Title

Integrating Stable Isotope and Zooarchaeological Analyses in Historical Archaeology: A Case Study from the Urban Nineteenth-Century Commonwealth Block Site, Melbourne, Australia.

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Integrating Stable Isotope and Zooarchaeological Analyses

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Abstract

This paper presents the first use of bone collagen stable isotope analyses for the purpose of reconstructing historical animal husbandry and trade practices in Australia. Stable carbon and nitrogen isotope analyses of 51 domesticate and commensal specimens demonstrate that meats consumed at the mid to late nineteenth-century Commonwealth Block site in Melbourne derived from animals with a diverse range of isotopic signatures. Potential factors contributing to this diversity including animal trade and variability in local animal husbandry practices are discussed. From these results we suggest that stable isotope-based paleodietary reconstructions have significant potential to illuminate a variety of human-animal relations in Australia's historical period as well as other New World contexts.

Keywords

Stable isotopes, animal husbandry, trade, Australia

1 Introduction

Stable isotope analyses have become a well-established technique in archaeological science for reconstructing past dietary regimes and patterns in mobility (for reviews see Katzenberg 2008; Pate 1994; Sealy 2001). The aim of this paper is to emphasize and explore the potential of applying stable isotope analyses to questions of human-animal relations in historical contexts in Australia through the use of a case study - the analysis of faunal material from the Commonwealth Block site in Melbourne (Figure 1).

An outline of theoretical underpinnings for stable carbon and nitrogen isotope analysis of archaeological bone collagen is followed by a brief overview of previous stable isotope research with particular attention to studies focusing on Australian archaeology, historical contexts, and human-animal relations. In this context, a case study using the first stable carbon and nitrogen isotope analyses aimed at reconstructing animal husbandry and trade in an Australian context is presented.

The case study consists of stable carbon and nitrogen isotope values obtained from the bone collagen of 51 specimens from eight introduced species recovered during archaeological excavations at the Commonwealth Block site in Melbourne, Australia. Discussion focuses on the potential for stable isotope work to identify variation in local animal husbandry practices and/or the presence of imported animals and animal products.

2 Stable Isotope Theory

Stable isotope analysis of human and animal remains is based on the notion that ‘you are what you eat’ and that certain kinds of food stuffs can have distinguishable isotopic compositions (Katzenberg 2008). Collagen is the primary component of bone protein, and may be constructed

from a variety dietary constituents. However, bone collagen stable isotope values may more strongly reflect dietary protein relative to carbohydrates and lipids (Ambrose and Norr 1993; Tieszen and Fagre 1993a).

Stable carbon isotope ratios, ^{12}C to ^{13}C (shown as a $\delta^{13}C‰$ value relative to the PDB standard [Craig 1957]), are capable of distinguishing between consumption of foods made up of carbon routed through plants with either C_3 or C_4 photosynthetic pathways (Van der Merwe and Vogel 1978). C_3 and C_4 plants produce isotopically lighter and heavier $\delta^{13}C$ values, respectively. Marine plants draw on a carbon source that is isotopically heavier (by ~7‰) than terrestrial plants and, for this reason, $\delta^{13}C$ values may also help distinguish between consumption of plants from marine *versus* terrestrial ecosystems (Chisholm et al. 1982). Due to variations in the dissolved bicarbonates in differing upstream and local geologies (e.g. Hitchson and Krouse 1972), freshwater aquatic (lacustrine and riverine) plant $\delta^{13}C$ values can vary widely.

Stable nitrogen isotope ratios, ^{14}N to ^{15}N (shown as a $\delta^{15}N‰$ value relative to the AIR standard [Mariotti 1980]), become elevated by between 3 and 5‰ at each ascending trophic level of an ecosystem (Ambrose and DeNiro 1986; DeNiro and Epstein 1981; for review see Hedges and Reynard 2007). Based on this relationship, $\delta^{15}N$ values can provide an indication of an animal's trophic position (i.e. herbivore, omnivore, carnivore). This trophic elevation also holds for infants that feed on their mother's breast milk, with the former having $\delta^{15}N$ values that are elevated over the latter (e.g. Schurr 1998). As food chains can be substantially longer in marine and freshwater ecosystems, in conjunction with $\delta^{13}C$, $\delta^{15}N$ values are also a useful indicator of marine, relative to terrestrial, dietary intake (Schoeninger et al. 1983). As the baseline data used in this study shows (Pate et al. 1998), it is also important to note that a variety of environmental

factors, particularly aridity, can have an effect on the $\delta^{15}N$ values of animals (Anson 1996; Heaton and Vogel 1987; for review see Vanderklift and Ponsard 2003).

3 Literature Background

Isotopic research has been developed in Australia largely through the efforts of Donald Pate and his students (Pate 2000) working in South Australia. Advances involving ancient and modern bone, tooth, and plant materials include dietary (Hedges et al. 2007; Hobson and Collier 1984; Collier and Hobson 1987; Pate 1995b; 1997a 1998a,b), mobility (Pate 1995a), and provenience (Pate et al. 2002) analyses of aboriginal human remains (McDonald et al. 2007); characterization of bone collagen preservation (Pate 1997b; Pate 1998c); the construction of an isotope baseline for the region (Anson 1996, 1998, Noble 1995; Pate and Anson 2008; Pate and Krull 2007; Pate and Noble 2000; Pate and Schoeninger 1993; Pate et al. 1998); reconstructing animal seasonality (Brookman and Ambrose 2012; Fraser et al. 2008); and the use of animals to understand past climate and environments (Ayliffe and Chivas 1990; Forbs et al. 2010; Gröke 1997a,b; Gröke et al. 1997; Murphy et al. 2007; Prideaux et al. 2009; Roberts et al. 1999).

Stable isotope analysis has also been constructively applied to questions about historical-period human activities. For instance, in North America successful analyses have been conducted on human diet (Carter et al. 2004; Ellerbrok et al. 2012; Grimes 2013; Katzenberg 1991a,b; Katzenberg et al. 2000; Page 2007; Price et al. 2012; Sparks et al. 2012; Ubelaker and Owsley 2003; Vanderpool 2011; Varney 2003, 2007), mobility (e.g. Goodman et al. 2009; Schroeder et al. 2009; Schwarcz et al. 1991), weaning practices (e.g. Katenberg and Pfeiffer 1995; Schurr 1998), and life history reconstructions more generally (Krigbaum et al. 2013; Owsley et al. 2006; Wescott et al. 2010). Similar research conducted on Australian remains has been sparse (Roberts

and Pate 2012) and, to our knowledge, presently there is one published study featuring stable analyses of a historical archaeological context in Australia (Pate and Anson 2012). Pate and Anson (2012; Anson 2004:290-295; Taylor 2001), used stable carbon and nitrogen isotope analyses of bone collagen from 54 individuals interred at St. Mary's Cemetery in Adelaide to reconstruct nineteenth-century dietary practices of a colonial working class population. From these analyses the authors were able to estimate the proportion of dietary protein derived from terrestrial and marine meats as well as vegetable sources and illuminate dietary differences between men and women. Based on the valuable contribution of this and similar research conducted in the Americas (above), South Africa (e.g. Cox et al. 2001; Cox and Sealy 1997; Sealy1993), and Europe (e.g. Beaumont et al. 2013), additional stable isotope research on historical archaeology in Australia would appear to have great potential.

Although it has long been recognized that stable isotope analyses of archaeological faunal remains is a productive avenue of research (e.g. Burleigh and Brothwell 1978), analyses of animal diets, mobility, and life histories *per se* have received comparatively little attention. Recently, however, there has been mounting interest in gaining information from work on archaeological faunal remains (Birch 2013), especially domesticates. For instance, stable carbon and oxygen isotope analyses of tooth enamel apatite can be used to assess seasonality of birth of livestock (e.g. Balasse et al. 2012; Frémondeau et al. 2012; Towers et al. 2011); stable nitrogen isotope analyses of tooth dentine collagen can be used to identify weaning ages (Balasse and Tesset 2002; Guiry et al. in review); and, in some cases, stable nitrogen isotope analyses of modern and archaeological plants can be used to identify historical field manuring and fertilizing patterns (e.g. Bogaard et al. 2007; Commisso and Nelson 2010; Kanstrup et al. 2011). Additional stable isotope applications include the identification of strategies for omnivore feeding (e.g. Arge

et al 2009; Hamilton and Thomas 2012; Rawlings and Driver 2010), herbivore foddering (e.g. Fisher and Thomas 2012; Madgwick et al. 2012; Peck-Janssen 2006:63-65) and grazing (e.g. Balasse et al. 2006; Britton et al. 2008; Mulville et al 2009), animal mobility (e.g. Millard et al. 2011; Pearson et al. 2007), and animal management practices more generally (e.g. Finucane et al. 2006; Nelson et al. 2012; Oelze et al. 2011). This research has largely focused on prehistoric archaeological contexts and few studies have taken, as their primary goal, an understanding of human-animal relations in historical New World and colonial contexts in North America or South America (Guiry et al. 2012a,b, in review; Klipple 2001). To our knowledge there have been no such studies conducted in Australia.

Guiry and colleagues (2012a, in review) have recently argued that there are a variety of reasons to suspect that numerous, relatively unique, human-animal relations occurring during the historical period are ideally suited for study using stable isotope techniques. For instance, new processes that may have altered animal diets and mobility (and may thus produce distinctive isotopic signatures) include: the expansion of livestock production in conjunction with other industrial processes (e.g. Guiry et al. 2012b; Rixson 2000:289; Wiseman 2000:8); the long-term preservation and long-distance trade of animal products (e.g. Staniforth 2000); and the introduction of more stringent meat quality regulations for animal husbandry and resulting products (e.g. Rixson 2000:195).

4 Historical Background of the Commonwealth Block Site

The Commonwealth Block site (also known as ‘Little Lon’ or ‘Casselden Place’) is located within Melbourne’s Central Business District and is bounded by Spring, Lonsdale, Exhibition and Little Lonsdale Streets (Figures 2). For a century (from roughly 1850 until 1950),

the Commonwealth Block site was a central city neighbourhood occupied by working-class residents together with small businesses and a few large factories. It was in the late nineteenth century that the inner-city landscape transformed from a predominately residential area to a place for commercial and industrial businesses.

From the mid-nineteenth century, Little Lon was widely regarded as a slum, an area associated with crime, prostitution, and poverty (McCarthy 1989, 1990; Ryan 1979). Since 1979, the Commonwealth Block site has been the focus of historical documentary research and archaeological investigations (see Lane 1995; Long et al 2001; McCarthy 1989, 1990; Ryan 1979). Later assessments confirmed that Little Lon was a poor and crowded neighbourhood but it was not a place of outcasts (Godden Mackay Logan et al. 2004).

The Little Lon neighbourhood was occupied mostly by Europeans, especially English, Irish, and Scottish nationals. Chinese, Syrian, and other migrants started to replace European occupants in the early twentieth-century. Occupations of owners and tenants included grocers, butchers, labourers, furniture manufacturers, tailors, dressmakers, bootmakers, painters, tobacconists, drapers, confectioners, and coal dealers.

Faunal specimens used in this study were obtained from the 2002-03 Casselden Place Archaeological Excavation collection (site B in Figure 2). Over 300,000 artefacts ranging from domestic ceramics to building materials were recovered, catalogued, and analysed during and after the excavation. Results of the excavation were presented in a four volume report (Godden Mackay Logan et al. 2004) and later published as a special issue in the International Journal for Historical Archaeology (Murray 2006). One of the contributions to this special issue discussed the consumption and dietary patterns at Casselden Place during the late nineteenth century. Based on the faunal and shell remains sampled from specified “hotspots” of the site, the faunal

analysis revealed that the Casselden Place inhabitants consumed fine cuts of meat and also cheaper varieties. Meat in the diet consisted mainly of mutton and some beef, large amounts of fish and oysters, small amounts of pork, mussels, rabbit, chicken, lamb and veal, and sometimes (although rarely) turkey and goose (Simons and Maitri 2006).

At the time of writing, Harpley is re-analyzing the Casselden Place faunal remains from all cesspits and rubbish pits (including the deposits from the butcher shop which were not originally analyzed) as part of her PhD research. Over 7,100 fragments (about 15% of the original faunal collection) were sampled. Preliminary findings indicated that sheep/goats (caprines) were the dominant species, followed by cows, fishes, chickens, rats, rabbits, dogs and pigs. Cat remains as well as other avian species, such as duck and goose, were also identified.

Faunal remains analysed here have been selected based on the sub-sample of the collection under re-analysis by Harpley and, based on datable materials such as ceramics and coins, specimens were dated to 1850-1890.

5 Methods

Faunal remains used in this study (n=55) were selected based on minimum number of individual counts to ensure that resulting isotopic data do not overlap. Sample selection was aimed at acquiring a maximum number of specimens from the major livestock species in a subset of the fauna collection made available to us at La Trobe University. This resulted in the sampling of bone from a total of 15 cesspits (Figure 3, Table 1), constructed of a variety of materials. Thus, for this preliminary project, cesspit location, type, and contents were not considered during sampling. Bone sampling and collagen extractions were conducted at the Molecular Archaeology Laboratory at La Trobe University, Australia. Bone samples of between 100 and 250 mg were

cut from generally well preserved bone using a diamond surfaced Dremel cut wheel and abraded using a dental bur to remove adhering surface contamination. Collagen extractions followed procedures laid out by Richards and Hedges (1999) and modified as seen in the work of Honch and colleagues (2006) and Müldner and colleagues (2011). Following Jørkov and colleagues, (2007), an NaOH pretreatment was not used in this study. In brief, samples were demineralized in 0.5M hydrochloric acid (HCl) at temperature of 4ºC. The remaining collagen pseudomorphs were gelatinized on a heating block at 70ºC for 48 hours in water adjusted to a pH of 3 using 0.5M HCL. Resulting gelatins were centrifuged and purified using 5-8μm mesh Ezee® filters. Purified gelatins were then frozen and lyophilized in a freeze dryer for 48 hours and sealed until isotopic analysis.

Isotope characterization was conducted at the CREAIT Stable Isotope Laboratory at Memorial University of Newfoundland, Canada. Stable carbon and nitrogen isotope analyses were performed on 1mg of collagen using a Carlo Erba NA 1500 Series II Elemental Analyzer® coupled via continuous flow to a Thermo Electron Delta V Plus® Gas Source Isotope Ratio Mass Spectrometer. Based on Protein B2155 standards (n=5), the instrumental error (1σ) was ±0.05‰ for $\delta^{13}C$ and ±0.12‰ for $\delta^{15}N$. Collagen integrity was investigated using three criteria (Van Klinken 1999). Stable isotope values were considered acceptable if they derived from collagen with a yield above 2%, percent elemental carbon and nitrogen values above 18 and 6%, respectively, and carbon to nitrogen ratios (C:N) falling between 2.9 and 3.6 (DeNiro 1985; Van Klinken 1999).

6 Results and Discussion

Stable carbon and nitrogen isotope ratios along with associated collagen integrity data can be found in Table 2 and Figures 4 and 5. Table 3 shows relevant data from a previously published stable isotope baseline for southern Australia (Pate et al. 1998; see also Anson 1996).

6.1 Collagen Quality

The vast majority of specimens sampled (n=51 of 55) produced valid $\delta^{13}C$ and $\delta^{15}N$ data. Three pig (*Sus domesticus*) specimens, each the sole specimen from their respective cesspits, produced unacceptable collagen yields and were not subjected to isotopic measurement. Data from these samples are not presented here. All remaining collagen samples produced C:N ratios within the acceptable range of 2.9 to 3.6. Carbon and nitrogen concentrations were more variable. While most samples showed carbon and nitrogen concentrations well above their respective cut-off values, one cow (*Bos Taurus*) specimen, MARC 1535 show evidence of poor collagen integrity.

This variability in preservation is interesting in light of the variety of archeological contexts sampled, all of which were built with the same intent – refuse disposal. Samples from four separate cesspits failed to satisfy collagen integrity criteria indicating that collagen preservation can vary between cesspits at the same site. Collagen preservation can also vary within an individual cesspit deposit as evidenced by the range of carbon and nitrogen concentration values produced by, for example, samples from cesspit 2.722. The type of material used to construct the lining of a cesspit does not appear to affect preservation. All three types of cesspit construction, chisel-dressed bluestone lined pits (e.g. 2.722), wooden barrel lined pits (e.g. 3.177), and unlined pits (2.512 and 2.290), produced both valid and compromised collagen

data. Overall, there does not appear to be any clear pattern underlying difference in collagen integrity between samples.

6.2 The Isotopic Baseline

Interpretation of $\delta^{13}C$ and $\delta^{15}N$ data for the Commonwealth Block site faunal remains is aided by an extensive bone collagen stable isotope baseline compiled by Anson (1996, 1998; Pate et al. 1998). Of particular interest are a substantial number of modern eutherian mammals (rabbits [*Oryctolagus cuniculus*], sheep [*Ovis aries*], and cattle) collected from four sites strategically selected along a north-south transect (east of the South Australia-Victoria/New South Wales boarder). These analyses provide an understanding of $\delta^{13}C$ and $\delta^{15}N$ variation within animals in different precipitation regimes (see Table 3 and Figure 1). In the temperate wet south, a climatic environment similar to that of the region surrounding the Commonwealth Block site, Anson (1996) analyzed animals from Mount Gambier and Karte. From the warmer arid north, animals were analyzed from Plumbago Station and Innamincka. Results show that samples from the southern sites produced systematically lower $\delta^{13}C$ and $\delta^{15}N$ values reflecting the dominance of C_3 plants and relatively low soil and foliar $\delta^{15}N$ values. Animals from the warmer arid north were found to have more variable and higher $\delta^{13}C$ and $\delta^{15}N$ values reflecting the dominance of C_4 grasses and elevated soil and foliar $\delta^{15}N$ values. Melbourne is roughly 400km east of Mount Gambier and 500km southeast of Karte and falls into a similarly C_3 dominated vegetation and precipitation regime (Hattersley 1983; see Figure 1). For this reason, geographically and environmentally speaking, the stable isotope data from faunal bone collagen from the Mount Gambier and Karte sites provide the most appropriate available comparative baseline for livestock raised locally around, and consumed at, the Commonwealth Block site.

It should also be noted that stable carbon and nitrogen isotope ratios can vary on temporal scales (e.g. Van Klinken et al. 2000:41-42; Gröke 1997b). For instance, global anthropogenic the carbon emissions from the burning of fossil fuels has depleted atmospheric $\delta^{13}C$ composition by roughly 1.5‰ over the past 250years (Marino and McElroy 1991; see also Tieszen and Fagre 1993b). However, considering the close geographical and temporal relationship between the Commonwealth Block site and Anson's (1996, 1998; Pate et al. 1998) baseline data set such isotopic variation may not significantly influence interpretations.

6.3 Herbivores

6.3.1 Rabbits

Rabbits were introduced to Australia in the eighteenth-century and spread rapidly afterwards (Stodart and Parer 1988). For this reason, it is relatively safe to assume that faunal remains from this herbivorous eutherian species collected from mid-late nineteenth-century Commonwealth Block site contexts do not derive from imported animals and should therefore provide a local baseline for the area surrounding the Commonwealth Block site.

It is important to note that rabbit bone collagen may not reflect dietary intake in precisely the same way as larger mammals analyzed in this study. Anson's (1996, 1998) study of stable isotope variation between Australian rabbits and other eutherian mammals (cattle and sheep) suggested that rabbits tend to produce $\delta^{15}N$ values that are systematically lower (by between 1.5 to 4‰) than sheep and cattle. Cattle and sheep exhibit a foregut fermenting digestive physiology and derive a large percentage of their complete protein intake from gut microbes, which can place them as much as a trophic level above none foregut fermenting fauna such as rabbits (see Coltrain et al. 2004). Additionally, Anson (1996:98) speculates that this isotopic difference may

reflect the lower metabolic rate of fossorial animals or their practice of caecotrophy. Despite this slight difference, Anson's study clearly shows that rabbits, sheep, and cattle feeding in the same environment will share generally similar $\delta^{13}C$ and $\delta^{15}N$ values and, for this reason, we use archaeological rabbits captured or raised in the vicinity of the Commonwealth Block site as a local isotopic baseline for terrestrial herbivores.

Rabbits (n=5) from the Commonwealth Block site produced a relatively tight cluster of $\delta^{13}C$ and $\delta^{15}N$ values that average -22.2±1.0‰ (ranging 2.3‰) and 4.7±0.5‰ (ranging 1.0‰), respectively. These data are consistent with a local ecosystem with abundant C_3 plants for browsing and possibly grazing.

6.3.2 Cattle and Sheep

Cattle and sheep, on the other hand, produced an extreme range of isotope values (~13‰ for $\delta^{13}C$ and ~5‰ for $\delta^{15}N$) and suggest a diverse set of dietary intake regimes. This variation could reflect: A) tremendous variability in local animal husbandry practices (including the import of exotic fodder); B) a sample population including some imported specimens deriving from heterogeneous origins; or C) considerable variation in local isotope ecologies.

It appears that at least some of these specimens probably derive from animals that were locally raised. Considering expected local isotope values, it is possible to describe one group of domesticate herbivores (Group A), four sheep (MARC 1508, 1509, 1511 and 1513; mean $\delta^{13}C$ = -20.5±0.8‰ and $\delta^{15}N$= 8.1±0.7‰) and four cattle (MARC 1547, 1550, 1551, and 1552; mean $\delta^{13}C$ = -20. 2±0.7‰; and $\delta^{15}N$ =7.4±0.5‰), which have statistically indistinguishable stable isotope values (One Way ANOVA, Post Hoc Bonferroni test, P> 0.05). These values are consistent with a diet deriving from the same environment as rabbits from the Commonwealth

Block site. In particular, together these cattle and sheep specimens (n=8) have mean $\delta^{13}C$ (20.3±0.7‰) and $\delta^{15}N$ (7.8±0.7‰) values that are ~2 and 3‰ higher, respectively, than those of the Commonwealth Block site rabbits. This is similar to the offsets between rabbits and domestic herbivores observed by Anson (1996) and Pate and colleagues (1998) at Mount Gambier and Karte. The 2‰ difference between livestock and rabbits in $\delta^{13}C$ is difficult to explain without detailed records of historical vegetation regimes in the Melbourne region but may, in addition to differing digestive physiologies, reflect the incorporation of marginally more C_4 plant materials into sheep and cattle diets. This could result from a species specific preference for differing fodder or habitation of regions with slightly different isotopic compositions (e.g. relatively fewer C_4 grasses and forbs consumed by rabbits). Despite the offset in $\delta^{13}C$ values between rabbits and Group A herbivores we find the most parsimonious interpretation to be that these animals represent livestock that was locally raised (see also Section 6.3.2.1). If this is the case we can suggest that some of the beef and mutton consumed by residents of the Commonwealth Block site derived from animals raised in pastures in the general vicinity of the developing city and that these pastures were typically composed mainly of C_3 plants with a minor presence of C_4 species.

Considering the herbivorous domesticates that do not have expected local values (Group B), three sheep (MARC 1510, 1512, and 1553; mean $\delta^{13}C$ = -16.4±0.5‰ and $\delta^{15}N$= 6.1±0.9‰) and four cattle (MARC 1533, 1546, 1548, and 1549; mean $\delta^{13}C$ = -13.8±3.9‰; $\delta^{15}N$=5.6±1.9‰), this group has isotopic signatures that are significantly different (One Way ANOVA, Post Hoc Bonferroni test, $P< 0.05$ [significance obtains when outlier MARC 1548 is removed]) from the $\delta^{13}C$ values of Group A specimens. The animals in Group B have been husbanded in an area or areas with a comparatively depleted $\delta^{15}N$ baseline (relative to Group A

animal) and ^{13}C enriched plants resulting in bone collagen $\delta^{13}C$ values between -17.6‰ and -8.4‰.

There are a number of possibilities that might explain these differing isotopic signatures. Higher $\delta^{13}C$ values might be caused by substantial grazing in more arid regions with pastures dominated by C_4 grasses such as those found further north towards the arid interior of the country (see Hattersley 1983). However, both wild and domesticate herbivores from modern and archaeological faunal assemblages from these regions show a concomitant elevation in $\delta^{15}N$ values (see Plumbago Station and Innamincka data in Figure 5; Anson 1996, 1998; Anson and Pate 2008; Pate et al. 1998) that is not observed in the Group B individuals. Only one cow specimen (MARC 1549) produced $\delta^{13}C$ and $\delta^{15}N$ values that might be consistent with this interpretation and it is possible that this individual was husbanded in Australia in a more arid region.

Alternatively, Group B herbivores could have simply been raised in an area with anomalously low soil and foliar $\delta^{15}N$ values. Gröke (1997b), for instance, observed very low $\delta^{15}N$ values in late Pleistocene fauna from Henschke Cave. These findings were difficult to explain, however, due to the cave site's close geographic proximity to Mount Gambier, the area from which Anson (1996; Pate et al. 1998) obtained much higher faunal $\delta^{15}N$ values, similar to those of the first group of herbivorous domesticates discussed above. In this context Gröke (1997b) argues that a later increase in soil nitrogen isotope values has affected the region and that $\delta^{15}N$ values of later modern fauna reflect this change.

Another possibility is that some animals from Group B were raised partly on aquatic or terrestrial plants from the local coastline. A diet focusing largely on low trophic level aquatic plants could theoretically produce comparatively low $\delta^{15}N$ and high $\delta^{13}C$ values (Balasse et al.

2005, 2006), although there is relatively little published literature analyzing this possibility. Recent research focusing on coastal salt marsh grazing sheep, furthermore, suggests that such animal husbandry practices (though not necessarily focusing on aquatic plants) would result in elevated $\delta^{15}N$ values (Britton et al. 2008). A final potential alternative is that these animals were raised locally but were fed partly on imported C_4 grains grown in a region with a relatively low $\delta^{15}N$ baseline. This suggestion, however, seems highly improbable as Australia has ample pasture land.

In the context of the early colonial port of Melbourne, we find the most parsimonious interpretation to be that these specimens derived from animals that were imported to Australia either as livestock or cured-meat, having been raised in regions with a higher abundance of C_4 plants and lower $\delta^{15}N$ baseline than was characteristic of the Melbourne region.

If this is the case, the isotopic data can also begin to suggest potential origins for certain specimens. For instance, the most extreme example comes from one cow specimen (MARC 1548) that produced a $\delta^{13}C$ value reflecting a heavy reliance on C_4 plants such as maize or sugar cane, crops known to have figured prominently in North American cattle husbandry at that time. Similar $\delta^{13}C$ values have allowed for the rough approximation of cattle origin in other colonial archaeological contexts (Klipple 2001). Unfortunately isotopic studies of historical livestock raised in North America and other potential sites of origin are limited and more exploratory research is needed.

6.3.2.1 A Caveat

We also acknowledge that a diet consistent with the incorporation of resources available from a particular environment does not provide certainty that an animal was husbanded there.

This uncertainly might be addressed in two ways. First, further analyses could focus on additional modern and/or archaeological faunal remains which are known to have been raised locally to provide a more robust characterization of the region's historical isotopic baseline. However, for archaeological livestock samples it can be difficult to establish the origin of a faunal specimen with complete certainty, and for modern samples, differences between contemporary and historical livestock husbandry and agricultural land management practices may complicate direct comparisons. Nonetheless, these lines of support merit investigation. Secondly, additional application of stable sulfur and oxygen as well as radiogenic strontium isotope analysis (provenance oriented isotope techniques [Bentley 2006; Nehlich et al. 2012]) to these faunal remains may allow for the identification of non-local animals and more detailed suggestions about the origin of outliers.

6.4 Omnivores and Carnivores

Consideration of stable isotope data from omnivores and carnivores from the Commonwealth Block site might provide further insight into the question of local *versus* non-local domestic herbivores. Rats (*Rattus* sp.), commensal omnivores, from the site would have scavenged in and around the settlement and, for this reason, produce stable isotope values that might be considered a rough averaging of domestic refuse in the vicinity. Isotopic signatures from rats (n=7) cluster relatively tightly (mean $\delta^{13}C$ = -17.7±0.6‰ and $\delta^{15}N$= 10.2±1.0‰) and reflect a diet incorporating variable quantities of animal and plant protein with a dominant C_3 origin and a small contribution from of C_4 sources. Meanwhile, dogs (*Canis familiaris*; n=4) and cats (*Felis catus*; n=3) produce $\delta^{13}C$ (-18.4±0.5‰ and -17.9±0.8‰, respectively) and $\delta^{15}N$ (10.7±1.2‰ and 11.4±0.5‰, respectively) values that are statistically indistinguishable from

those of rats (One Way ANOVA, Post Hoc Bonferroni test, P> 0.05), though they fall at the higher end of the range of rat $\delta^{15}N$ values suggesting the consumption of relatively higher amounts of animal protein. This is consistent with the carnivorous diet of cats and more omnivorous feeding of dogs.

The sheep and cattle interpreted above as deriving from local animal husbandry (Group A) plot in-between those of local rabbits and omnivores/carnivores (see Figure 5), providing further support for the interpretation of their local origin. Similarly, those sheep and cattle (Group B) producing values outside the 'local' range between rabbits and omnivores/carnivores (i.e. with high $\delta^{13}C$ and low $\delta^{15}N$ values), represent non-local livestock, which were presumably less frequently consumed by scavengers such as rats, dogs, and cats. Given that the scavengers are likely to reflect what was available (and not particular dietary preferences) this would imply that the 'non-local' livestock was less frequently available than the local. Historical records of meat prices in nineteenth-century Melbourne are limited, but this tentative evidence for relatively restricted consumption of imported, possibly preserved, meats at the Common Wealth block might reflect the lower income of its residents. According to Timothy Augustine Coghlan (1918), a government statistician, fresh meat of all descriptions was inexpensive in Australian colonies. During the late nineteenth-century, the price of beef ranged from 2½d. to 4d. per pound, mutton averaged 2¼d. per pound and pork was usually sold at 6½d. per pound. However, the consumption of bacon, a cured meat, was not wide spread and relatively expensive in comparison (between 7d. and 8½d per pound).

Remaining omnivorous livestock domesticates, pigs (n=9) and chickens (n=8) produced variable $\delta^{13}C$ (ranging ~3 and 2.5‰, respectively) and $\delta^{15}N$ (ranging ~6 and 6.5‰, respectively) values but, unlike those of some (non-local; Group B) herbivorous domesticates, these fall within

the range that would be expected for animals raised in the vicinity of the Melbourne. Pigs and chickens have $\delta^{13}C$ (-19.7±1.5 and -19.1±0.9‰, respectively) values that are indicative of a predominately C_3 based diet and have $\delta^{15}N$ (9.7±2.0 and 11.5±2.6‰, respectively) values that range from a primarily vegetarian diet to one that might include a substantial intake of animal protein. If these animals were raised locally, this isotopic evidence suggests that swine and poultry husbandry practices involved the consumption (via scavenging and/or intentional feeding) of local offal, including table scraps and animal waste (i.e. unwanted entrails and body parts) from local livestock production. It is also possible, particularly in the case of two chickens (MARC 1524 and 1531) with highly elevated $\delta^{15}N$ values (14.4‰ and 14.6‰, respectively), that some of these animals were partially fed a diet consisting of marine or freshwater fish or perhaps the flesh of other chickens and livestock.

While it is unlikely that chickens would be regularly imported for immediate consumption, pigs and particularly cured-pork products were imported into the region to satisfy animal protein needs of the community (Staniforth 2000, 2007). A study (English 1990) of the remains of salt meats that were historically destined for Melbourne demonstrated that a wide variety of skeletal elements could be present in barreled pork products and, for this reason, traditional body part representation analyses of pig bone have not been able to ascertain the presence of imported pork products at the Commonwealth Block site using zooarchaeological techniques (Harpley unpublished data). Nonetheless, it remains possible that some of these specimens reflect animals that were raised and slaughtered elsewhere and procured by the colony through international or inter/intra colonial trade. This possibility might be assessed through the further analyses of these and other specimens form historical sites in and around Melbourne using stable sulfur, oxygen, and radiogenic strontium isotope analyses in addition to $\delta^{13}C$ and

$\delta^{15}N$ work. Interpretations of such data would also be aided by the additional analysis of comparative collections that include barreled salt-meat faunal remains with known origins such as those from shipwrecks (i.e. the *William Salthouse* [English 1990] or the *Sydney Cove* [Nash 2001]) or from localized sites such as industrial whaling stations (e.g. Lawrence and Tucker 2002) with well-characterized salt-meat faunal assemblages.

6.5 Significance

These preliminary findings could shed light on life for residents at the Commonwealth Block site, animal husbandry and food procurement practices in Melbourne and the surrounding region, and future methodological developments for historical archaeology and faunal analyses in Australia and abroad.

Food Procurement and Animal Husbandry at the Commonwealth Block site

These analyses provide interesting, if preliminary, clues about the foodways (from production, to procurement, to disposal) of some residents at the site. For example, rats produced stable isotope data suggesting that the majority of food refuse available to scavengers had isotopic signatures consistent with the locally produced food stuffs. This finding suggests that much of the food consumed and discarded by the Commonwealth Block site community was locally sourced. Likewise, data from local omnivores, pigs and chickens, are generally consistent with this local baseline but show more variable animal husbandry practices perhaps indicating a variety of small scale local livestock raising regimes based on household food scraps. Additional provenience oriented isotope techniques will be needed to assess this possibility.

Methodological Implications for Determining Meat Origins

This study (see also Guiry et al. 2012b; Klipple 2001; Varney 2003) suggests that in some contexts, and with varying degrees of resolution, it is possible to distinguish between imported animals and meat products and locally raised livestock – a distinction that may reflect social and economic factors such as the adequacy of local food supplies and emphases on maritime activities (Staniforth 2000, 2007). Our results have suggested that some animal products consumed at the Commonwealth Block site derive from imported livestock and/or probably, at least partly in the case of cattle (MARC 1548), from barreled salted beef. This provides additional confirmation and evidence for English's (1990) assertion not only that barreled salt-meats from historical periods contained bones that appear in the archaeological record (e.g. Crader 1990; Gurlday 1977), but also that at least some of the salt-meat products that were bound for Port Phillip did contain bone. Additionally, a capacity to separate barreled meat elements from locally butchered remains opens the way for new zooarchaeological analyses of Australian historical faunal remains. For instance, use of additional sulfur and strontium isotope techniques to more firmly identify elements from imported animal products, may allow for an assessment of the distribution of pig and cow skeletal elements that were included in barreled salt-meat consumed by colonists. This information remains unknown but could have a wide and crucial applicability for identifying the presence or absence of barreled salt-meat at other historical archaeological sites around the globe.

Tracing Intra-Site Meat Consumption

As each cesspit is associated with particular users, who can in some cases be characterized through historical documentation (Murray and Mayne 2003; Table 1), we can also

begin to piece together who was eating what and from where. While additional in-depth analyses would be needed to fully realize this possibility, we can already point to some relationships. For instance, stable isotope signatures from chicken remains disposed of in context 2.722, a blue stone cesspit associated with a butcher (1858 – 1872), show separate animal husbandry practices and could reflect separate sources from two different poultry producers (confirmation of this example might be made through stable sulfur isotope analysis). Such tantalizing clues suggest that further, larger scale analyses of faunal remains from individual well contextualized cesspit or midden deposits could allow for relatively high resolution reconstructions of diachronic trends in meat consumption practices for small groups of people in urban settings.

Tracing Intersite Meat Provisioning

On a larger scale, the extension of these analyses in scope and design could inform understandings of socio-economic processes in the early development of Melbourne and the surrounding region. For instance the application of stable carbon, nitrogen, and sulfur as well as radiogenic strontium isotope analyses, to a larger suite of faunal remains deriving from refuse from different urban and rural places and times that reflect more variable social and environmental circumstances (e.g. statuses, ethnic backgrounds, and activity settings) would provide an opportunity to dissect the consumption of non-local animal products across a much broader and more inclusive historical period. Such broad and yet fine grained studies are becoming more frequent (e.g. Stevens et al. 2013) and could also address equally significant aspects of trade in livestock and animal products as, from the colony's earliest days, both Melbourne and the surrounding Port Phillip region are known to have had historically significant trading relationships (e.g. Staniforth 2000).

7 Conclusion

We have analyzed the stable carbon and nitrogen isotope ratios of bone collagen from 51 eutherian mammals from the historical archaeological context of the Commonwealth Block site in Melbourne, Australia. Results show tremendous diversity in livestock diets and suggest that husbandry practices for animal products consumed on the site were varied. We have argued that this evidence probably reflects the consumption of animals that were locally raised as well as some imported/non-local animals and animal products. While this preliminary data does not, for the most part, provide conclusive evidence for partial reliance on imported animal products we have suggested ways that this possibility can be further addressed and outlined how such research might advance understandings of food ways in historical Australia as well as provide an opportunity to advance and test zooarchaeological and archaeological bone chemistry techniques.

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Table Captions

Table 1. List and details of cesspits from which faunal remains analyzed in this study were excavated.

Context	Cesspit Type	Lot Number	Street Number/Name	Tenant Occupations Included
1.400	Bluestone	25C	22 Leichardt Street	Not available
1.401	Bluestone	27	18 Leichardt Street	Not available
1.219	Wooden Barrel-lined	28A	16 Leichardt Street	Not available
2.402	Wooden Barrel-lined	28B	14 Leichardt Street	Not available
2.556	Wooden Barrel-lined	32	143/54 Lonsdale Street	Draper, bootmaker, furniture manufacturer, engineer, tobacconist
2.069	Wooden Barrel-lined	35	Little Leichardt Street / Eagle Alley	Householder, butcher
2.290	Stone-Capped	33A	145/50-52 Lonsdale Street	Saloon proprietor, factory owner, butcher
2.722	Bluestone	33B	147/48 Lonsdale Street	Painter, coal dealer, dressmaker, butcher, cabinetmaker, carver and gilder, bootmaker
1.230	Bluestone	36A	Little Leichardt Street	Not available
1.279	Wooden Barrel-lined	36A	Little Leichardt Street	Not available
3.177	Wooden Barrel-lined	41B	Tuckers Lane / Little Leichardt Street	Dealer
3.035	Wooden Barrel-lined	41D	Little Leichardt Street	Labourer
3.040	Wooden Barrel-lined	41D	Little Leichardt Street	Labourer
3.341	Wooden Barrel-lined	41D	Little Leichardt Street	Labourer
1.023	Bluestone	84A	128/45 Little Leichardt Street	Painter, agent, boarding house keeper, carpenter, wood dealer, sweep

Table 2. Stable carbon and nitrogen isotope and associated collagen integrity data from faunal remains collected at the Commonwealth Block site. Asterisks indicate duplicate analyses.

Lab No.	Cat. no.	Animal	Taxon	Context	Element	$\delta^{13}C‰$	$\delta^{15}N‰$	Yield %	%C	%N	C:N
MARC 1496	LL4201	Pig	*Sus domesticus*	2.069	Mandible	-18.3	12.0	9.0	36.3	13.0	3.3
MARC 1494	LL88230	Pig	*Sus domesticus*	1.023	Mandible	-20.2	7.1	8.2	43.0	15.6	3.2
MARC 1497*	LL36698	Pig	*Sus domesticus*	1.230	Ulna	-17.2	11.1	19.7	43.7	15.8	3.2
MARC 1498	LL89131	Pig	*Sus domesticus*	1.230	Ulna	-19.2	12.9	5.1	42.3	15.3	3.2
MARC 1499	LL19091	Pig	*Sus domesticus*	2.402	Phalange	-20.7	8.4	9.0	43.1	15.3	3.3
MARC 1501*	LL11681	Pig	*Sus domesticus*	3.341	Long bone	-19.2	9.1	15.5	43.7	15.3	3.3
MARC 1502	LL23723	Pig	*Sus domesticus*	3.035	Fibula	-21.7	9.4	15.7	45.4	16.4	3.2
MARC 1503	LL89785	Pig	*Sus domesticus*	2.722	Fibula	-21.6	7.6	7.1	36.8	13.1	3.3
MARC 1507	LL23576	Pig	*Sus domesticus*	3.040	Vertebra	-19.1	9.8	17.1	45.4	16.0	3.3
MARC 1512	LL89882	Sheep	*Ovis aries*	1.230	Humerus	-16.9	5.9	6.1	30.5	11.1	3.2
MARC 1553	LL89893	Sheep	*Ovis aries*	1.230	Humerus	-16.6	5.3	12.3	42.0	15.0	3.3
MARC1510	LL33811	Sheep	*Ovis aries*	1.023	Tibia	-15.8	7.1	15.2	45.0	16.4	3.2
MARC 1508	LL88071	Sheep	*Ovis aries*	1.023	Tibia	-19.4	8.5	10.3	43.7	15.6	3.3
MARC 1509	LL34071	Sheep	*Ovis aries*	1.023	Tibia	-20.8	8.9	13.4	45.1	16.3	3.2
MARC 1513	LL89893	Sheep	*Ovis aries*	1.230	Humerus	-20.7	7.8	15.7	43.8	15.8	3.2
MARC 1511	LL90493	Sheep	*Ovis aries*	1.023	Tibia	-21.1	7.3	9.0	42.6	14.6	3.4
MARC 1495	LL88232	Dog	*Canis familiaris*	1.023	Mandible	-18.8	9.2	11.0	43.9	15.9	3.2
MARC 1514	LL88284	Dog (pup)	*Canis familiaris*	1.401	Femur	-18.9	12.7	14.7	46.0	16.6	3.2
MARC 1515	LL89228	Dog	*Canis familiaris*	1.230	Mandible	-17.9	10.6	5.4	42.3	15.2	3.3
MARC 1516	LL23104	Dog	*Canis familiaris*	1.400	Mandible	-18.0	11.4	8.0	43.8	15.7	3.3
MARC 1518	LL88777	Rabbit	*Oryctolagus cuniculus*	3.177	Maxilla	-23.5	5.3	4.7	41.2	13.8	3.5
MARC 1519	LL18736	Rabbit	*Oryctolagus cuniculus*	3.177	Mandible	-21.2	4.4	5.4	26.3	8.9	3.5
MARC 1520	LL33820	Rabbit	*Oryctolagus cuniculus*	1.023	Mandible	-22.9	5.1	8.3	42.6	14.9	3.4
MARC 1521	LL36708	Rabbit	*Oryctolagus cuniculus*	1.230	Maxilla	-21.8	4.3	6.4	43.8	16.0	3.2
MARC 1523	LL29870	Rabbit	*Oryctolagus cuniculus*	3.341	Mandible	-21.7	4.5	16.2	42.6	15.4	3.2
MARC 1524	LL89707	Chicken	*Gallus* sp.	2.722	Tarsometatarsus	-18.0	14.4	5.7	43.2	15.4	3.3
MARC 1526	LL89700	Chicken	*Gallus* sp.	2.722	Tarsometatarsus	-18.8	8.3	-	39.4	14.4	3.2

MARC 1530	LL89697a	Chicken	*Gallus* sp.	2.722	Tarsometatarsus	-18.8	9.1	12.8	43.8	15.6	3.3
MARC 1531	LL89697b	Chicken	*Gallus* sp.	2.722	Tarsometatarsus	-18.2	14.6	8.1	43.4	15.6	3.3
MARC 1532*	LL89697c	Chicken	*Gallus* sp.	2.722	Tarsometatarsus	-18.7	8.5	8.5	36.0	12.8	3.3
MARC 1528	LL88653	Chicken	*Gallus* sp.	2.402	Ulna	-20.4	12.6	13.5	42.9	14.9	3.4
MARC 1527	LL88656	Chicken	*Gallus* sp.	2.402	Ulna	-20.3	12.9	7.5	40.9	13.8	3.5
MARC 1529	LL19105	Chicken	*Gallus* sp.	2.402	Ulna	-19.8	11.8	16.4	39.9	14.0	3.3
MARC 1534	LL88429	Cat	*Felis catus*	1.400	Humerus	-18.8	11.5	8.3	42.7	15.0	3.3
MARC 1536	LL33851	Cat	*Felis catus*	1.023	Metacarpal	-17.6	11.3	19.5	43.8	16.1	3.2
MARC 1537	LL89132	Cat	*Felis catus*	1.230	Ulna	-17.3	10.6	8.4	42.9	15.6	3.2
MARC 1538	LL36728	Rat	*Rattus* sp.	1.230	Femur	-17.7	10.7	11.4	46.5	16.9	3.2
MARC 1539	LL90305	Rat	*Rattus* sp.	1.279	Femur	-18.4	10.4	10.6	38.7	13.9	3.3
MARC 1540	LL90304	Rat	*Rattus* sp.	1.279	Femur	-18.2	11.8	11.1	42.1	14.5	3.4
MARC 1542	LL88659	Rat	*Rattus* sp.	2.402	Femur	-16.9	8.8	12.7	43.0	15.1	3.3
MARC 1541	LL88658	Rat	*Rattus* sp.	2.402	Femur	-17.5	9.4	10.6	42.5	14.7	3.4
MARC 1544	LL19103	Rat	*Rattus* sp.	2.402	Femur	-18.1	10.4	13.2	41.6	14.5	3.4
MARC 1545	LL90255	Rat	*Rattus* sp.	2.402	Femur	-17.1	9.9	16.1	42.8	15.0	3.3
MARC 1533	LL35264	Cow	*Bos taurus*	2.722	Maxilla	-14.4	4.9	15.7	44.8	16.3	3.2
MARC 1535	LL35267	Cow	*Bos taurus*	2.722	Mandible	-17.1	5.4	2.3	12.4	4.3	3.4
MARC 1548	LL17459	Cow	*Bos taurus*	2.556	Rib	-8.4	3.8	7.8	42.2	15.3	3.2
MARC 1549	LL32508	Cow	*Bos taurus*	1.219	Vertebra	-14.9	8.3	9.9	41.7	14.7	3.3
MARC 1547	LL12436	Cow	*Bos taurus*	2.290	T vertebra	-20.5	7.5	2.5	40.0	13.3	3.5
MARC 1550	LL6620	Cow	*Bos taurus*	1.401	Tibia	-19.0	8.1	6.1	40.5	14.5	3.3
MARC 1551	LL23765	Cow	*Bos taurus*	2.402	Humerus	-20.6	6.9	11.7	42.5	15.2	3.3
MARC 1552	LL23470	Cow	*Bos taurus*	1.400	Femur	-20.5	7.2	5.2	43.0	15.6	3.2

Table 3. Average stable carbon and nitrogen isotope data from modern faunal bone collagen taken from sites along a south-north (C_3-C_4 dominated) transect of the Victoria/New South Wales-South Australia boarder. Standard deviations are 1σ. Domestic herbivores consist of sheep and cattle. Data except for $\delta^{13}C$ from rabbits is from Pate and colleagues (1998). Rabbit $\delta^{13}C$ data is unpublished from Anson (1996) and is reproduced here with his permission.

Animal Group	**Site**	**Mean Annual Rain Fall (mm)**	**n=**	**$\delta^{13}C$‰**	**$\delta^{15}N$‰**
Rabbits	Mt. Gambier (37°56’ S, 140°47’ E)	700 - 800	7	-23.9±1.0	4.3±0.9
Domestic Herbivores	Mt. Gambier (37°56’ S, 140°47’ E)	700 - 800	17	-23.2±1.2	8.3±1.5
Rabbits	Karte (35°56’ S, 140°42' E)	300 - 400	11	-23.2±0.8	6.2±0.9
Domestic Herbivores	Karte (35°56’ S, 140°42' E)	300 - 400	7	-21.8±0.8	7.7±0.4
Rabbits	Plumbago (32°04’ S, 139°53’ E)	200 - 250	7	-21.9±1.7	12.0±1.9
Domestic Herbivores	Plumbago (32°04’ S, 139°53’ E)	200 - 250	8*	-18.9±2.2	13.4±1.1
Rabbits	Innamincka (27°56’ S, 140°47’ E)	150 - 175	18	-19.6±2.4	10.6±2.0
Domestic Herbivores	Innamincka (27°56’ S, 140°47’ E)	150 - 175	8*	-16.8±1.5	12.2±1.2

Figure Captions

Figure 1. Map showing location of the Commonwealth Block site in regional context of southern Australia. Sites in the region from which modern comparative data derive are also marked. Hattersley's (1983) geographical percent C_3-C_4 composition lines are overlain across the map to provide a scale for environmental $\delta^{13}C$ baselines. Map modified from Google Maps and Hattersley (1983).

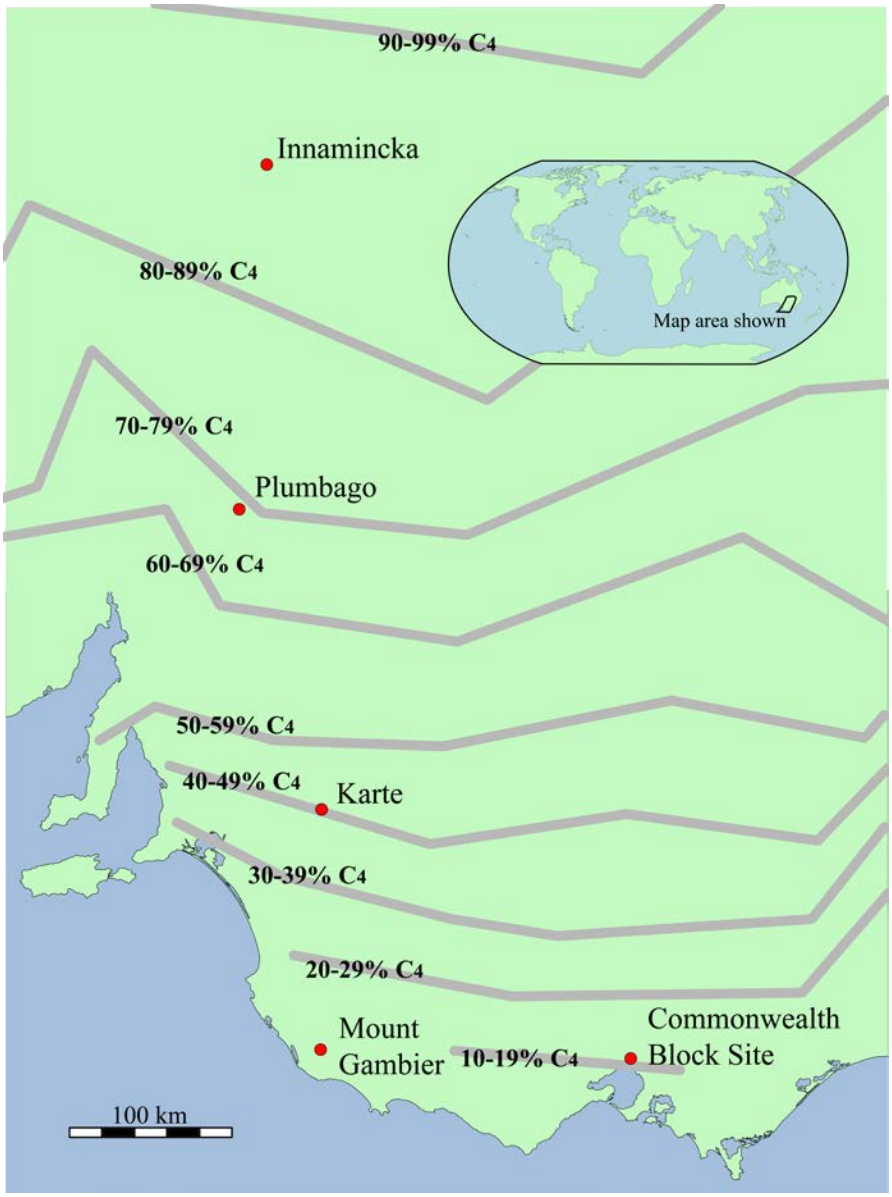


Figure 2. Location of the Commonwealth Block site and its components in the Central Business Distinct of Melbourne (modified from illustration by Wei Ming from La Trobe University).

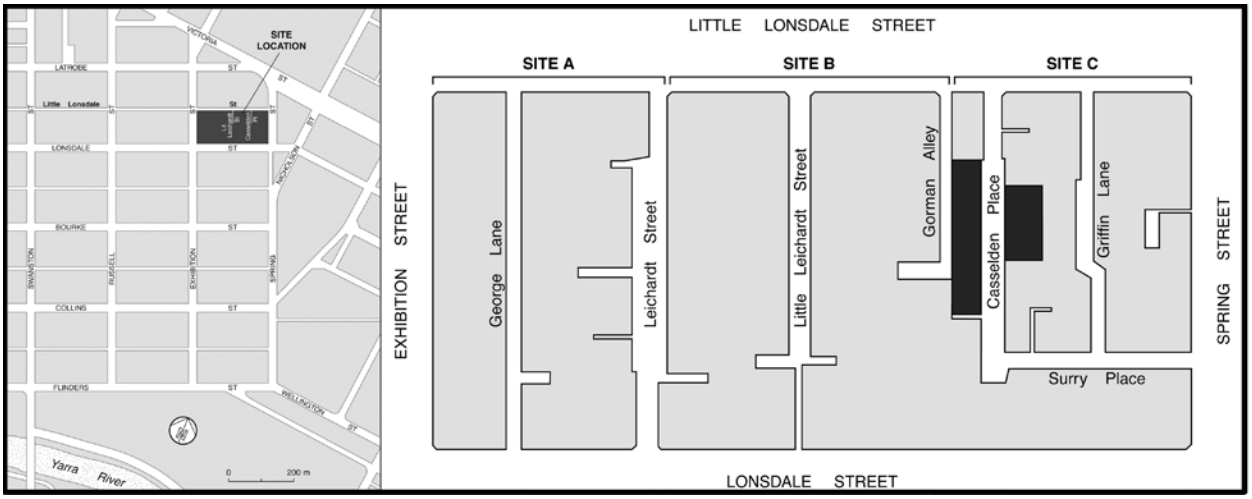


Figure 3. The Casselden Place site at the close of excavation with property allotments plan superimposed. Allotments selected for this study are highlighted in red and cesspits are coloured blue. Square/rectangular cesspits are constructed from bluestone and circular cesspits are wooden barrel-lined (see Table 1. Modified by BH from Godden Mackay Logan et al. 2004: Figure 1.4).

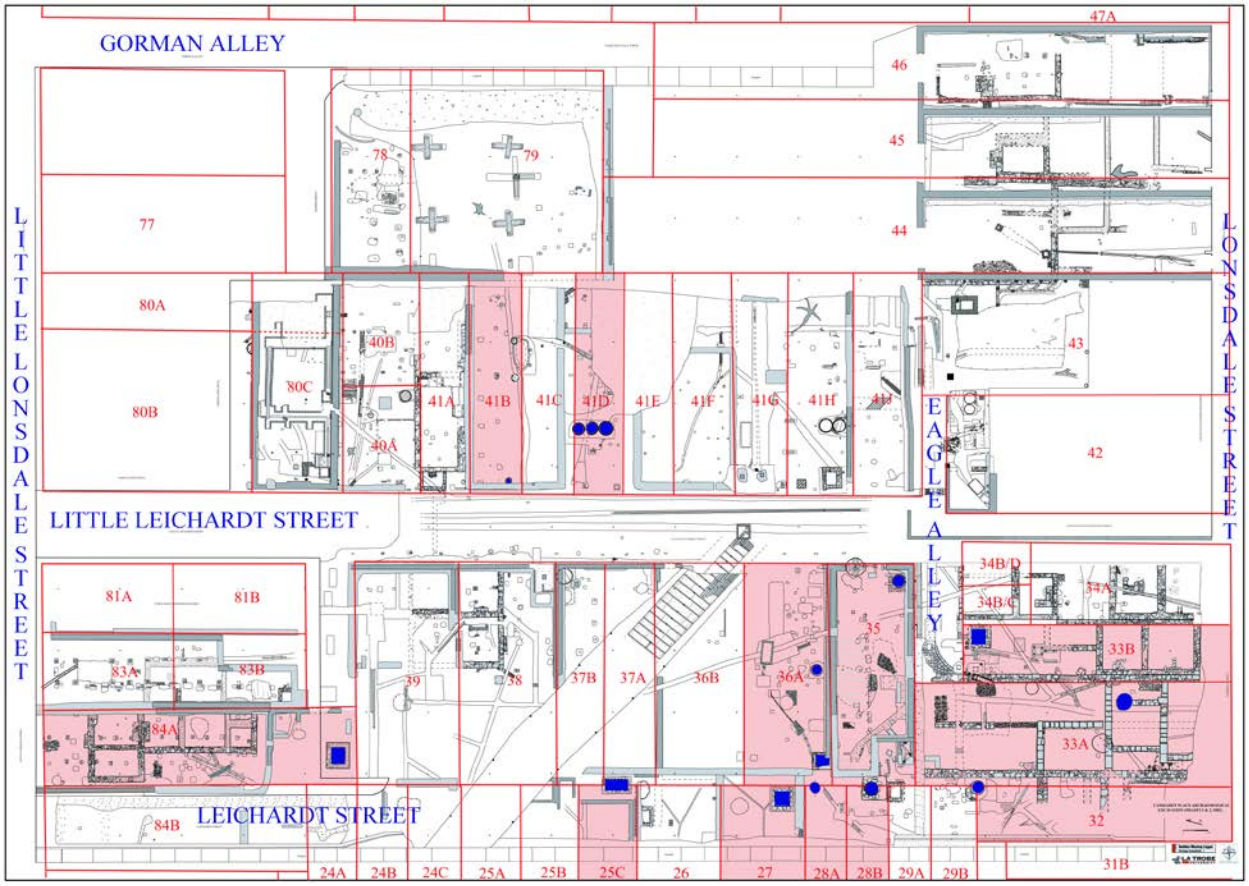


Figure 4. Stable carbon and nitrogen isotope data from faunal remains collected at the Commonwealth Block site (see Table 2). CW= Commonwealth Block Site, MG = Mount Gambier, K= Kart, P = Plumbago, I = Innamincka. Error bars show one standard deviation.

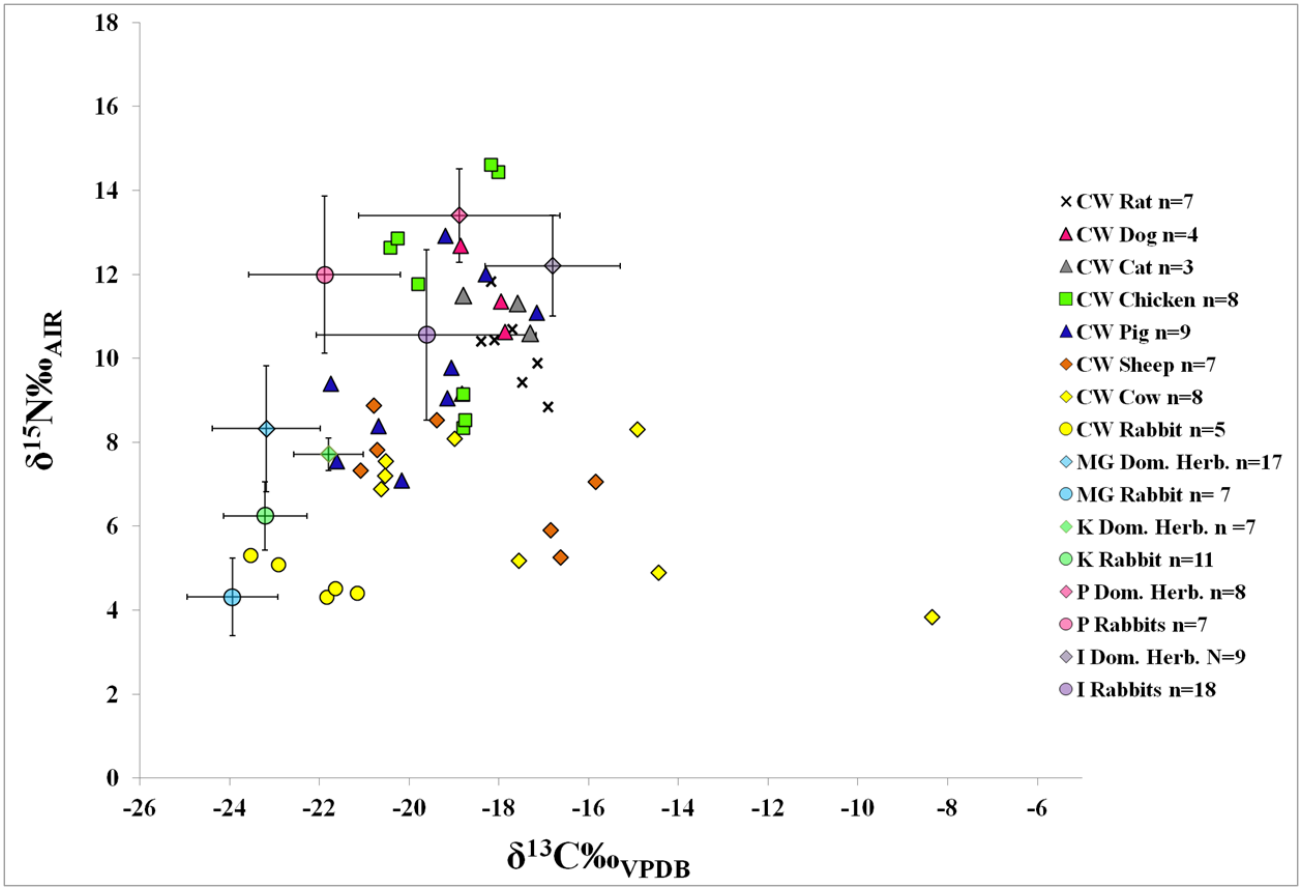
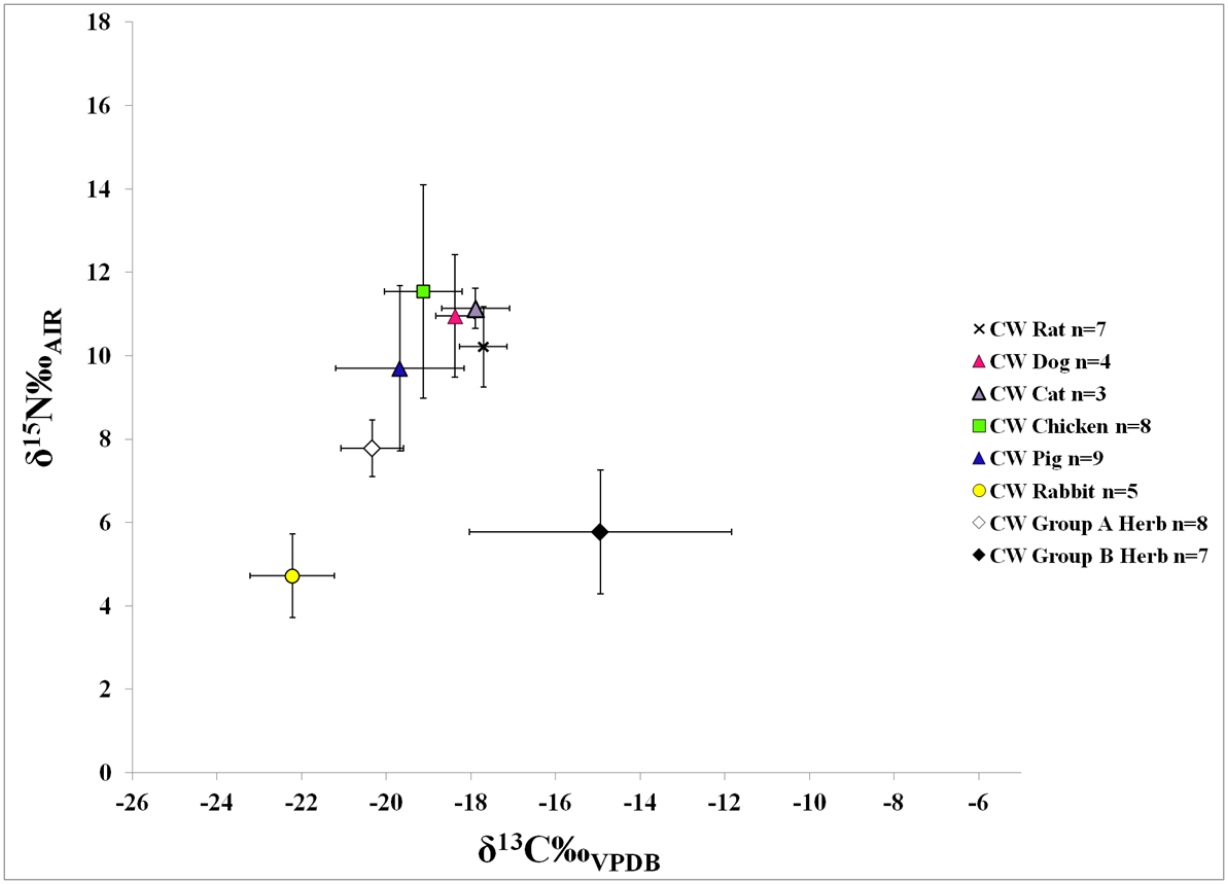


Figure 5. Averaged and regrouped stable carbon and nitrogen isotope data from faunal remains collected at the Commonwealth Block site (see Table 2). Error bars show one standard deviation.



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