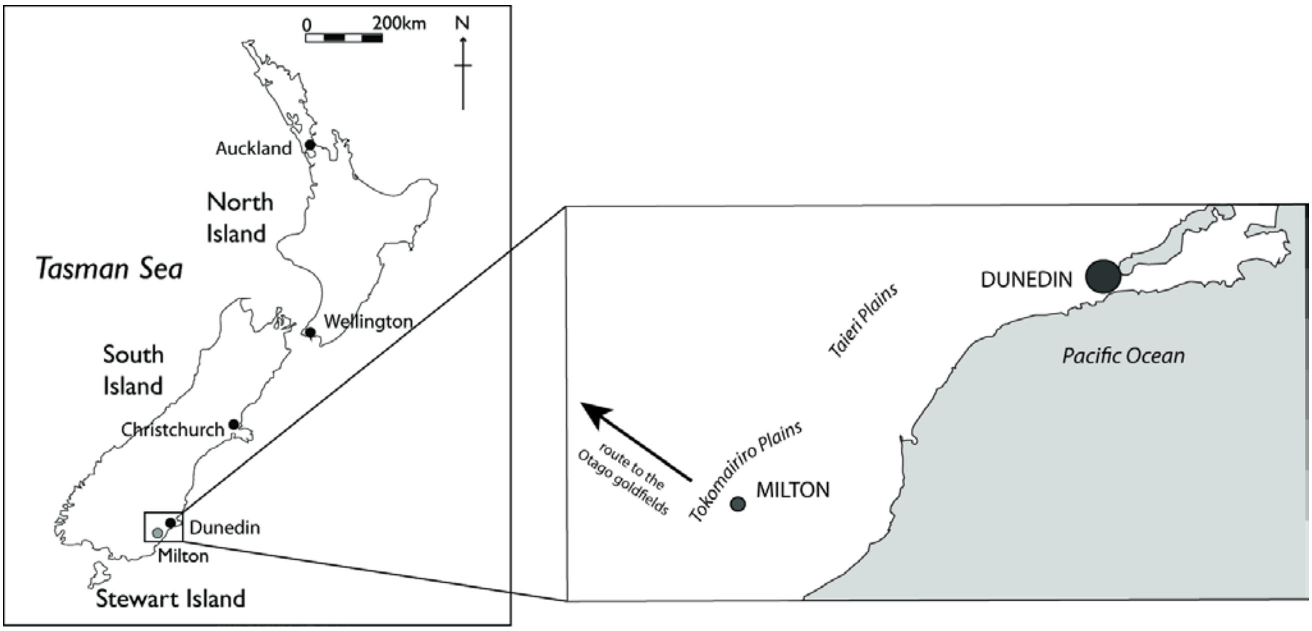


FIGURE 2

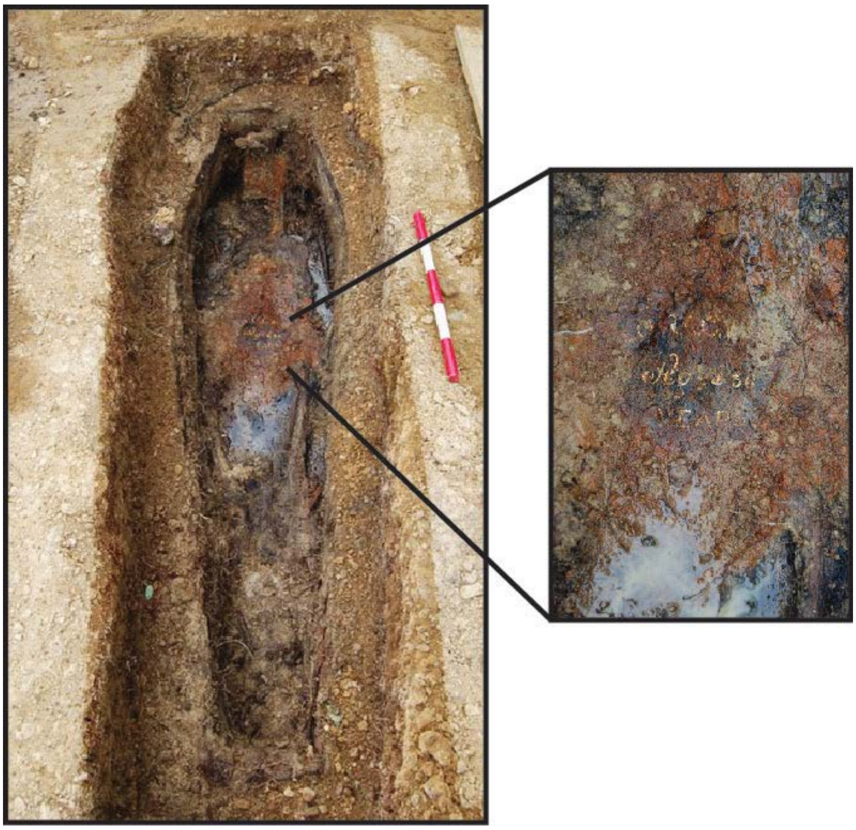


FIGURE 3

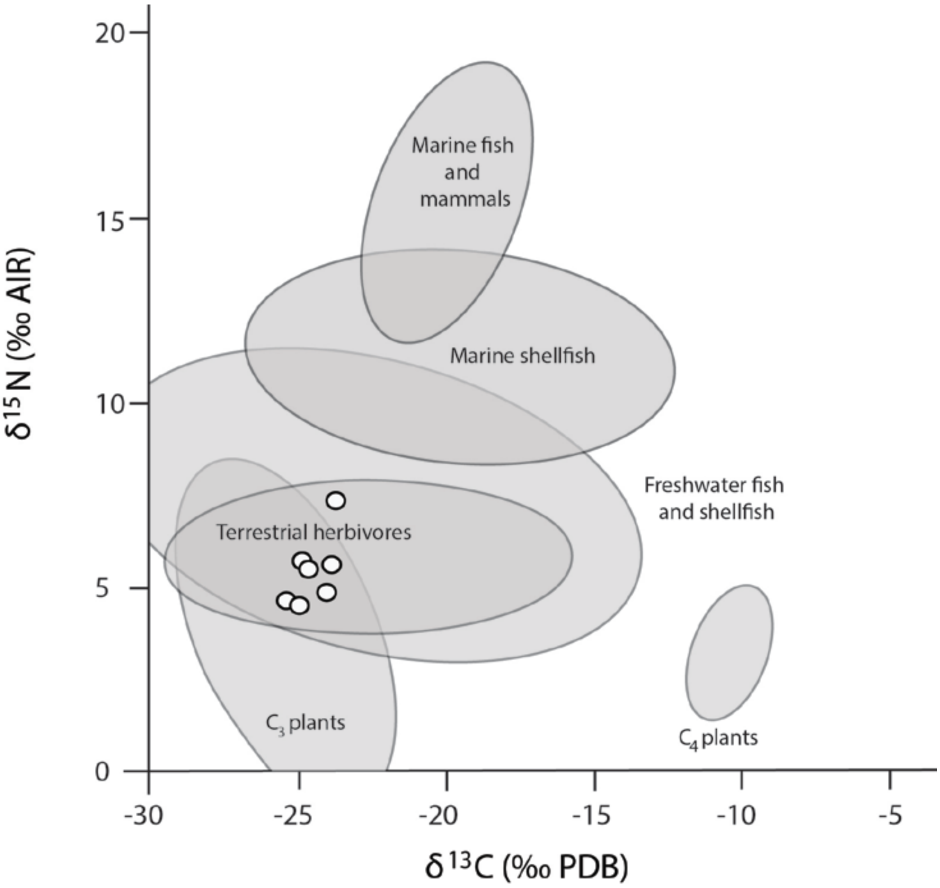
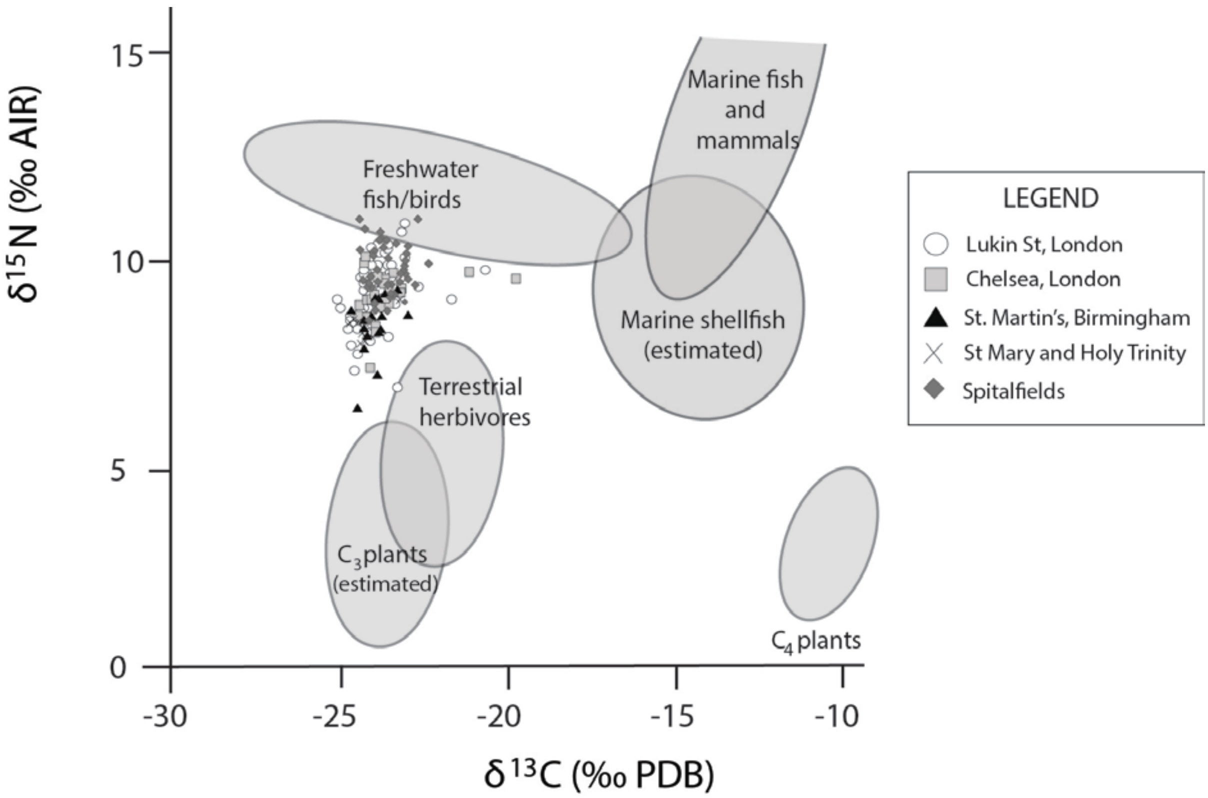


FIGURE 4 Comparative UK population isotope data, corrected for diet-tissue offset and plotted against foodweb data from northern English post-medieval contexts (Fisher & Thomas, 2012; Müldner & Richards, 2005). This data is the closest published proxy for nineteenth century UK foodwebs.



Disclosure of Potential Conflicts of Interest

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