Diet in Medieval Gaelic Ireland: A Multiproxy Study of the Human Remains from Ballyhanna, Co. Donegal

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ABSTRACT

This study investigates the nature of diet in a predominantly Late Medieval Gaelic Irish skeletal population and explores whether any sex-based and/or age differences were evident in the population. A smaller sub-sample was also examined to determine whether there was any evidence for dietary change over time between the Early Medieval (*c*.700–*c*.1200) and Late Medieval periods (*c*.1200–*c*.1600). The dietary evidence was derived using a multiproxy approach that combined information from dental palaeopathology (*n*=356 adults) and analysis of carbon (δ^{13}C) and nitrogen (δ^{15}N) stable isotope compositions (*n*=72 individuals). A higher proportion of females were affected by carious lesions when compared to males. This is possibly suggestive of differing levels of carbohydrate consumption between the sexes, although other factors such as eating habits, and genetic and physiological differences may also have influenced the patterns in the data. The isotopic values indicated that both

sexes were consuming similar amounts and types (marine *vs*. terrestrial) of dietary protein. Elevated δ^{15}N indicated breastfeeding among the youngest in society but, once children had been weaned, the dietary protein was isotopically similar across the different age categories. Among a smaller radiocarbon-dated sub-sample (*n*=37), there was an increase in both the percentage of individuals affected by dental caries and the percentage of teeth affected by dental caries between the Early Medieval and Late Medieval periods. This increase may indicate a greater inclusion of plant-based carbohydrates, such as cereals, in the diet over time, although it may also reflect the younger age distribution of the Early Medieval sample. Interpretations for each of these patterns are discussed with reference to the historical and archaeological evidence. Multiproxy palaeodietary studies for Medieval Ireland are limited and this is the first substantial study of evidence derived from both dental palaeopathology and stable isotope analysis.

1. Introduction

Writing in 1584, the Dublin intellectual Richard Stanihurst stated that Ulster was 'almost devoid of the cultivation of man. You will not see many tilled fields there and, as a consequence, the men of Ulster are not great eaters of bread. Among them are many herdsmen but few tillers to break the soil – although it is naturally quite fertile – with the ploughshare' (Barry and Morgan 2013, 105). By arguing that the indigenous population was not fully exploiting the commercial potential of their land, the Anglo-Irish Stanihurst portrayed the Gaelic Irish of the north as uncivilised in comparison to the people living within Dublin and the Pale. This device would become part of an effective argument used in the early seventeenth century in support of British colonisation in Ulster, since it helped to justify the transfer of land to newcomers from England and Scotland (Farrell 2017, 36-38).

In contrast to this view, however, the historical and archaeological evidence suggests that the economy of Late Medieval Gaelic Ireland (*c*.1200– *c*.1600) was based upon a mixture of pastoral and arable farming, with dairy, meat and cereal products all incorporated into the diet (Nicholls 2003, 133-137; O'Dowd 1986, 130). It is somewhat unclear, however, whether aquatic sources such as seaweed, shellfish, fish and marine mammals were regularly consumed by the population. The historical sources tend to focus on the upper strata of society, and relatively few contemporary documentary accounts survive which make reference to the diet of the lower classes (for examples see McKenzie and Murphy 2018, 34).

Indeed, information about the everyday lives of tenant farmers, labourers, clergy, merchants, artisans and the very poor, who would have comprised the majority of the population, are conspicuously absent from the records. Given this paucity of evidence, the human skeletal remains from Ballyhanna (Fig. 1), the largest Gaelic Medieval population to have been excavated from Ireland to date, is of particular importance since it provided an unparalleled opportunity to study the physical remains of these people, who are largely invisible to history (see McKenzie and Murphy 2018). Using data derived from the Ballyhanna population, the overall aim of this study was to reconstruct the long-term dietary composition of the ordinary Late Medieval Irish and to explore whether there were any discernible sex-based and/or age-based differences in diet. This was achieved by incorporating evidence from dental palaeopathology and stable isotope analysis, with the scant historical and archaeological evidence. A secondary aim was to investigate whether there was any evidence for dietary change over time from the Early Medieval to Late Medieval periods. The study also provided an opportunity to ascertain if scientific evidence can provide grounds for the suspicion of political bias in Stanihurst's 1584 statement (Barry and Morgan 2013, 105; Farrell 2017, 36-38).

A close link exists between the diet consumed during life and dental health (Lukacs 2012). The type, consistency, and preparation of food will all influence the oral environment and the subsequent development of dental pathologies, particularly dental caries, in an individual (Hillson 2008, 116). Data collected on pathological lesions in the dentition can therefore be used in the reconstruction of past diets (Larsen 2015, 66-86). While a wealth of dental palaeopathological information exists for the Medieval period in Ireland, much of this remains unpublished and it is rarely combined with stable isotope data. Stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope analyses of human and animal tissues can provide direct evidence for dietary practices (for review see Lee-Thorp 2008). This technique has been widely used to reconstruct the diets of human and animal populations from many different time periods and geographical locations, but only a few studies have been undertaken on Irish material and none of these have focused on the Late Medieval period (e.g. Beaumont *et al*. 2013; Geber 2010; Geber 2011; Guiry *et al*. 2018a; Knudson *et al*. 2012; Ryan *et al*. 2018).

2. Background

The townland of Ballyhanna is located on the outskirts of the town of Ballyshannon in southern County Donegal, Ireland, approximately 1 km from the Atlantic coast. In 2003-2004 a small, single-celled church and graveyard were excavated (NGR 188105, 360834) during a roadwork scheme financed by the National Roads Authority and Donegal County Council. Radiocarbon dates indicate that the graveyard was in use for over a millennium, from the second half of the seventh century into the first quarter of the seventeenth century, although the vast majority of individuals (approximately 86%; 62/72 of those radiocarbon dated) were laid to rest between the mid- thirteenth and seventeenth centuries (Macdonald and Carver 2015, 56).

By the late twelfth century, Ireland had witnessed the arrival of the Anglo-Normans from England. Their conquest of the country proved to be incomplete, however, and much of the northern province of Ulster – including modern-day County Donegal – remained under Gaelic Irish control. The church at Ballyhanna was a chapel-of-ease that would have served the local community working on an estate owned by the Bishop of Clogher (Crown Commission's Inquisition at Enniskillen on 18 September 1609 cited in Hatchell 1966, 383-4; Donnelly 2015, 39). People interred in the graveyard are likely to have been the sub-tenants of the *erenagh*, or estate manager, as well as hired labourers who farmed the surrounding church lands (Donnelly 2015, 39). Burials were mostly supine, extended, single interments, aligned west-east, as would be expected for a Christian population (for a detailed discussion of burial practices at Ballyhanna see McKenzie and Murphy 2018).

Small quantities of faunal remains were mixed within the soil of the graveyard including waste from butchery, cooking, craftworking and the remains of non-food species. The assemblage comprised 227 identifiable fragments of bone, derived from cattle, sheep and goat, pig, horse, dog, cat, deer, rabbit and rat, as well as corvid (rook/crow) and pike. Among the domesticated animals, cattle predominated, followed by sheep/goat, and a lesser proportion of pig bones. The isotopic compositions of faunal remains from these graveyard deposits were used to construct a baseline for interpreting human diets, although it does have to be appreciated that the dating of the faunal remains is ambiguous since none were deliberate inclusions within the burials.

3. Dietary Reconstruction

3.1 Historical and archaeological evidence for diet

Although Late Medieval historical sources are largely silent in relation to the diet of the lower classes in Gaelic Ireland, continuity is presumed throughout the Medieval period, and a richer record of Early Medieval historical sources exist, including law and religious tracts. These suggest that, for the majority, the diet would have comprised bread and milk, supplemented by vegetables, fruit, salted meats, honey, seaweed and salt (Kelly 1997, 316-317). Historical documents suggest that oats were the main crop grown and were used to make porridge, gruel, soups, stews, cakes and bread (Nicholls 2003, 133). Other cereals were grown in Gaelic areas – notably barley, rye and wheat – but these tended to be used as rent-in-kind payments to the local lord (Ó Doibhlin 1998, 60; O'Dowd 1986, 130). Small amounts of grains would have been processed using quern stones at home, with local mills used for larger quantities (Nicholls 2003, 133). A watermill managed by the *erenagh* at Ballyhanna would have processed the grain grown locally on the church lands (Donnelly 2015, 40).

Cattle were of particular importance in Gaelic society, as the size and quality of dairy herds were reflective of the wealth and status of a lord (O'Dowd 1986, 130). Milk, primarily from cattle, but also from goats and sheep, would have been used to make products such as cream, cheese, butter, buttermilk, whey, and sour curds, and these would have comprised the main source of dietary protein for the lower classes (Beglane in press; Kelly 1997, 323-330; Nicholls 2003, 137). Since milk production would have peaked between the months of April and September, fresh milk products were consumed predominantly in the summer months, while processed dairy products, such as hard cheeses, would have been kept for the winter (Kelly 1997, 52).

The quantity and quality of meat would have varied depending upon status, with the ruling elites eating the best cuts (Kelly 1997, 358). Meats available would have included beef, mutton, goat and pork and each of the associated species are represented in the small faunal assemblage from Ballyhanna. Most Medieval animal bone assemblages also contain very small numbers of bones from wild animals, such as red deer and wild boar, along with bird and fish (see e.g. Beglane 2012; McCormick and Murray 2007, 39; Murphy 2007). Evidence from historical sources and faunal remains also indicate that poultry (hens and geese) were sometimes kept, for both their eggs and meat (McCormick and Murray 2007, 106).

Cartographic evidence suggests that river fish such as salmon and eels may also have been incorporated into the diet. In a map drawn on 10 October 1593 (British Library Cotton MS Augustus I.ii.38) showing the Battle of the Erne Fords, which took place at Belleek near

Ballyshannon, the English solider and cartographer John Thomas depicted a large salmon in the River Erne, along with a couple of weirs and the famous salmon 'leape' to the north of Ballyhanna. In the Crown Commission's Inquisition at Lifford in 1609 on church land in County Donegal it was stated that the land of the McGockquin lineage – the erenagh lineage associated with Ballyhanna – included a fishing weir for eels, a watermill, and the 'moytie of a salmon leape called O'Skullion', for all of which they paid an annual rent of three shillings and fourpence to the Bishop of Clogher (Donnelly 2015, 39). For methodological and taphonomic reasons fish bones are rarely recovered from archaeological sites. Sieving was not employed during the excavations at Ballyhanna meaning that the faunal assemblage is biased to larger skeletal elements (O'Connor 2000, 31). Recovery of a pike bone from Ballyhanna, however, was suggestive that fish formed at least part of the diet. Two salmon bones were discovered from secure Late Medieval contexts at the excavated tower house (small castle) at Parke's Castle, Co. Leitrim, indicating that salmon was certainly being eaten at this high status Gaelic site (Hamilton-Dyer 2012, 120). Given the riverine nature of Ballyhanna, it seems probable that shellfish may have formed a supplementary component of the diet (see Murray 2007) but only a single scallop shell was recovered during the excavations, and this was considered to have been a pilgrim badge related to the shrine of St James of Compostela in Spain (McKenzie and Murphy 2018, 45-46).

The Ó Domnaill sept, who were the overlords of much of Donegal during the Late Medieval period, have been described as a maritime lordship, largely dependent upon the fisheries of the coast and the inland rivers for wealth and trade (Mac Eiteagáin 1995, 207; Nicholls 2003, 145). Ports in Donegal traded with ships from England, Scotland, France, and Spain and exports included salmon, herring, eel, and oyster (Mac Eiteagáin 1995, 206). The Ó Domnaill leaders directly facilitated foreign fishing off the west coast of Donegal, taxing the vessels for fishing in their waters (Mac Eiteagáin 1995, 206; Nicholls 2003, 145). Donnelly (2015, 17) notes how a Tudor English official claimed in 1561 that Maghnus Ó Domnaill was the 'best lord of fish in Ireland and he exchangeth fish always with foreign merchants for wine, by which [he] is called in other countries, the king of fish'. Despite the presence of a fishing industry off the west coast, however, it is unclear from the historical sources the extent to which the native diet incorporated marine resources. The suggestion that marine mammals may have been, at the very least occasionally, exploited for meat was supported by archaeological evidence from a Late Medieval animal bone assemblage from Portmuck, Co. Antrim, where butchery marks were identified on two grey seal bones (Murphy 2004, 101).

Advice provided in *Bretha Crólige*, an Early Medieval law tract dealing with the maintenance of the sick, notes that invalids suffering from stomach problems should not be supplied with whale-flesh, implying that whale-meat may also have been consumed as and when the opportunity arose (Kelly 1997, 348-349).

3.2 Dental pathology

The dental lesions analysed here comprised dental caries and calculus, which previous studies have shown are particularly useful for palaeodietary reconstruction (e.g. Keenleyside 2008). Dental caries are cavities that develop in the crown or root surface of a tooth as a result of demineralisation by organic acids that are produced by oral bacteria during the breakdown of fermentable carbohydrates (Larsen 2015, 67). The aetiology of dental caries is incompletely understood, but factors that influence their development include diet, food texture, speed of food consumption, nutrition, oral and plaque acidity, the nature and flow of saliva, age, genetics, enamel composition, and tooth size and morphology (Hillson 2008; Larsen 2015, 68; Lukacs 2012). A correlation is also evident between the prevalence of dental caries and the amount and frequency of consumption of refined sugars and fermentable carbohydrates in the diet (Hillson 2008, 115-116). A global study by Lukacs (1989, table 7) revealed a general increase, albeit with considerable variability, in the prevalence of carious lesions in teeth from hunter-gatherers (average 1.3%) to those who practiced a mixed foraging/agriculture economy (average 4.8%) to agriculturists (average 10.4%).

Dental calculus is a mineralised plaque deposit, comprised of a combination of food debris, saliva and bacteria, which attaches to the crown or root of a tooth (Hillson 1996, 254-255). Its aetiology is complex and the precise nature of the relationship between diet and calculus formation is not fully understood. When the frequencies of calculus and caries are compared, however, they can be used to assess the relative levels of proteins versus carbohydrates within the diet of a group. In general terms, diets high in fermentable carbohydrates and low in protein lead to high levels of dental calculus and high levels of dental caries, while diets low in carbohydrates and high in protein result in high levels of dental calculus and low levels of dental caries (Keenleyside 2008).

3.3 Stable isotope analysis

The isotopic composition of bone and dentine collagen reflects that of food and drink, particularly protein (Ambrose and Norr, 1993) consumed during life (for review see Lee-Thorp 2008). In terrestrial environments, human and animal bone collagen $\delta^{13}C$ reflects the importance of carbon derived from C_3 and C_4 plants (Vogel and van der Merwe, 1977, DeNiro and Epstein, 1978, Tieszen, 1991) As Ireland has a temperate environment dominated by C_3 plants, human $\delta^{13}C$ values are most useful for distinguishing between the importance of terrestrial (animals and crops) and aquatic (particularly marine fish) foods, which have relatively low and high $\delta^{13}C$ values, respectively (Chisholm *et al*. 1982; DeNiro and Epstein 1978). Stable nitrogen isotope compositions can provide information about the relative importance of different kinds of plant and animal proteins in human diet become increasingly elevated (+3-4‰) with each trophic level step up in a food web (Bocherens and Drucker 2003; Hedges and Reynard 2007; Post 2002; Szpak *et al*. 2012). For this reason, $\delta^{15}N$ values can provide a means of assessing the relative importance of plant *versus* animal foods (DeNiro and Epstein 1981). Moreover, because aquatic ecosystems can have longer food chains, with more trophic levels than their terrestrial counterparts, diets including upper-trophic level marine or freshwater fish species can be distinguished based on $\delta^{15}N$ values (Schoeninger *et al*. 1983). The isotopic composition of plants and animals at the base of the food web can also vary between time periods, geographical areas, environmental conditions, and cultural practices (Guiry *et al*. 2018a; Szpak 2014; Van Klinken *et al*. 2002). Interpretation of human stable isotope data therefore ideally requires associated faunal data to provide a contemporaneous isotopic baseline (Katzenberg 1989).

4. Materials and Methods

4.1 Human Remains

A total of 1296 skeletons, 869 adults and 427 juveniles, were recorded using standard osteological techniques (McKenzie and Murphy 2018) that conform to professional guidelines (Mitchell and Brickley 2017). Of the adults, 356 had a partial or complete dentition present, 44.6% (159/356) were from males, 48.9% (174/356) from females and 6.5% (23/356) derived from individuals of indeterminate sex. A total of 6238 teeth were examined. Radiocarbon dating, and $\delta^{13}C$ and $\delta^{15}N$ analyses were undertaken on 72 individuals (n=54 adults; n=18 juveniles). The samples were primarily selected to understand the stratigraphy of the graveyard, although a smaller number of individuals were also

included in the sample as they displayed unusual pathological lesions or traumatic injuries. The radiocarbon-dated sample comprised individuals of both sexes and a range of ages. A smaller sub-sample of 37 adult skeletons had both a radiocarbon date and a dentition present for analysis.

The age-at-death of juveniles was estimated using a combination of epiphyseal fusion data, the diaphyseal lengths of long bones, dental eruption and dental mineralisation (Cunningham *et al*. 2016; Moorrees *et al*. 1963; Smith 1991). Biological age estimations were based upon Scheuer and Black (2000, 468-469) and were divided into the following age categories – preterm (< 37 lunar weeks), full term (37-42 weeks), neonatal (*c*. 40-44 weeks), infant (1 month to 1 year), younger child (1-6 years), older child (6-12 years) and adolescent (12-18 years). Adult sex determination involved recording sexually dimorphic morphological traits of the skull and pelvis following the recommendations of Ferembach *et al.* (1980) and Phenice (1969). Adult age estimation was based upon the assessment of late fusing epiphyseal sites throughout the post-cranial skeleton (Cunningham *et al*. 2016), degeneration of the auricular surface (Lovejoy *et al*. 1985) and pubic symphysis (Brooks and Suchey 1990), and dental wear (Brothwell 1981). The adult skeletons were divided into three broad age categories – young adults (18-35 years), middle-aged adults (35-50 years) and old adults (50+ years). Adult skeletons that could not be allocated to one of these categories were catalogued as adults (>18 years).

4.2 Dental palaeopathology

The assessment of dental palaeopathology in this study focuses solely on prevalence rates of dental caries and calculus in adult dentitions (full details of the dental diseases evident in both adult and juvenile dentitions can be found in McKenzie and Murphy 2018).

The number, location (occlusal, buccal/lingual, interproximal, or root), and approximate size of the carious lesions were recorded for each tooth. Likewise, the amount of dental calculus – mild, moderate, or considerable – was also recorded for each tooth (Brothwell 1981, 155). The dental diseases are reported according to both the crude prevalence rate (CPR; the proportion of individuals affected by a dental disease as a proportion of the number of individuals with dentitions present) and true prevalence rate (TPR; the proportion of teeth affected by each disease calculated out of the total number of teeth present). Differences

between the sexes and age categories were explored using chi-squared tests (Pearson 1900), and statistical significance was defined by probability levels of p=<0.05.

4.3 Stable isotopes

Of the 72 humans selected for isotopic analyses, samples from 61 individuals originated from bones (primarily rib fragments), while teeth (first molars) were sampled for 11 individuals (Tables 1 and 2). Radiocarbon dates for all humans were measured at the ^{14}CHRONO Centre at Queen's University Belfast (QUB) and calibrated using the CALIB REV 6.0.0 calibration programme and the IntCal09 calibration curve (Reimer *et al*. 2009). Eleven faunal samples were selected for isotopic analysis and these were derived from ten herbivores (six cattle, three sheep/goat, and one horse) and one omnivore (pig) (Table 3). All of the elements sampled were either fused (adult) bones or, where fusion could not be established, were of essentially adult size, so eliminating the possibility that the results reflect unweaned animals. Additional faunal baseline data were sourced from the literature (for discussion see section 6.2) (Guiry, et al., 2016a, Harrod, et al., 2005, Hutchinson, et al., 2015).

Collagen extractions for humans and animals were performed at the ^{14}CHRONO Centre at QUB and the Archaeology Chemistry Laboratory (ACL) at the University of British Columbia (UBC), respectively, and followed similar procedures based on a modified Longin method (Brown *et al*. 1988; Bronk Ramsey *et al*. 2004; Longin 1971). Bone samples were demineralised in hydrochloric acid (HCI; 0.50 M and c. 0.25 M at UBC and QUB, respectively). At UBC, demineralised samples were then treated with 0.1 M sodium hydroxide (NaOH) in an ultrasonic bath (solution refreshed every 15 minutes until the solution remained clear) to remove base-soluble contaminants (Szpak *et al*. 2017a). Samples were then refluxed in a 10^{-3}M HCl solution in an oven (56°C for 16hr at QUB; 70°C for 48 hr at UBC). Solubilised collagen samples were then purified using 45-90-μm mesh filters (Sartorius Group at QUB, Elkay Laboratory Products at UBC) and 30,000 molecular weight cutoff filters (Sartorius Group at QUB, Pall Corporation at UBC), with the >30kDa fraction being saved, frozen, and lyophilized for isotopic analyses.

Differing collagen extraction procedures could lead to greater variation in the isotopic composition of resulting collagen extracts if the methods applied differ in the extent to which they: 1) effectively remove humic acid, lipid, and non-collagenous protein contaminants (Szpak, et al., 2017a, Guiry, et al., 2016b, Guiry and Hunt, 2020); and 2) cause selective

amino acid loss (Collins and Galley, 1998). The main methodological differences between extraction protocols for human and animal bone collagen employed in this study are that NaOH was not utilised for the human samples, as well as varying demineralization and refluxing conditions. The demineralization and refluxing conditions used in both protocols are within standard guidelines and there is no reason to suspect that these should influence the comparability of results with respect to contamination or selective amino acid loss (Ambrose, 1990; Brown, et al., 1988; Collins and Galley, 1998; Longin, 1971). However, if samples were heavily contaminated with humic acids, it is possible that omission of NaOH pre-treatment for human collagen extracts could result in slightly lower $\delta^{13}C$ in human samples relative to animals since humic acids do not contain nitrogen and will have $\delta^{13}C$ that is lower than collagen. However, any potential effects of humic acid contamination should be mitigated by the use of well-established collagen quality control protocols for screening data, including $C:N_{Atomic}$ ratios (2.9 to 3.6) (DeNiro, 1985).

Faunal $\delta^{13}C$ and $\delta^{15}N$ values were measured on 0.5 mg subsamples of bone collagen using an Elementar Vario MICRO cube elemental analyser coupled via continuous flow to an Isoprime isotope ratio mass spectrometer in the ACL at UBC in 2016. Duplicate analyses were performed on all samples. Isotopic measurements were calibrated using a two point calibration curve anchored to United States Geological Survey (USGS) 40 and USGS 41 relative to the Vienna Pee Dee Belemnite (VPDB) for $\delta^{13}C$ and Ambient Inhalable Reservoir (AIR) for $\delta^{15}N$ (Qi *et al*. 2003). Accuracy of measurements was assessed using internal check standards with the following long-term δ-values: methionine (MET, $\delta^{13}C$ –28.62 ± 0.11‰ and $\delta^{15}N$ –5.03 ± 0.15‰), caribou bone collagen (SRM1, $\delta^{13}C$ –19.36 ± 0.11‰ and $\delta^{15}N$ 1.81 ± 0.10‰), and walrus bone collagen (SRM2, $\delta^{13}C$ –14.76 ± 0.12‰ and $\delta^{15}N$ 15.59 ± 0.11‰). The average absolute difference between measured and known δ-values for all check standards (reproducibility) was 0.01‰ for $\delta^{13}C$ and 0.04‰ for $\delta^{15}N$. The average difference between duplicate pairs of samples was 0.02‰ and 0.01‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively. The overall standard uncertainty for samples was ±0.16 for both $\delta^{13}C$ and $\delta^{15}N$ (Szpak *et al*. 2017b).

Human $\delta^{13}C$ and $\delta^{15}N$ values were measured on 1.0 mg subsamples of bone collagen using a Flash elemental analyser coupled via continuous flow to a Thermo Delta V isotope ratio mass spectrometer in the ^{14}CHRONO Centre at QUB in 2009-2010. Duplicate analyses were performed on all samples. Isotopic compositions were calibrated using a single-point calibration anchored to Iso-Analytical (IA)-RO41 (L Alanine using, long-term $\delta^{13}C$ = –23.33

± 0.10‰, δ^{15}N = –5.56 ± 0.14‰) (Brooks and Belanger 2005). The standard deviations for IA-RO41 over the course of seven runs was ± 0.05 for δ^{13}C and ± 0.08 for δ^{15}N. The standard deviation for replicate sample analyses (n=72) was ± 0.02 for δ^{13}C and ± 0.07 for δ^{15}N. Although these analyses occurred at a time prior to the adoption of routine two-point calibration and inclusion of check standards in some archaeological stable isotope laboratories (Coplen, et al., 2006, for review see, Szpak, et al., 2017b), an in-house standard with different δ-values (L-Glutamic Acid, long-term δ^{13}C = –37.63‰, δ^{15}N = 47.60‰) was periodically run to ensure that isotopic compositions for samples with lower δ^{13}C and higher δ^{15}N were not skewed. Therefore, while acknowledging the possibility of calibration-induced differences in measured isotopic compositions between labs, the human and faunal datasets should be broadly comparable. While, ideally, human and faunal isotopic compositions would have been measured in the same way, it is not always practical to apply current best practices (Szpak, et al., 2017b) to data generated over a decade ago.

Statistical comparisons of isotopic compositions were performed using PAST Vision 3.22 (Hammer, et al., 2001). Normality of distribution was established prior to comparisons of means using Shapiro Wilk tests (Shapiro and Wilk, 1965). Comparisons involving one or more non-normally distributed groups were performed using Mann-Whitney *U* tests (Mann and Whitney, 1947). Comparisons between two normally distributed groups were performed with a Student's *t* test (if variances are equal; Student, 1908). Comparisons between more than two normally distributed groups were performed with a One Way ANOVA followed by either a Tukey's post hoc test (if variances are equal; Tukey, 1949) or individual Welch's *t* tests (if variances are unequal; Welch, 1947). A Levene's test (Levene, 1960) was used to assess homogeneity of variance. A Spearman's ρ test (Spearman, 1907) was used to determine the significance of stable isotope and radiocarbon data.

5. Results

5.1 Dental palaeopathology

Carious lesions were recorded in 37.6% (134/356) of adults and, overall, 5.5% (344/6238) of teeth were affected by the lesions. Females had a higher CPR (41.4%; 72/174) than males (31.4%; 50/159), although the difference was not statistically significant (χ^2=3.5, df=1, p=0.06) (Fig. 2). A higher proportion of female teeth (6.8%; 210/3098) were affected by cavities when compared to male teeth (4.0%; 109/2757) (Fig. 3). The number of teeth with

dental caries in the female dentitions ranged from one to ten (mean 2.9 ± 2.3), while in males the range was from one to seven (mean 2.2 ± 1.5). These data indicate that females were more frequently affected by carious lesions than their male counterparts and displayed, on average, a higher number of lesions per affected individual. Dental calculus was almost ubiquitous in the Ballyhanna dentitions with 96.1% (342/356) of adults, and 90.8% (5667/6238) of teeth affected. The CPR of dental calculus for males and females was similar with 96.2% (153/159) and 96.0% (167/174) of individuals affected respectively.

A lower proportion of young adults (26.5%; 48/181) were affected by cavities when compared to middle-aged (58.1%; 61/105) and older adults (52.6%; 10/19) (see Fig. 2). Some 3.3% (123/3714) of young adult teeth, 8.8% (165/1865) of teeth from the middle-aged people and 9.1% (23/254) of older adult teeth were affected (see Fig. 3). Calculus deposits were frequent in all adult age categories, and the CPR for young adults of 96.1% (174/181), increased to 100.0% (105/105) for middle-aged adults, and decreased to 89.5% (17/19) for older adults. The decrease in CPR rate among older adults is caused by the inclusion of two older adults with tooth sockets present for analysis, but no surviving teeth due to ante- and post-mortem loss. Although almost every dentition was affected by dental calculus, the majority of deposits tended to range from flecks to slight deposits.

Of the 54 adult skeletons with a radiocarbon date, 37 had dentitions present for analysis. These 37 individuals were separated into two groups, an Early Medieval (*c*.700– *c*.1200) sample (*n*=9) and Late Medieval (*c*.1200– *c*.1600) sample (*n*=28). Even with the small sample sizes, there was an increase in the percentage of individuals affected by carious lesions between the Early Medieval (22.2%; 2/9) and the Late Medieval period (32.1%; 9/28), and this was also reflected in the percentage of teeth affected between the Early Medieval sample (1.3%; 3/223) and the Late Medieval sample (2.0%; 11/545). However, the sample from the Early Medieval period has a higher number of young adults (7/9) when compared to the Late Medieval sample (18/28) and so it is likely that the lower prevalence rate of caries in the Early Medieval sample is reflective of the relatively young age of the sample population.

The CPR of dental calculus was 100% for both the Early Medieval (9/9) and the Late Medieval (28/28) samples. Overall, the Ballyhanna population is characterised by a low prevalence of dental caries with a high prevalence of minimal deposits of dental calculus. This profile is characteristic of a mixed subsistence economy.

5.2 Stable isotopes

Stable isotope compositions of human samples (*n*=72) are provided in Tables 1 and 2, while animal (*n*=11) samples are presented in Table 3. Human δ^{13}C values ranged from –22.1‰ to –19.1‰ (mean –20.9 ± 0.5‰), with δ^{15}N values ranging from 9.4‰ to 14.7‰ (mean 10.9 ± 0.8‰). Excluding the five youngest individuals (all three years old or younger at death) who may have been breastfeeding, in the case of infants, or neonates who may potentially have died of nutrition-related complications during pregnancy, the results are as follows – δ^{13}C values range from –22.1‰ to –19.5‰ (mean –20.9 ± 0.5‰), and δ^{15}N values range from 9.4‰ to 11.9‰ (mean 10.7 ± 0.5‰). Some samples were derived from adult teeth and will have isotopic compositions reflecting diet earlier in life, during the time that the tooth was forming. However, there were no statistically significant differences between tooth (*n*= 11, mean δ^{13}C –20.7 ± 0.3‰; δ^{15}N 10.8 ± 0.4‰) and bone (*n*=46, mean δ^{13}C –21. 0 ± 0.4‰; δ^{15}N 10.7 ± 0.5‰) datasets for either δ^{13}C (Student's *t* test, $t = 1.75$, $df = 56$, $p = 0.089$; Levene's test, $p = 0.736$) or δ^{15}N (Student's *t* test, $t = 0.196$, $df = 56$, $p = 0.845$; Levene's test, $p = 0.195$) suggesting that childhood and adult diets were similar (Fig. 4). For this reason, data from bones and teeth are combined in subsequent comparisons.

A total of 52 adolescents and adults were of determinable sex, including 17 females and 35 males (see Fig. 4). Female (means δ^{13}C = –20.9 ± 0.4‰, δ^{15}N = 10.8 ± 0.5‰) and male (mean δ^{13}C = –20.9 ± 0.5‰, δ^{15}N = 10.7 ± 0.5‰) isotopic compositions show no statistically significant differences in either δ^{13}C (Mann-Whitney *U* test, $U = 290.5$, $p = 0.900$) or δ^{15}N (Student's *t* test, $t = 0.320$, $df = 61$, $p = 0.756$; Levene's test, $p = 0.883$).

There was also very little isotopic variation evident between age cohorts (Fig. 5). Statistical comparisons between age categories, including children, aged three and older, and adolescents (*n*=13), young adults (*n*=27), middle-aged adults (*n*=17), and old adults (*n*=3) and adults (*n*=7), showed no statistically significant age-related differences in δ^{13}C (One way ANOVA, $F_{3,63} = 1.18$, $p = 0.325$; Levene's test, $p = 0.539$) or δ^{15}N (One way ANOVA, $F_{3,63} = 0.79$, $p = 0.502$; Levene's test, $p = 0.760$). As expected the five youngest individuals (neonates SK 43 and SK 830; infants SK 455, SK 858, and SK 1100) show elevated δ^{15}N values ranging from 11.8‰ to 14.7‰ (means δ^{13}C = –20.7 ± 1.0‰, δ^{15}N = 12.9 ± 1.1‰).

Human (aged three and older, *n*=67) isotopic compositions were compared with mean radiocarbon age (Fig. 6). While no significant correlations were found between ^{14}C (mean of

2σ calibrated age range) and bone collagen $\delta^{13}C$ (Spearman's ρ test, $\rho = 0.233$, $p = 0.060$), a significant correlation was found for $\delta^{15}N$ (Spearman's ρ test, $\rho = –0.378$, $p = 0.002$). This correlation appears to be driven by higher $\delta^{15}N$ for seven samples dating earlier than AD 1000 (means $\delta^{13}C = –21.1 \pm 0.4‰$, $\delta^{15}N = 11.4 \pm 0.7‰$). When these individuals are removed (n=60, means $\delta^{13}C = –20.9 \pm 0.5‰$, $\delta^{15}N = 10.6 \pm 0.5‰$), no significant correlation is observed between radiocarbon dates and $\delta^{15}N$ (n=60, $p = 0.060$; for $\delta^{15}N$, $\rho = –0.054$, $p = 0.681$).

Relative to humans, domestic livestock (n=11) had lower mean $\delta^{13}C$ (–22.6 ± 0.5‰) and $\delta^{15}N$ (6.4 ± 0.9‰) values (Fig. 7). The mean $\delta^{13}C$ and $\delta^{15}N$ for cattle (n=6) are –22.8 ± 0.6‰ and 6.2 ± 0.7‰, respectively, while the corresponding data for sheep (n=3) are –22.4 ± 0.5‰ and 6.7 ± 1.0‰, respectively. The lone pig sample produced a $\delta^{13}C$ of –22.0‰ and a $\delta^{15}N$ of 7.2‰. Excluding individuals under the age of three years, the mean human data are approximately 1.7‰ less negative for $\delta^{13}C$ and 4.3‰ more positive for $\delta^{15}N$ than the domestic animals sampled.

6. Discussion

6.1 Dental palaeopathology

Overall, there was a true prevalence rate of 5.5% (344/6238) of teeth affected by dental caries among the Ballyhanna adults. A lower true prevalence rate of 1.3% (3/223) of teeth were affected in the Early Medieval sub-sample increasing to 2.0% (11/545) in the Late Medieval sub-sample. It is worth highlighting that the phased sub-sample was particularly small and comprised a total of 37 individuals. The overall true prevalence rate is higher than corresponding values previously recorded (3.0%; 98/3233) across five Early Medieval Irish populations (Novak 2015, 1301), but broadly comparable with data derived from other Medieval skeletal collections, such as those from Early Medieval Ballykilmore 6, Co. Westmeath (4.6%; Randolph-Quinney 2009), and Late Medieval St Mary of the Isle, Co. Cork (4.9%; Power 1995, 80). Higher true prevalence rates have been reported for other Irish Medieval population groups, however, including the Early Medieval site of Faughart Lower, Co. Louth (9.0%; Buckley *et al*. 2010, 34), and the Late Medieval population from Ardreigh, Co. Kildare (9.6%; Troy 2010, 23).

A higher proportion of females than males at Ballyhanna were affected by carious lesions. A similar pattern has been reported in a survey of Early Medieval data from elsewhere in Ireland (see Novak 2015, 1301), as well as at Ballykilmore 6, Co. Westmeath (Randolph-Quinney 2009), and at Faughart Lower (Buckley *et al*. 2010, 34). This trend has also been widely reported in other geographically diverse populations (see Larsen 2015, 73). It is possible that the higher proportion of dental cavities amongst female dentitions is indicative of sex-based dietary differences, with females consuming a greater proportion of carbohydrates and males consuming a greater proportion of animal protein. Alternatively, the trend may be related to differences in consumption patterns with females perhaps eating more frequently throughout the day (Larsen 2015, 75). The aetiology of dental caries is complex, however, and many other genetic and physiological factors related to hormonal differences, salivary flow, and changes in the oral environment during pregnancy could also contribute to this difference (Lukacs and Largaespada 2006; Lukacs 2012). Indeed, reproductive factors may be particularly important given the potentially cumulative effect of the higher number of pregnancies in the past.

Dental calculus was frequently identified in the adult dentitions with an overall TPR of 90.2% (3350/3714) of teeth affected, and an almost equal distribution between males and females. A comparable 100% of individuals were affected by dental calculus in the radiocarbon dated Early Medieval sub-sample and in the Late Medieval sub-sample. A similarly high TPR of 88.9% was reported in a survey of Early Medieval Irish collections (Novak 2015, 1301), but a lower proportion (68.6%) of adult teeth were affected in the Early Medieval population at Ballykilmore 6 (Randolph-Quinney 2009). The TPR was not reported for Faughart Lower, but deposits were noted in almost 95% of sexed adults with teeth present for analysis (Buckley *et al*. 2010, 38). While almost every adult with a dentition at Ballyhanna was affected by dental calculus, the vast majority of deposits were slight.

Overall, the high prevalence of dental calculus and low prevalence of caries in the Ballyhanna population are indicative of a mixed subsistence diet, and reflect a lack of refined sugars and fermentable carbohydrates in the diet. This corroborates the historical evidence that suggests dietary carbohydrates would have come from starch-rich plant foods, such as cereals, particularly oats. If the diet at Ballyhanna had been based predominantly on cereals, however, a higher prevalence of dental caries would be expected. Indeed, the higher true prevalence rates for dental caries reported at Faughart Lower (9.0%) and Ardreigh (9.6%), may potentially indicate a greater reliance on cereals. These latter populations were situated

in the east of the country, in areas where wheat was commonly cultivated and used for bread (Murphy and Potterton 2010, 306). Indeed accounts in historical sources, such as the *Annals of Ulster* for 1497, emphasise this distinction and refer to wheat as the standard crop of the Pale – the area under Anglo-Norman influence – and the oats 'of the Gaels' (Nicholls 2003, 133). Research on the cariogenicity of cereals found that rats fed on wheat were more prone to developing caries compared to those that consumed an oat-based diet (Dodds 1960). As such, it is possible that the lower rate of caries in the Ballyhanna population is due to the consumption of oats, as opposed to wheat. The variation in the main type of cereal grown in different parts of the country may have contributed towards the differences evident in the prevalence of caries observed between Ballyhanna and the other populations.

6.2 Stable isotopes

Before interpreting palaeodietary patterns in human bone collagen isotopic compositions, it is important to first consider the suitability of the faunal stable isotope baseline. While it is never possible to know which animals were consumed by humans in the past, palaeodietary analyses should strive to construct isotopic baselines using fauna from the most closely associated spatiotemporal context that is relevant to the human study population. This is important because if faunal isotopic baselines come from a place or time when different proportions of C_3 and C_4 plants were available, or when factors affecting local nitrogen sources and cycling differed, then resulting interpretations of human $\delta^{13}C$ and $\delta^{15}N$ may be skewed. While Ireland does not have substantial variation in the proportion of C_3 and C_4 plants (Collins and Jones, 1986), it has undergone large changes in herbivore $\delta^{15}N$ through time (Guiry, et al., 2018a), reflecting patterns in prevailing mycorrhizal communities, shifting from ectomycorrhizae- to arbuscular mycorrhizae-dominated, nitrogen cycle openness due to more open land, with increased soil disturbance, and nitrogen inputs (e.g. from stocking or manuring practises; for a review of relevant variables, see Szpak, 2014). This means that, with respect to faunal baseline suitability in Ireland, variation in animal $\delta^{15}N$ may require closer attention.

While the faunal baseline used here is constructed from animals from the same graveyard as the humans, and are thus spatially well suited for the analysis, it is not possible to assess when these animals were raised and consumed. For this reason, it is unclear whether they are from exactly the same timeframe as the human population. There are, however, a number of

circumstantial reasons to anticipate that these faunal data are also temporally suitable. The animals included in the baseline come from several grave fills and therefore they are likely to be representative of foods consumed in the region over a long period of time. Although the animal remains will predate the graves from which they were collected, the *c.*1000 year interment history at this graveyard means that they may still be contemporaneous with some earlier individuals. Recent δ^{15}N evidence from Irish domesticates provides a further line of support. Medieval domesticate δ^{15}N from sites across Ireland (15 sites, herbivore *n*=100, 6.3 ± 1.2‰; 15 sites, omnivore *n*=79, 7.9 ± 1.9‰ (Guiry, et al., 2018a) are close to those observed at Ballyhanna (herbivore *n*=10, 6.3 ± 0.8‰; omnivore *n*=1, 7.2‰) suggesting that these data reflect typical values for the time period. It is also worth bearing in mind that substantial intra-site variability in δ^{15}N (up to *c.* 5‰) in both herbivores and omnivores is evident across many Irish Medieval sites (Guiry, et al., 2018a), a pattern that is common across historical archaeological sites around the world (Guiry, et al., 2017, Guiry, et al., 2014, Guiry, et al., 2018b, Reitsema, et al., 2015, Guiry, et al., 2012, Guiry, et al., 2015). The extreme degree of isotopic variation in Medieval Irish fauna likely reflects a high level of heterogeneity in both animal husbandry and local nitrogen cycling at relatively small spatial and temporal scales. In this context, even faunal remains that can somehow be directly linked temporally with human populations may not provide a representative baseline for the ebb and flow of isotopic variation in human diets. Given that the Ballyhanna faunal data fits well with others datasets from across Ireland's Medieval period (Guiry, et al., 2018a, Knudson, et al., 2012), it is considered valid for interpreting human diets at Ballyhanna. In doing so, the assumption is that this faunal baseline is not somehow systematically skewed to omit animals with unusually high δ^{15}N due to extreme alterations of local nitrogen cycling and nitrogen inputs, such as due to manuring or the preferential consumption of suckling animals.

Diet at Ballyhanna appears to have been isotopically similar for all individuals, regardless of age or sex, from the age of three years onwards. This lack of variation persists across the entire study period, with δ^{13}C showing no change and δ^{15}N showing only a slight, although significant, –0.8 ‰ shift between the Early and Late Medieval periods (discussed in detail below).

Mean human isotopic compositions are higher for both δ^{13}C and δ^{15}N than would be expected for a solely terrestrially based diet, suggesting that aquatic protein may have been consumed. In the context of the faunal isotopic baseline, mean human δ^{15}N values are elevated by +4.3‰ (+4.2‰ if Early Medieval is excluded) over the mean for domestic animals. If no

aquatic protein had been included in the diet, then to account for this trophic offset the assumption would be not only a relatively high δ^{15}N trophic enrichment factor (although some have offered more extreme values; O'Connell, et al., 2012 a vast majority of studies estimate this offset at +3-4 ‰; for reviews, see Hedges and Reynard, 2007, Bocherens and Drucker, 2003, Szpak, et al., 2012, Post, 2002), but also that the people buried at Ballyhanna derived nearly all dietary protein from animal products (either dairy and/or meat). The archaeological and historical evidence suggests this was not the case, however, and that domestic crops, particularly cereals, were an important part of Gaelic diet. In this context, the most parsimonious explanation for higher mean human δ^{15}N values is that they reflect a diet primarily based on terrestrial cereals and vegetables and animal protein in the form of dairy and meat sources, with a supplementary contribution from aquatic protein sources. The relatively large offset between mean δ^{13}C values for humans and domestic animals (+1.7‰) provides further evidence suggestive of a dietary contribution from alternative protein sources with δ^{13}C values higher than those in the local terrestrial environment.

Ballyhanna's location on the bank of the River Erne and its close proximity to the Atlantic coastline would have provided access to both freshwater (e.g. eels) and marine (e.g. seaweed, fish and shellfish) resources that could, in turn, contribute a potentially wide range of isotopic values to the local human diet (for review see Guiry 2019). For instance, although Atlantic salmon are born in freshwater environments, they migrate to the ocean before adulthood, later returning to their natal river to spawn, meaning that they have isotopic compositions reflecting a pelagic marine ecosystem. In comparison with terrestrial foods, dietary protein derived from the consumption of anadromous Atlantic salmon (*Salmo salar*; Guiry *et al*. 2016a; Medieval period, n=10, means δ^{13}C –15.0 ± 0.5‰, δ^{15}N 11.3 ± 2.2‰) would contribute to elevated human δ^{13}C and δ^{15}N values. Atlantic cod (*Gadus morhua*; Hutchinson *et al*. 2015; Medieval period, n=17, means δ^{13}C –12.6 ± 0.7‰, δ^{15}N 15.2 ± 0.8‰), which could have been caught locally, also have high δ^{13}C and δ^{15}N values. Given the potentially high costs of cod procurement, in comparison with locally abundant and accessible salmon, as well as the relatively low status of the people interred at Ballyhanna, it seems that a significant dietary contribution from the consumption of cod would be unlikely. Eels are born in a marine environment and then migrate to freshwater lakes and rivers during adulthood, before returning to the sea again to spawn. As such, eels caught during their spawning migrations will have isotopic compositions reflecting a predominantly freshwater environment. Protein derived from catadromous European Eels (*Anguilla Anguilla;* Harrod *et*

al. 2005; modern estuary *n*=37, means δ^{13}C –17.1 ± 0.3‰ [corrected by +5‰ for muscle collagen offset and +1.5‰ for Suess effect], δ^{15}N 12.1 ± 0.6‰), which were also locally abundant and collected from the River Erne, would likely contribute to relatively low δ^{13}C and high δ^{15}N values for human consumers. Shellfish such as oysters and mussels are yet another potential source of marine-derived protein that has a long history of exploitation in Ireland (Milner and Woodman 2007; Murray 2007; Went 1961). Shellfish middens dating to the Late Medieval period are known from Ireland, such as those at Mannin 4, Co. Galway, and Carrickfin, Co. Donegal, as well as substantial oyster middens, dated on the basis of associated Medieval pottery, in Cork Harbour (McCormick *et al*. 1996, 82). As marine organisms, shellfish have generally elevated δ^{13}C and δ^{15}N values, but modern studies have shown them to have highly variable isotopic values depending on local environmental conditions (for Irish examples see, Jennings and Van Der Molen, 2015; Maloy, et al., 2013) and it is therefore difficult to assess the isotopic effect that local shellfish consumption may have had on Medieval human diet.

Evidence for slightly higher δ^{15}N during the Early Medieval may reflect a greater availability of aquatic resources to earlier populations at Ballyhanna. It is typically assumed that increased consumption of marine resources should result in strong elevation in δ^{13}C, concomitant with increasing δ^{15}N. However, a growing awareness of the complexities of aquatic carbon and nitrogen cycles (for review see, Guiry, 2019) demonstrates that this will not necessarily be the case in all contexts, particularly when pelagic and diadromous species are involved. Baseline data assembled here for aquatic species, for instance, shows that some 'marine' resources such as eels and salmon can have δ^{13}C values that are much lower than for example cod. Moreover, as demonstrated by the recovery of a freshwater pike bone from the excavations at Ballyhanna, which can also have a higher δ^{15}N but a much lower δ^{13}C, it is possible that consumption of other aquatic resources could have contributed to higher human δ^{15}N during the Early Medieval period. However, given the very small difference between results from Earlier and Late Medieval populations (<1‰), and the possibility of temporal variation in terrestrial nitrogen baselines in Ireland (Guiry, et al., 2018a), it was not possible to explore this shift in greater detail.

6.3 Comparison between dental palaeopathology and stable isotopes

The dietary evidence from both the dental palaeopathology and stable isotope analyses suggests a mixed subsistence diet primarily based on terrestrial plant and animal protein, with a supplementary contribution from aquatic protein sources. Evidence from dental palaeopathology was suggestive that females may have been consuming a greater proportion of fermentable carbohydrates than their male counterparts, although it seems highly probable that the difference in the prevalence of dental caries between the sexes could also be due to genetic and physiological differences, hormones, multiple pregnancies and perhaps eating patterns. Human bone collagen isotopic compositions, which are more strongly influenced by dietary protein intake (Ambrose and Norr, 1993), showed no differences between male and female diets. These two lines of evidence are complementary rather than contradictory, with the dental palaeopathology informing about the levels of fermentable carbohydrates in the diet and the isotopic composition of bone collagen providing information on the dietary protein intake. In this context, the differing but complementary observations offered by each approach provide a valuable example of the potential of combining multiple lines of evidence. They also serve as a cautionary tale for the kinds of interpretations that may be missed when a single technique is used.

6.4 Isotopic evidence for childhood

Caution is required when interpreting the isotopic composition of collagen from young children because their bone collagen represents a relatively short-term dietary average and may therefore be more strongly affected by seasonal variation or anomalous situations, and their premature deaths could be related to atypical nutritional stresses (Beaumont, et al., 2018). Elevated δ^{15}N values among the very youngest members of the Ballyhanna population provide evidence for nutritional processes influencing mothers and/or neonatal babies as well as infants. As neonates should have isotopic compositions similar to their mothers, the high δ^{15}N of two neonate individuals included in this study, SK 43 and SK 830, may indicate that their mothers' were undergoing nutritional stress (which can cause similar isotopic shifts, e.g., Hobson, et al., 1993) or had otherwise unusual diets. High δ^{15}N in one infant (SK 1100) and two younger children (SK 455, SK 858), followed by lower values in slightly older children (SK 121, SK 528, SK 1029) suggest that babies and young children were breastfed until approximately 1-3 years of age after which children aged 3-12 years began eating an isotopically similar diet to adolescents and adults.

7. Conclusion

This paper has presented an investigation into the nature of diet within Medieval Gaelic Ireland through an assessment of dental palaeopathology and stable isotope compositions from the skeletal population excavated from a graveyard at Ballyhanna, Co. Donegal, in the northern province of Ulster. The start of the article highlighted Richard Stanihurst's statement of 1584 that inferred the people of Ulster did not cultivate the naturally fertile land (Barry and Morgan 2013, 105). This was then used as a political device to help justify the British colonisation of Ulster in the early seventeenth century – the native people did not use the land so it could legitimately be transferred to newcomers from England and Scotland (Farrell 2017, 36-38).

Stanihurst's view, however, is contradicted by the evidence in Medieval Gaelic historical sources which highlight that animal proteins were indeed an important component of the Gaelic Irish diet, but that so too were cereals, particularly oats, which were used in the production of porridge and oatcakes (Nicholls 2003, 133). The results obtained in the current study now provide scientific evidence that support these historical sources. The Gaelic Irish engaged in both pastoral and arable farming and they consumed a mixed diet comprised of cereals and animal products. The consumption of oats by the people buried at Ballyhanna may be responsible for the lower level of caries evident in their dentitions compared to those of comparator populations who lived in the east of the island in areas of Anglo-Norman influence where wheat would have been the predominant cereal crop (see Dodds 1960; Nicholls 2003, 133).

A further finding of interest is the determination that the mean human isotopic compositions are higher for both $\delta^{13}C$ and $\delta^{15}N$ than would be expected for a solely terrestrially based diet, thereby suggesting that aquatic protein may have been consumed. Given Ballyhanna's location on the River Erne and close proximity to the Erne estuary it might appear unsurprising that the local population were incorporating aquatic foods in their diet, and the isotopic evidence now suggests that fish and sea products were indeed part of the Gaelic diet. Fish were important to the economy of the local Ó Domnaill lordship and it is documented that foreign fishermen brought them wine in return for fishing rights (Donnelly 2015, 28; Mac Eiteagáin 1995, 207). While it has been surmised that local people may have provided help to the foreign crews by processing their catches on shore, there was no definitive

evidence that the population were consuming aquatic foods. The results from the current study, however, now suggest that they were, either by way of fish received in payment for their assistance to the foreign fishermen, or through the marine foods gathered and caught by their own endeavours along the seashore and the River Erne.

The isotopic results also suggest no significant difference in the protein composition of the diet of adult males and females, however a difference in the prevalence of carious lesions was recorded between males and females. Given the widespread trend in different temporal and geographical populations of females having a higher prevalence of caries it seems probable that physiological reproductive factors may be influencing this pattern (Lukacs and Largaespada 2006). Once children were weaned onto solid foods, there seems to have been little variation in diet, with most children and adults consuming a diet that was comprised of cereals, animal products, and some aquatic protein sources. To conclude, results obtained through the current study have consolidated our understanding of diet in Medieval Gaelic Ireland by confirming the evidence from the contemporary Gaelic historical sources and refuting those of a colonial nature. New insights have also been gained into the use of aquatic foodstuffs. The study has highlighted the importance of employing a multi-proxy approach in palaeodietary reconstructions to enable a more nuanced and complete interpretation of past diet.

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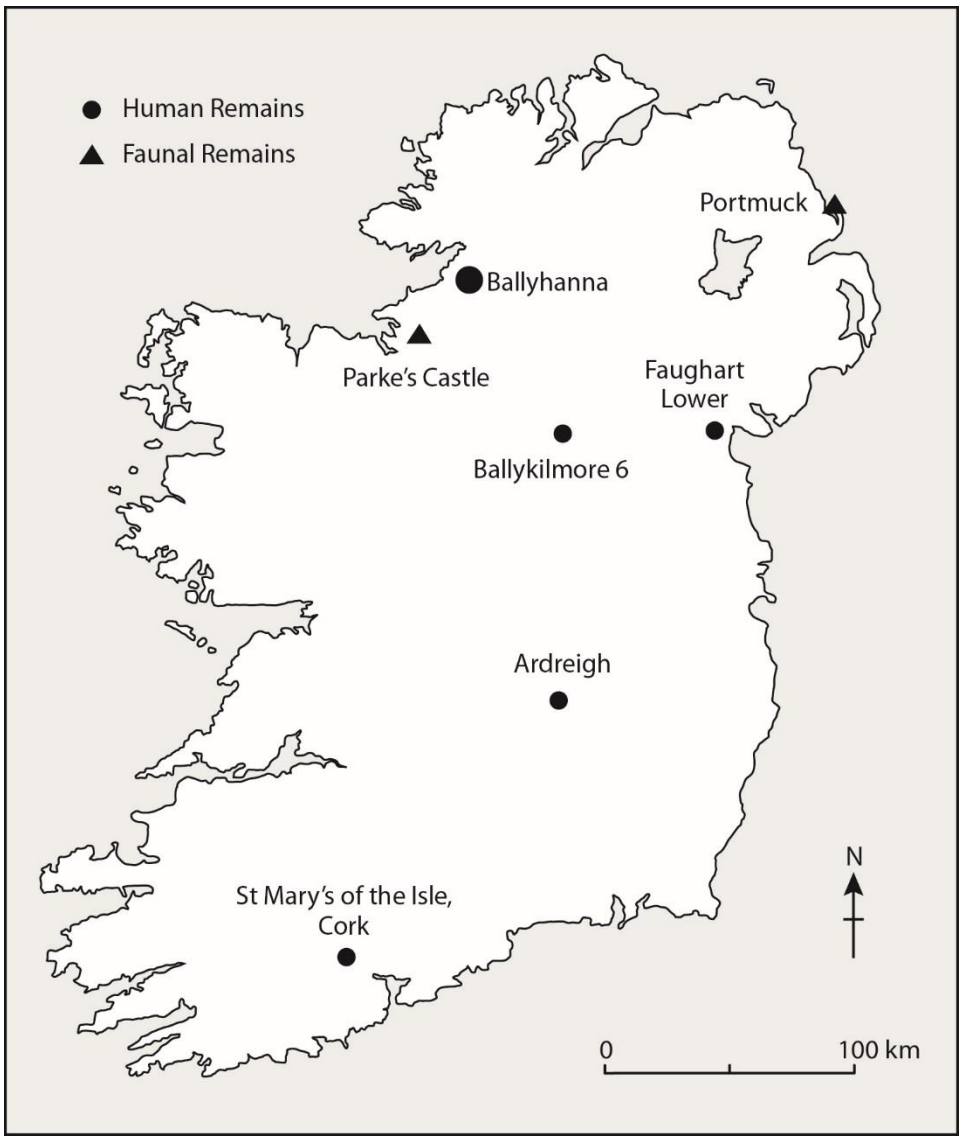

Fig. 1: Location map of Ireland showing the sites mentioned in the text. Human and faunal remains from Ballyhanna were included in the analysis, with human and faunal remains from a range of other sites across the island used for additional information or for comparative purposes.

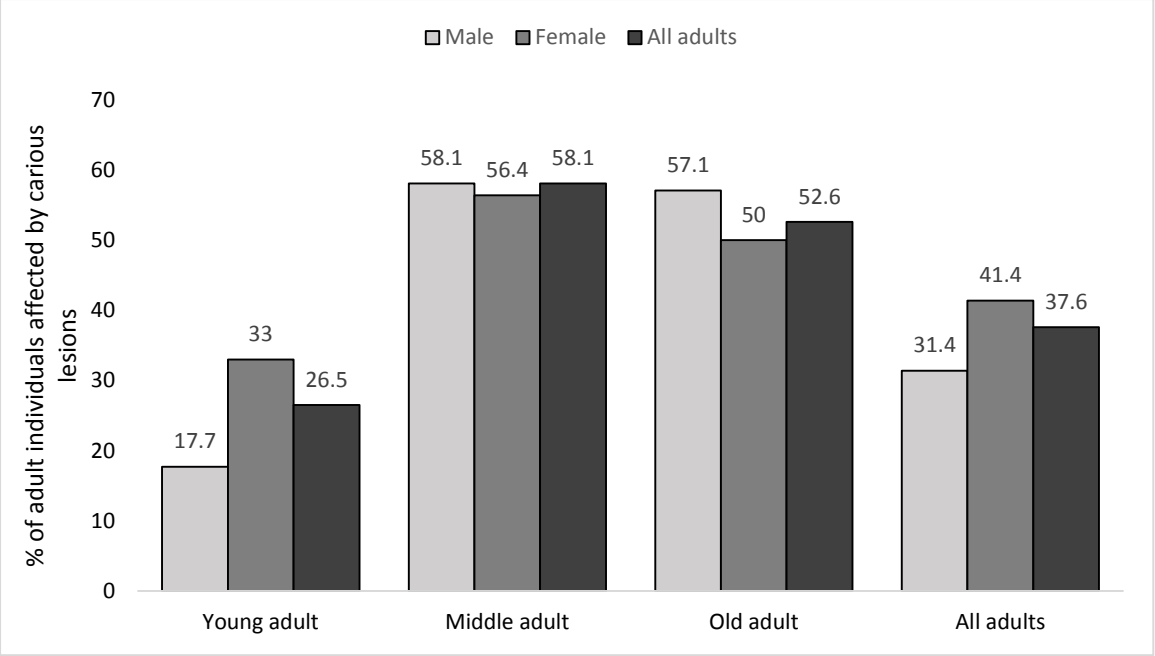

Fig. 2: Percentage of individuals affected by carious lesions by age and sex (*n*=134/356).

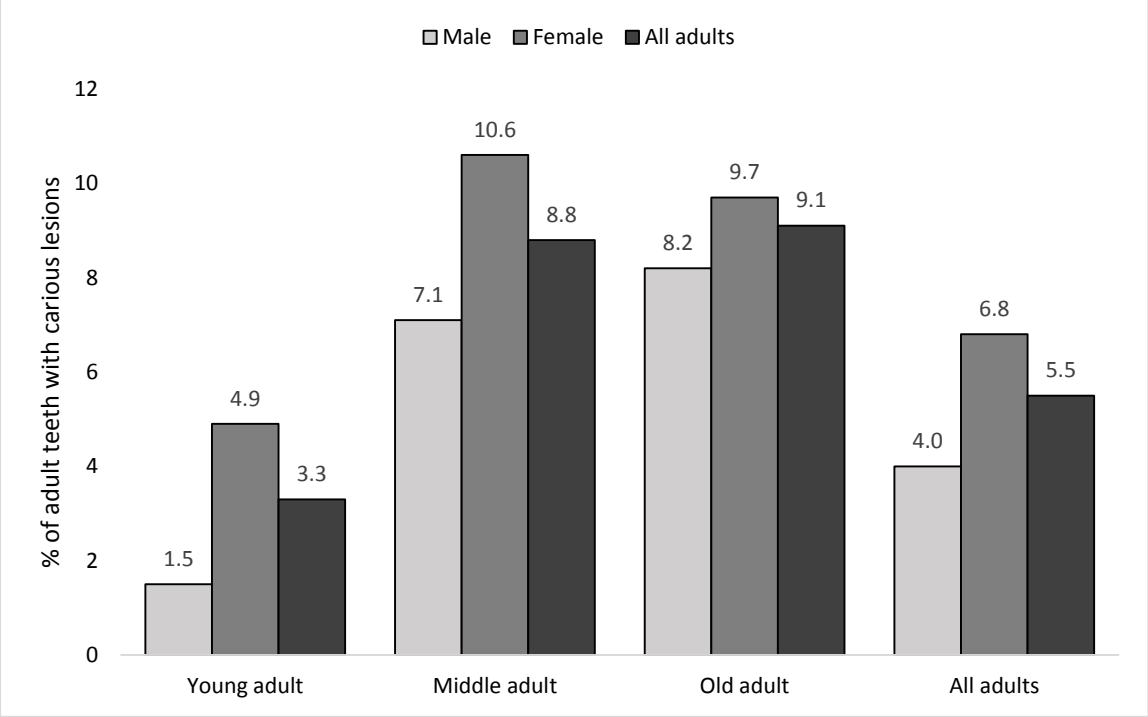

Fig. 3: Percentage of teeth with carious lesions by age and sex (*n*=344/6238).

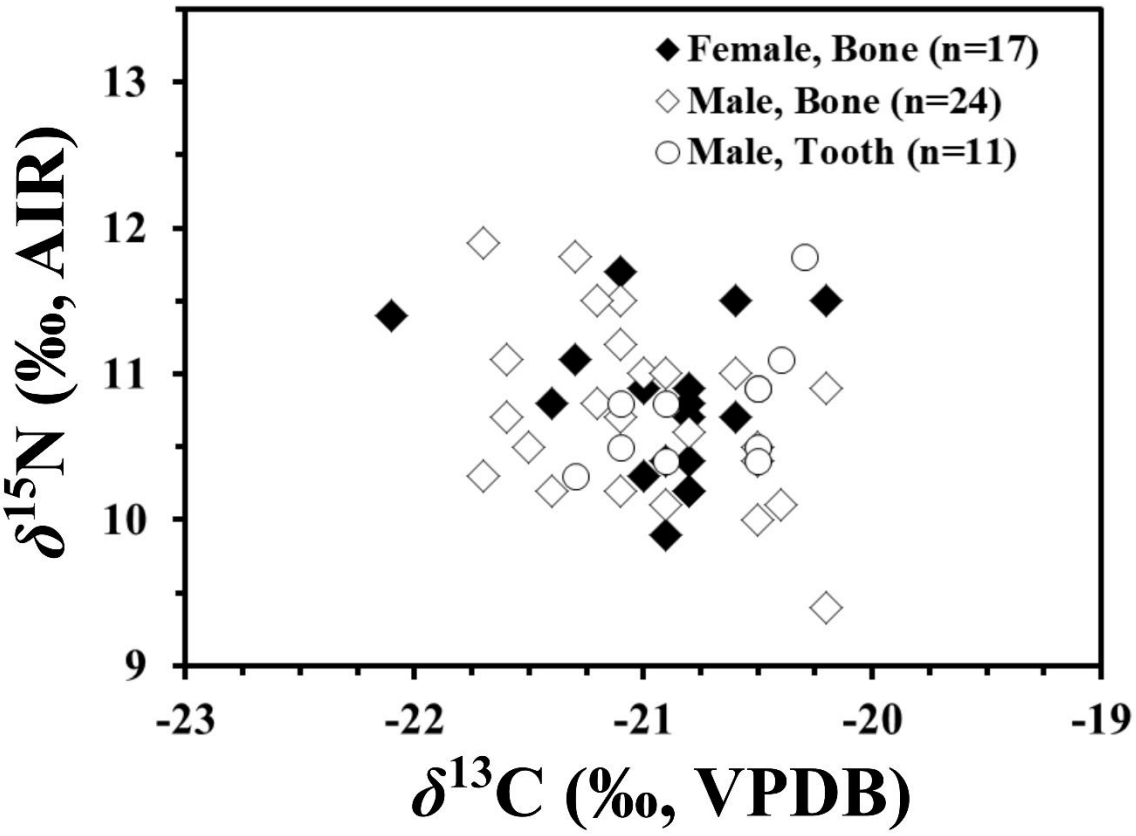

Fig. 4: Plot of $\delta^{13}C$ and $\delta^{15}N$ for human adults differentiated by sex and sample materia

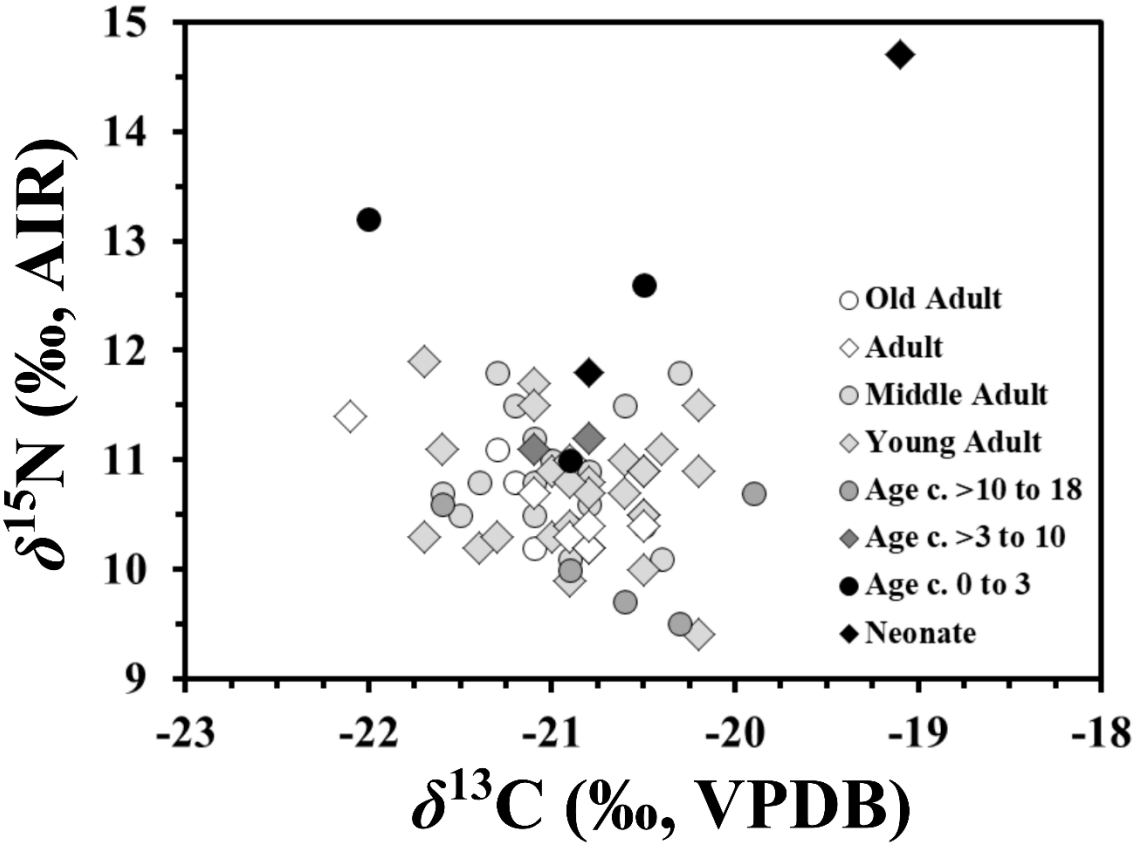

Fig. 5: Plot of $\delta^{13}C$ and $\delta^{15}N$ for all humans differentiated by age group.

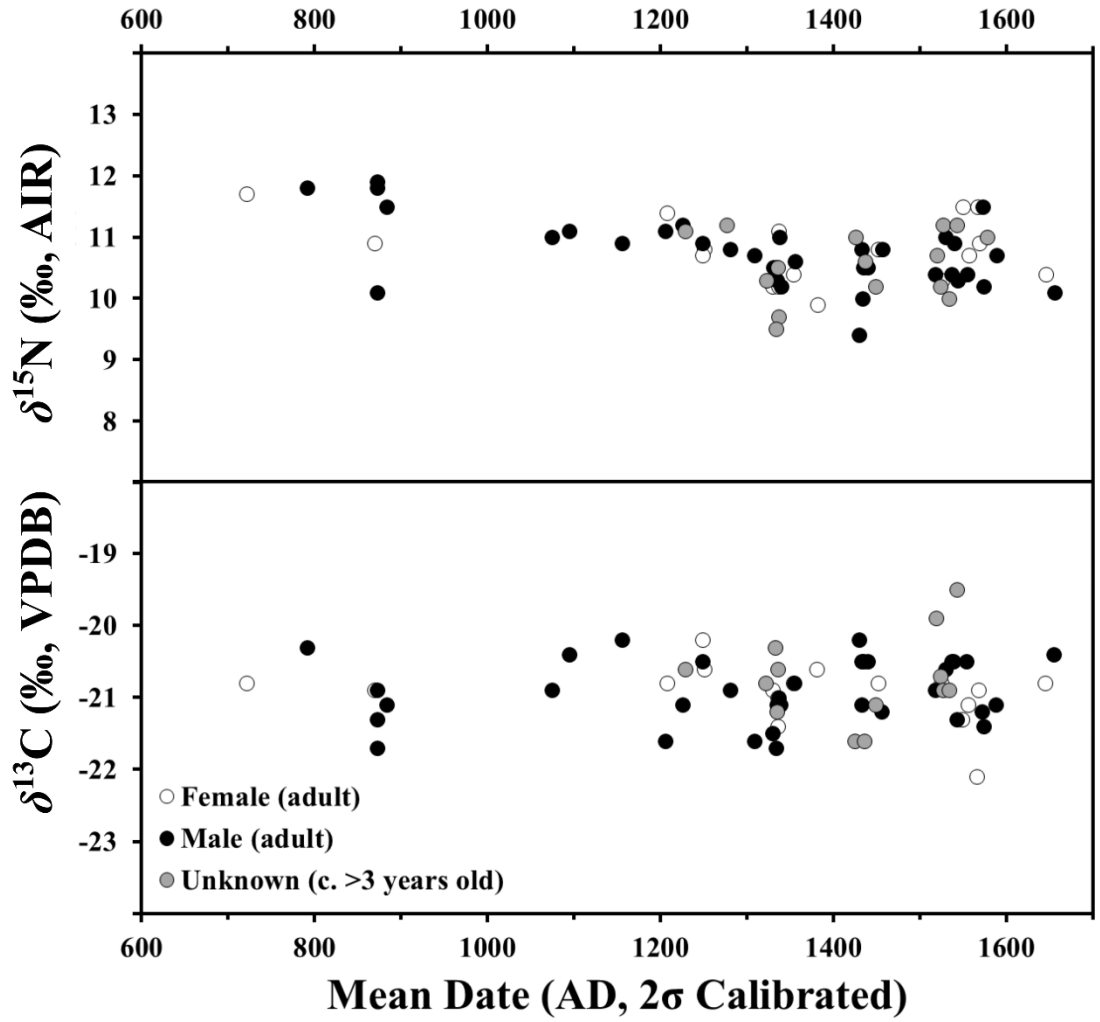

Fig. 6: Plot of $\delta^{13}C$ and $\delta^{15}N$ versus time for humans.

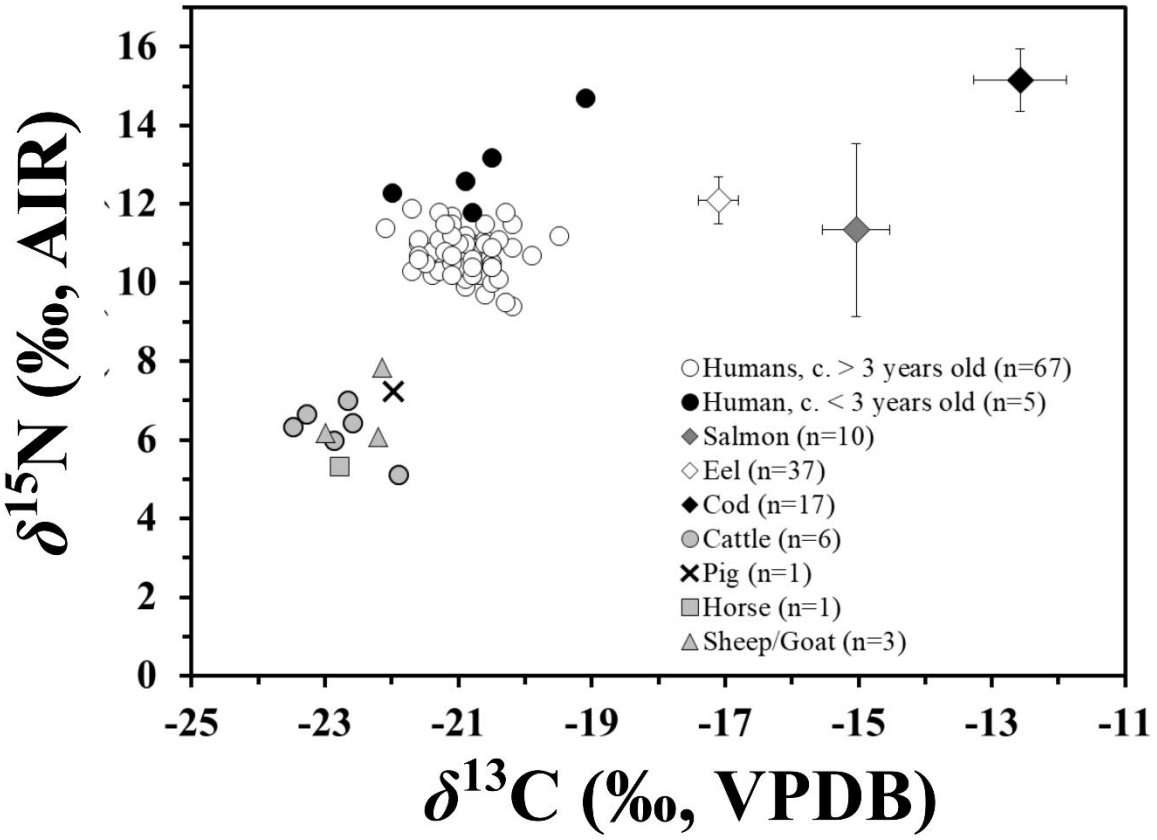

Fig. 7: δ^{13}C and δ^{15}N for humans showing faunal baseline. Fish data are from (Guiry, et al., 2016a, Harrod, et al., 2005, Hutchinson, et al., 2015).

Table 1: Details of the adults from Ballyhanna included in the study.

Context	UB Number	Calibrated date	Calibrated date	Skeletal element	Sex	Age	$\delta^{13}C$	$\delta^{15}N$	Collagen	C:N
		1 sigma	2 sigma	sampled					yield %	
SK 24	14974	AD 1439–1451	AD 1432–1465	Tibia	-	Adult	-20.8	10.2	5.9	3.3
SK 787	14972	AD 1273–1290	AD 1263–1381	Vertebra	-	Adult	-20.9	10.3	0.8	3.3
SK 70	14985	AD 1285–1386	AD 1277–1395	Rib	Female	Young Adult	-20.8	10.2	20.3	3.2
SK 153	14975	AD 1228–1271	AD 1223–1274	Rib	Female	Young Adult	-20.8	10.7	5.7	3.3
SK 182	11441	AD 1494–1631	AD 1477–1635	Rib	Female	Young Adult	-20.6	10.7	14.8	3.1
SK 477	14979	AD 1441–1486	AD 1430–1620	Rib	Female	Young Adult	-21.0	10.3	3.0	3.2
SK 670	11446	AD 1402–1430	AD 1324–1438	Rib	Female	Young Adult	-20.9	9.9	26.3	3.2
SK 857	11447	AD 782–936	AD 778–961	Rib	Female	Young Adult	-21.0	10.9	17.1	3.2
SK 1009	14988	AD 1435–1455	AD 1425–1478	Rib	Female	Young Adult	-20.8	10.8	4.7	3.3
SK 1201A	11451	AD 1484–1631	AD 1460–1638	Rib	Female	Young Adult	-20.2	11.5	23.0	3.4
SK 1242	11453	AD 679–767	AD 670–772	Rib	Female	Young Adult	-21.1	11.7	25.0	3.5
SK 407	14981	AD 1519–1635	AD 1489–1643	Rib	Female	Middle Adult	-20.6	11.5	4.8	3.2
SK 495	14990	AD 1524–1654	AD 1499–1791	Rib	Female	Middle Adult	-20.9	10.4	4.1	3.3
SK 543	14995	AD 1244–1276	AD 1225–1276	Rib	Female	Middle Adult	-21.4	10.8	3.6	3.3
SK 882	11448	AD 1521–1642	AD 1488–1648	Rib	Female	Middle Adult	-20.8	10.9	17.6	3.4
SK 111	14977	AD 1290–1383	AD 1284–1388	Rib	Female	Old Adult	21.3	11.1	6.7	3.2
SK 432	14982	AD 1173–1220	AD 1160–1254	Rib	Female	Adult	-22.1	11.4	1.4	3.3
SK 680	15156	AD 1312–1397	AD 1302–1405	Scapula	Female	Adult	-20.8	10.4	5.9	3.3
SK 1135	14987	AD 1279–1378	AD 1273–1386	Femur	Female	Adult	-20.8	10.2	5.6	3.3
					Female mean		**-20.9**	**10.8**		
SK 30	11440	AD 1427–1444	AD 1415–1451	Rib	Male	Young Adult	-20.5	10.0	17.9	3.4
SK 86	15981	AD 1421–1447	AD 1403–1476	M1 tooth	Male	Young Adult	-20.5	10.5	7.6	3.2
SK 102A	14978	AD 1430–1444	AD 1420–1449	Rib	Male	Young Adult	-20.5	10.5	4.3	3.2
SK 295	15973	AD 1227–1273	AD 1220–1277	I2 tooth	Male	Young Adult	-20.5	10.9	3.4	3.3
SK 331	11443	AD 1169–1215	AD 1057–1254	Rib	Male	Young Adult	-20.2	10.9	4.3	3.2
SK 484	15982	AD 1226–1281	AD 1182–1379	M3 tooth	Male	Young Adult	-20.9	10.8	4.1	3.3
SK 555	14971	AD 1017–1151	AD 994–1155	Rib	Male	Young Adult	-20.9	11.0	0.8	3.4
SK 566	11445	AD 783–942	AD 779–966	Rib	Male	Young Adult	-21.7	11.9	3.2	3.2
SK 571	15975	AD 1040–1154	AD 1028–1161	M3 tooth	Male	Young Adult	-20.4	11.1	2.5	3.3

SK 824	14992	AD 1422–1442	AD 1409–1450	Rib	Male	Young Adult	-20.2	9.4	4.0	3.3
SK 850	15976	AD 1469–1619	AD 1455–1631	M1 & M2 teeth	Male	Young Adult	-21.3	10.3	2.7	3.3
SK 927	15977	AD 1438–1462	AD 1429–1606	M1 tooth	Male	Young Adult	-20.9	10.4	6.4	3.2
SK 982	15983	AD 1522–1647	AD 1494–1653	Rib	Male	Young Adult	-21.4	10.2	23.8	3.3
SK 1113	15984	AD 1286–1382	AD 1280–1388	Rib	Male	Young Adult	-21.7	10.3	7.1	3.6
SK 1134	14983	AD 1447–1606	AD 1441–1618	Rib	Male	Young Adult	-20.6	11.0	9.6	3.2
SK 1151	15978	AD 1453–1617	AD 1446–1632	M2 tooth	Male	Young Adult	-20.5	10.9	3.7	3.3
SK 1224	11452	AD 881–971	AD 782–984	Rib	Male	Young Adult	-21.1	11.5	22.8	3.4
SK 1239B	14984	AD 1174–1217	AD 1158–1252	Rib	Male	Young Adult	-21.6	11.1	4.9	3.2
SK 150	15971	AD 1425–1445	AD 1410–1455	M2 tooth	Male	Middle Adult	-21.1	10.8	8.4	3.2
SK 197	11442	AD 783–940	AD 779–965	Rib	Male	Middle Adult	-20.9	10.1	15.7	3.5
SK 198	15972	AD 1286–1384	AD 1280–1389	M2 tooth	Male	Middle Adult	-21.1	10.5	3.5	3.3
SK 530	11444	AD 1527–1654	AD 1519–1791	Rib	Male	Middle Adult	-20.4	10.1	21.8	3.2
SK 542	14970	AD 1312–14	AD 1298–1412	Rib	Male	Middle Adult	-20.8	10.6	2.3	3.3
SK 554	14980	AD 1217–1256	AD 1183–1268	Vertebra	Male	Middle Adult	-21.1	11.2	3.8	3.3
SK 809	14993	AD 1280–1378	AD 1275–1385	Rib	Male	Midde Adult	-21.5	10.5	5.9	3.3
SK 885	11449	AD 781–936	AD 774–971	Rib	Male	Middle Adult	-21.3	11.8	21.0	3.6
SK 936A	15980	AD 1447–1617	AD 1440–1633	C tooth	Male	Middle Adult	-20.5	10.4	4.5	3.3
SK 984	11450	AD 1522–1645	AD 1495–1649	Vertebra	Male	Middle Adult	-21.2	11.5	28.3	3.3
SK 1054	14991	AD 1266–1377	AD 1229–1388	Rib	Male	Middle Adult	-21.6	10.7	5.0	3.3
SK 1185	15979	AD 774–870	AD 694–889	C tooth	Male	Middle Adult	-20.3	11.8	4.8	3.2
SK 1225	15985	AD 1291–1385	AD 1284–1390	Rib	Male	Middle Adult	-21.0	11.0	25.2	3.3
SK 84	14976	AD 1439–1457	AD 1432–1480	Rib	Male	Old Adult	-21.2	10.8	5.3	3.3
SK 1030	14989	AD 1294–1386	AD 1287–1391	Rib	Male	Old Adult	-21.1	10.2	13.8	3.3
SK 931	14986	AD 1524–1646	AD 1515–1661	Rib	Male	Adult	-21.1	10.7	5.6	3.3
SK 1038	14994	AD 1493–1630	AD 1474–1634	Pelvis	Male	Adult	-20.5	10.4	7.6	3.3
					Male mean		**-20.9**	**10.7**		

Table 2: Details of the juveniles from Ballyhanna included in the study.

Context	UB Number	Calibrated date	Calibrated date	Skeletal element	Sex	Age	$\delta^{13}C$	$\delta^{15}N$	Collagen	C:N
		1 sigma	2 sigma	sampled					yield %	
SK 830	11459	AD 1451–1611	AD 1445–1620	Rib	-	Full term infant, 41 weeks gestation	-20.8	11.8	4.9	3.3
SK 43	11456	AD 1451–1611	AD 1445–1620	Rib	-	Neonate, 43 weeks gestation	-19.1	14.7	5.0	3.3
SK 1100	11461	AD 1278–1292	AD 1271–1381	Rib	-	Infant, 1-2 months	-22.0	12.3	2.7	3.6
SK 455	14999	AD 1271–1283	AD 1263–1289	Rib	-	Younger Child, 1-3 years	-20.9	12.6	15.0	3.3
SK 858	15002	AD 1522–1650	AD 1494–1661	Rib	-	Younger child, 1-3 years	-20.5	13.2	4.1	3.3
SK 528	15000	AD 1219–1256	AD 1186–1270	Rib	-	Younger Child, 2-4 years	-20.8	11.0	3.8	3.3
SK 1029	11460	AD 1443–1469	AD 1435–1612	Femur	-	Younger Child, 4.5-6.5 years	-21.1	11.2	17.5	3.3
SK 121	14997	AD 1443–1606	AD 1434–1619	Rib	-	Younger Child, 5-7 years	-20.6	11.1	3.2	3.3
SK 294	14998	AD 1288–1382	AD 1282–1388	Femur	-	Older child, 5.5-7.5 years	-20.7	10.2	6.1	3.3
SK 31	14996	AD 1466–1624	AD 1451–1634	Rib	-	Older Child, 6-8 years	-20.9	11.2	17.8	3.3
SK 541	15001	AD 1417–1433	AD 1410–1440	Rib	-	Older Child, 6-9 years	-21.2	10.5	18.3	3.3
SK 755	11458	AD 1440–1463	AD 1431–1607	Rib	-	Older Child, 7.5-9 years	-19.5	11.2	10.8	3.3
SK 1155	11463	AD 1289–1384	AD 1283–1389	Femur	-	Older Child, 8.5-10.5 years	-21.6	11.0	20.8	3.4
SK 1117	11462	AD 1453–1613	AD 1447–1620	Rib	-	Older Child, 9-12 years	-19.9	10.7	26.6	3.3
SK 355	11457	AD 1431–1446	AD 1419–1453	Rib	-	Adolescent, 12-14 years	-20.6	9.7	20.8	3.3
SK 1C	11454	AD 1291–1386	AD 1284–1391	Rib	Male	Adolescent, 14-18 years	-21.6	10.6	29.6	3.4
SK 861	15003	AD 1282–1383	AD 1276–1390	Tibia	-	Adolescent, 14-18 years	-20.9	10.0	2.3	3.3
SK 35	11455	AD 1270–1283	AD 1260–1291	Rib	Male	Adolescent, 15-18 years	-20.3	9.5	22.4	3.3

Table 3: Isotope values of the Ballyhanna faunal samples.

SUBC No.	Cat. No.	Taxon	Element	$\delta^{13}C$	$\delta^{15}N$	%C	%N	% Col.	C:N
11593	15005	Cattle	Ulna	–22.6	6.4	40.6	14.3	12	3.3
11594	15006	Cattle	Scapula	–23.5	6.3	39.9	12.9	16	3.6
11595	15007	Cattle	Calcaneus	–22.9	6.0	41.0	13.7	17	3.5
11596	15008	Cattle	Calcaneus	–21.9	5.1	40.7	14.3	27	3.3
11597	15009	Cattle	Calcaneus	–23.3	6.7	39.0	13.5	12	3.4
11598	15010	Cattle	Calcaneus	–22.7	7.0	40.4	14.0	24	3.4
11599	15011	Horse	Phalanx 3	–22.8	5.3	40.6	14.4	22	3.3
11601	15013	Sheep/goat	Humerus	–22.1	7.8	40.3	14.2	15	3.3
11602	15014	Sheep/goat	Humerus	–22.2	6.1	40.2	14.3	20	3.3
11603	15015	Sheep/goat	Humerus	–23.0	6.2	39.8	13.3	14	3.5
		Herbivore mean		**–22.7**	**6.3**	**(n=10 excluding pig)**			
11600	15012	Pig	Ulna	–22.0	7.2	40.6	14.3	25	3.3

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