Food for the Body, Sustenance for the Soul: Dietary contrast between Pictish and Medieval populations at Portmahomack, Scotland, using Stable Isotope Analysis.

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*THE DISCOVERY AND EXCAVATION of the first Pictish monastery in Scotland, has enabled dietary reconstructions on skeletal remains from the monastery (*c.*AD 550-900) and the later Medieval parish church that succeeded it (*c.*AD 1100-1600). Carbon and nitrogen isotope analyses of bone and tooth root collagen from these individuals were measured for dietary reconstructions. Faunal bone collagen was also analysed to provide isotopic baselines. The purpose of this pilot-study was to ascertain if changes in diet occurred from the early to late medieval periods at Portmahomack. Variations in diet relating to age and sex were also evaluated to establish whether divisions in the types of foods consumed were present. Results demonstrated the presence of a diachronic change in diet between the early and late medieval periods at Portmahomack. Diets from the monastic groups consisted of C_3-based terrestrial foods, including a significant proportion of animal protein but no marine protein. In contrast to their predecessors, the high - late medieval folk consumed both terrestrial and marine protein. No major dietary differences relating to age or sex were detected. Faunal data presented dietary differences between the two phases at the site, perhaps related to a change in husbandry practices. A dietary distinction between the two groups is therefore apparent and consistent with previous studies on diet in Scottish antiquity.*

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Recent studies have offered isotopic data on the diets of individuals from Medieval monastic communities in Scotland.[1] This paper offers a first opportunity to examine diet from a Pictish monastic establishment (6th to 9th century AD) and compare it with the diet of the parish that succeeded it in the Middle Ages (11th to 16th century AD). Dietary reconstructions at Portmahomack, Tarbat, in north east Scotland may reveal changes between both a monastic and subsequent lay community, and between the Pictish and later period, so contributing to recent studies that suggest a diachronic change in diet in Scotland around this time.[2] Comparable isotope data from a selection of Iron Age to medieval sites in Scotland were examined to gain a broader understanding of diet during these periods.[3]

THE SITE: PORTMAHOMACK

The site is situated in the coastal village of Portmahomack on the Tarbat Peninsula in northeast Scotland (Fig.1), with the area of archaeological interest centred around St Colman's church.[4] The historical importance of this site has been known from the nineteenth century AD, when antiquaries noted carved stones in and around the church, among them one with a Latin inscription.[5] The modern campaign (between 1994 and 2007) recovered another 200 carved stones including one carrying images of the Apostles. The excavations also unearthed a wealth of finds relating to craft-working activities, including butchery, glass, leather and metal-working. There was also evidence for the making of books from vellum. A number of cattle metapodials, arranged in the ground were probably used as pegs in a wooden frame for stretching cattle skins. Other associated finds include needles, pumice rubbers and a bone stylus.[6] These finds, along with the Latin inscription and Apostle stone suggest evidence of an early Christian literate community at Portmahomack.[7]

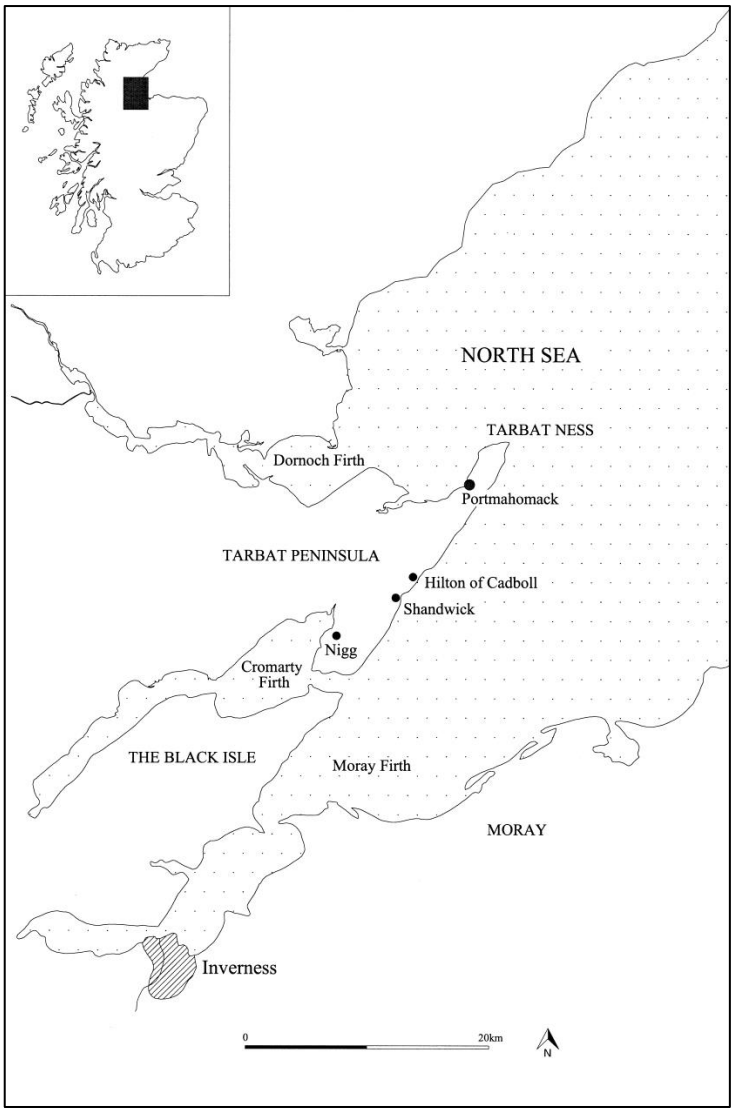

FIG 1
Location map of Portmahomack. © *University of York*.

THE BURIALS AT PORTMAHOMACK

The burials at Portmahomack were well stratified and comprise two distinct groups: the early medieval (Pictish) burials (6th to 9th century AD) and the late medieval (lay) burials (11th to 16th century AD). The sequence has been divided into four periods: (1) AD 550-700, Pre- or Proto-monastic (2) AD 700-800, Monastic (3) AD 800-1100, Post-monastic and (4) AD 1100-1600, Medieval. The period 1 burials (*n*=15) are characterised by the presence of long-cist graves. The period 2 burials (*n*=58) were predominately adult males, featuring the

head-support burial rite and are assigned to the monastery. The monastery was raided and burnt between AD 780 and AD 830 and only two burials have been recognised from the subsequent Period 3. Period 4 represents the parish church founded during the 12th century. Burials from this period (*n*=116) are those of men women and children and date mainly to the 15th and 16th centuries. Burial in the church ceased about AD 1620 when the church was reformed and a stone floor was laid.

Very little is known about the members of early monastic communities in Scotland. Only one child burial was found within the monastic phase at Portmahomack, suggesting that as with Medieval monasteries, the community largely comprised of adult males.[8] In contrast to the monastic phase the later medieval burials represent more of a normal demographic profile, with the presence of men, women and children. Period 1 represented the greatest investment with large slabs lining the majority (12) of graves. In Period 2, just under half (21) were head-support graves, with stones placed either side of the skull. In Period 4, there were several suspected coffin and shroud burials. However, it is likely that most medieval corpses would have been transported to the burial place in coffins, but then removed and their shrouded bodies placed in the grave.[9] Therefore, there was little decisive evidence for social differentiation in the burial rites and little in either population to indicate differences in status.

EVIDENCE FOR DIET IN MEDIEVAL SCOTLAND

Archaeological evidence suggests that cattle were a highly important commodity for meat and milk throughout the medieval period in Scotland.[10] The exploitation of fish is less clear. In the early medieval (Pictish) period, stable isotope evidence suggests a high terrestrial meat protein intake, with little marine protein consumption,[11] even though many sites have been found near the coast and there is some archaeological evidence for marine exploitation.[12]

There is an expectation that monastic communities should eat fish. The Rule of St. Benedict (c.AD 560) proscribed the consumption of meat on fast days, unless a person was ill,[13] and in the later medieval period, Benedictines following this rule substituting fish for meat on fasting days. However, fasting practices of the early communities in the north is not certain. Before the spread of the Black Death in Scotland in AD 1350,[14] most peasants relied on cereals, yet by the 15th century AD peasant diets changed with the consumption of wheat, ale, fish and meat, providing a range of vitamins that were previously deficient in the diet of many people.[15]

STABLE ISOTOPES AND PALEODIET: A BRIEF OVERVIEW

Since the 1970s, stable carbon and nitrogen isotope analysis has developed to become a powerful research tool, and more recently, has been successfully used for reconstructing medieval diets.[16] Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes are measured in delta (δ) units and are expressed in parts per mil (‰) relative to particular standards: AIR for nitrogen and Vienna Pee Dee Belemnite (V-PDB) for carbon.[17] A number of systematic changes in $\delta^{15}N$ ratios have been observed when organic matter is transferred up the food chain, for example, from plants to herbivores to carnivores. This 'trophic level effect' is estimated at 3‰ to 5‰ enriched in ^{15}N for each trophic level.[18] Nitrogen isotopes are therefore used to examine tropic level effects and to measure the level of marine versus animal protein consumption. By measuring isotope ratios in bone collagen, an individual's position in the food chain may be reconstructed. However, a number of factors may influence nitrogen isotope ratios, such as aridity,[19] salinity [20] and physiological effects.[21] It is therefore important to include faunal baselines from animals of known geographical locations (preferably from the site under investigation) and temporality to enable comprehensive dietary reconstructions.

Carbon isotopes ratios vary between terrestrial and marine ecosystems and between plants of different photosynthetic pathways. These photosynthetic pathways are C_3, C_4 and CAM, the latter of which can alternate between C_3 and C_4 pathways and mirror their $\delta^{13}C$ values.[22] C_3 plants, which are found in most temperate zones and are native to Britain, include all trees, bushes, shrubs and most marine plants.[23] C_4 plants include tropical vegetation such as sugar cane, maize, millet and sorghum. No natural C_4 vegetation exists in Britain and before foods like sugar cane were imported in the late medieval period, this dietary component was rare,[24] although two recent studies have discovered the presence of C_4 foods from stable isotope analysis on Romano-British individuals.[25]

Collagen is an extremely useful material for stable isotope dietary reconstructions as it can survive for thousands of years[26] and is a source of nitrogen, which is not present in bone apatite.[27] Moreover, apatite is susceptible to mineral decomposition through diagenetic factors, such as low pH, groundwater activity and high temperatures.[28] Therefore $\delta^{13}C$ in apatite was not examined in this study. Bone turns over at a rate of around ten to thirty years,[29] depending on the type of bone,[30] therefore providing a long-term averaged value. Unlike bone, tooth dentine does not continuously remodel,[31] hence, tooth dentine should retain $\delta^{13}C$ and $\delta^{15}N$ values from when it was formed.[32] The mandibular first permanent molar (M1), the tooth chosen for this study, mineralises at the peri-natal stage, with the crown complete by 2.5 to 4 years, eruption between 5 to 7 years and completion of the root apex by around 9 to 11.5 years.[33] As the bulk of M1 root dentine was laid down after cessation of breastfeeding, isotope values from this location should not reflect any breastfeeding signals, where for example, $\delta^{15}N$ values would be increased to a trophic level above the mother.[34] Stable isotope data can therefore elucidate the diet of an adult's life from the last ten years or so and from childhood if tooth dentine collagen is measured.

MATERIALS AND METHODS

Human cortical rib samples from 40 individuals (*n*=3 Period 1, *n*=16 Period 2, *n*=2 Period 3, *n*=19 Period 4) were selected and for ten of theses (*n*=6 Period 2, *n*=1 Period 3, *n*=3 period 4), a sample of first molar bulk root dentine was also taken. Bone samples were taken from sixteen animals: cattle, sheep, pig, dog and cod. Sample preparation and isotope analysis procedures were performed similarly to that of Richards and Hedges,[35] with an extra stage of ultrafiltration proposed by Brown et al,[36] following a modified Longin method.[37]

Approximately 200-300 mg of bone and tooth were cleaned by air abrasion and demineralised in 0.5M hydrochloric acid (HCl) at a refrigerated temperature of 4°C for several days. Each sample was rinsed in deionised water (H_2O) and three drops of 0.5M dilute HCl was added to produce a pH 3 solution. The samples were then gelatinised in a Techne Dri-block DB.2A heating block at 70º C for 48 hours. After gelatinisation, each sample was fed through an Amicon® Ultra Ezee™ filter to a clean test tube, with the insoluble residue retained in the 0.4μm filter.

Although an additional step of ultrafiltration is not a strict requirement of stable isotope sample preparation, its use may aid the isolation of intact "collagen".[38] An Amicon® Ultra Centrifugal Filter tube for each sample was filled with 0.1M sodium hydroxide solution (NaOH) and centrifuged for twenty minutes to remove any contaminants. Each sample was placed into an ultrafilter tube and centrifuged, with the remaining filtered liquid transferred to clean test-tubes and frozen at -35ºC. All samples were then freeze-dried, weighed (0.9-1.1mg) and analysed in duplicate using a Roboprep-CN analyser, coupled to a Europa Scientific 20-20 continuous flow isotope ratio mass spectrometer (CF-IRMS). All mass-spectrometric analysis was performed at the University of Bradford's Stable Light Isotope Facility. $\delta^{13}C$ and

$\delta^{15}N$ ratios are reported relative to the international standards of Vienna-PDB and AIR respectively. International standards used were N_2 ($\delta^{15}N$ value of +20.41‰) and IAEA 600 ($\delta^{13}C$ and $\delta^{15}N$ values of -27.77‰ and +1.0‰ respectively). The analytical precision for both carbon and nitrogen was ± 0.2‰ (1σ).[39]

RESULTS

All $\delta^{13}C$ and $\delta^{15}N$ data are presented in Tables 1 and 2. The majority of samples yielded good quality collagen, with those for the human samples ranging from 1.2 wt. % to 12.4 wt. %,[40] One tooth sample (140T) was excluded due to a low collagen yield of 0.2 wt. %, hence will not be discussed further. All weight percentages for carbon and nitrogen fell within the acceptable range of 30-50 wt. % for carbon and 10-20 wt. % for nitrogen. C:N ratios for human and faunal samples were between 3.2 and 3.6 and are therefore within the acceptable range of well-preserved collagen.[41] For convenience, human and faunal samples from the early medieval periods (1-3) will be referred to as 'monastic', with those from the high - late medieval period (4) referred to as 'lay'. Human samples will be identified by their individual skeleton/burial (SK) number and faunal samples by their sample number.

TABLE 1

$\delta^{13}C$ and $\delta^{15}N$ faunal bone collagen results and archaeological data from Portmahomack.

Sample No.	Animal/Bone analysed	Mass Coll (mg)	$\delta^{13}C$	$\delta^{15}N$	Coll Yield (%)[a]	%C	%N	C:N[b]	Period
C3122/1	Pig/skull	12.6	-21.4	8.8	3.2	42.7	15.4	3.2	1-3
C3122/2	Pig/ zygomatic	6.1	-21.5	8.1	1.5	40.8	14.8	3.2	1-3
C3122/3	Pig/skull (juvenile)	15.0	-21.4	8.3	3.6	41.0	15.0	3.2	1-3
C3122/4	Cattle/rib	21.7	-22.3	6.8	5.6	41.9	15.2	3.2	1-3
C3122/5	Cattle/rib	27.2	-22.4	6.3	6.8	42.1	15.3	3.2	1-3
C3122/6	Cattle/rib	21.6	-22.2	6.4	5.3	41.6	15.2	3.2	1-3
C3122/7	Cattle/long bone	26.2	-21.8	6.6	6.2	42.5	15.2	3.3	1-3
C3122/8	Cattle/long bone	26.7	-22.4	5.9	7.1	42.2	15.3	3.2	1-3
C3122/9	Cattle/ humerus	16.3	-21.8	6.2	4.3	42.1	15.2	3.2	1-3
C3122/10	Cattle/ humerus	25.6	-21.9	3.4	6.4	42.0	15.0	3.3	1-3
C1280/1	Sheep/Goat/ metacarpal	8.5	-22.0	8.8	2.2	41.7	14.7	3.3	4
C1280/2	Cattle/tibia	29.4	-22.0	10.0	6.8	42.2	15.4	3.2	4
C1280/3	Dog/ L.humerus	11.5	-16.8	15.3	2.9	41.5	14.9	3.2	4
C1280/4	Pig/ sphenoid	14.1	-21.1	11.9	3.4	41.5	14.8	3.3	4
C1280/5	Pig (juvenile) 4th metacarpal	15.7	-21.7	11.8	3.9	41.8	15.0	3.2	4
C1303/1	Cod vertebra (16-17th)	5.7	-12.3	14.3	1.3	41.1	14.6	3.3	4

[a] Yield (%) = Mass mg collagen / weight (bone) mg x 100

[b] Acceptable C:N ratio (see DeNiro 1985)

TABLE 2
$\delta^{13}C$, $\delta^{15}N$ human bone and dentine collagen results and archaeological data from Portmahomack.

Skeleton (burial) No.[a]	Mass Coll (mg)	$\delta^{13}C$	$\delta^{15}N$	Collagen Yield (%)[b]	C:N[c]	Age[d]	Sex[d]	Period[e]
166	44.4	-21.0	10.8	10.4	3.2	adult	F?	1
169	37.8	-20.7	10.0	8.8	3.2	26-45	M	1
172	41.9	-20.8	10.9	10.1	3.2	46+	F	1
116	43.9	-20.3	13.0	11.0	3.2	26-45	M	2
124	21.3	-20.8	11.4	5.1	3.2	17-25	M	2
124T	1.2	-21.2	11.7	0.6	3.3	17-25	M	2
127	45.4	-20.4	11.8	10.6	3.2	26-45	F?	2
128	18.4	-20.5	11.7	4.4	3.3	46+	M?	2
140	8.1	-20.3	12.5	2.0	3.2	17-25	M	2
144	10.6	-19.1	14.6	2.4	3.2	46+	M	2
144T	25.5	-19.9	14.6	8.1	3.2	46+	M	2
147	21.5	-20.4	11.2	5.4	3.2	26-45	M	2
147T	12.0	-20.5	12.2	4.7	3.2	26-45	M	2
151	25.8	-20.6	12.6	6.6	3.2	46+	M	2
152	25.3	-20.5	11.7	6.0	3.2	26-45	M	2
152T	7.4	-20.9	12.6	3.5	3.2	26-45	M	2
154	37.5	-20.4	11.8	9.3	3.2	26-45	M	2
158	33.9	-20.3	12.4	8.6	3.2	46+	M	2
158T	12.0	-20.5	12.8	4.7	3.2	46+	M	2
160	32.7	-20.7	11.1	7.7	3.2	46+	M?	2
164	34.1	-20.2	12.8	8.3	3.2	26-45	M	2
168	15.1	-20.0	12.3	3.8	3.2	26-45	M?	2
171	11.7	-19.7	12.2	2.9	3.2	26-45	M	2
174	53.5	-21.1	11.4	12.4	3.2	adult	F?	2
112	28.1	-18.9	14.3	7.1	3.2	46+	M	3
112T	17.1	-19.5	14.1	7.5	3.2	46+	M	3
136	5.5	-21.1	11.9	1.3	3.3	46+	M	3
35	9.4	-17.3	15.4	2.4	3.2	17-25	M	4
64	29.5	-19.3	13.9	7.8	3.2	46+	M	4
69	4.8	-19.7	14.4	1.2	3.6	46+	F	4
83	26.8	-19.4	14.9	6.4	3.2	26-45	F?	4
85	22.1	-18.0	15.1	5.2	3.2	17-25	M?	4
88	14.8	-18.4	15.0	3.5	3.2	26-45	F	4
88T	10.5	-19.2	13.8	4.9	3.2	26-45	F	4
90	14.5	-17.9	15.1	3.7	3.2	46+	M	4
91	15.1	-19.8	14.0	3.5	3.2	26-45	F	4
93	35.1	-17.1	16.6	8.7	3.2	26-45	M	4
97	22.4	-18.3	14.9	5.2	3.2	46+	F?	4
98	32.5	-17.9	15.8	7.7	3.2	26-45	M	4
100	16.6	-19.3	15.0	3.8	3.2	26-45	F	4
100T	12.1	-19.1	15.8	5.6	3.2	26-45	F	4
102	31.5	-17.8	16.1	7.5	3.2	26-45	F	4
103	27.1	-18.0	15.5	7.0	3.2	26-45	M	4
105	27.4	-20.4	12.7	6.8	3.2	46+	F	4
106	14.8	-18.7	15.5	3.4	3.2	46+	F	4
108	28.2	-19.5	14.7	6.8	3.2	26-45	M	4
109	49.2	-18.2	14.4	11.5	3.2	46+	M	4
113	23	-19.1	13.8	5.8	3.2	46+	M	4
113T	16.1	-20.0	13.1	7.7	3.2	46+	M	4

[a] Human bone samples taken from ribs. 'T' denotes tooth sample (permanent 1st molar root).
[b] Yield (%) = Mass mg collagen / weight (bone) mg x 100
[c] Acceptable C:N ratio (see DeNiro 1985)
[d] Ageing and sexing (M = male, F = female, ? = probable) information extracted from King (2000)
[e] Periods: 1= Pre-/Proto-monastic, 2= Monastic, 3= Post-Monastic, 4= Medieval.

FAUNAL BONE COLLAGEN DATA

Faunal samples from Portmahomack (Table 1) were included in this study to provide baseline isotopic data to interpret the human $\delta^{13}C$ and $\delta^{15}N$ values (Fig.2). Mean $\delta^{13}C$ and $\delta^{15}N$ values for the monastic period cattle (n=7) were -22.1‰ ± 0.3‰ (1σ) and 5.9‰ ± 1.2‰ (1σ) respectively. One cattle sample (C3122/10) from the monastic period is considerably lower when compared to mean $\delta^{15}N$ values from cattle in the same period. This difference (Δ = 3.0‰) may be due to a number of factors, such as originating from a different geographical region and consuming different types of fodder or grazing on unimproved pasture, which resulted in lower $\delta^{15}N$ values.[42] For example, $\delta^{15}N$ values in chaff and cereal straw are suggested to be lower and more variable than in grain.[43] The faunal baseline shift in $\delta^{15}N$ values from the monastic to the late medieval period is reflected in the human isotope ratios. The $\delta^{15}N$ ratios for monastic individuals are around +2-5‰ higher than the corresponding cattle and pigs, reflecting a trophic level increase, which are higher than the fauna by around $\delta^{15}N$ +2-6‰ and in $\delta^{13}C$ by around +2-3‰.

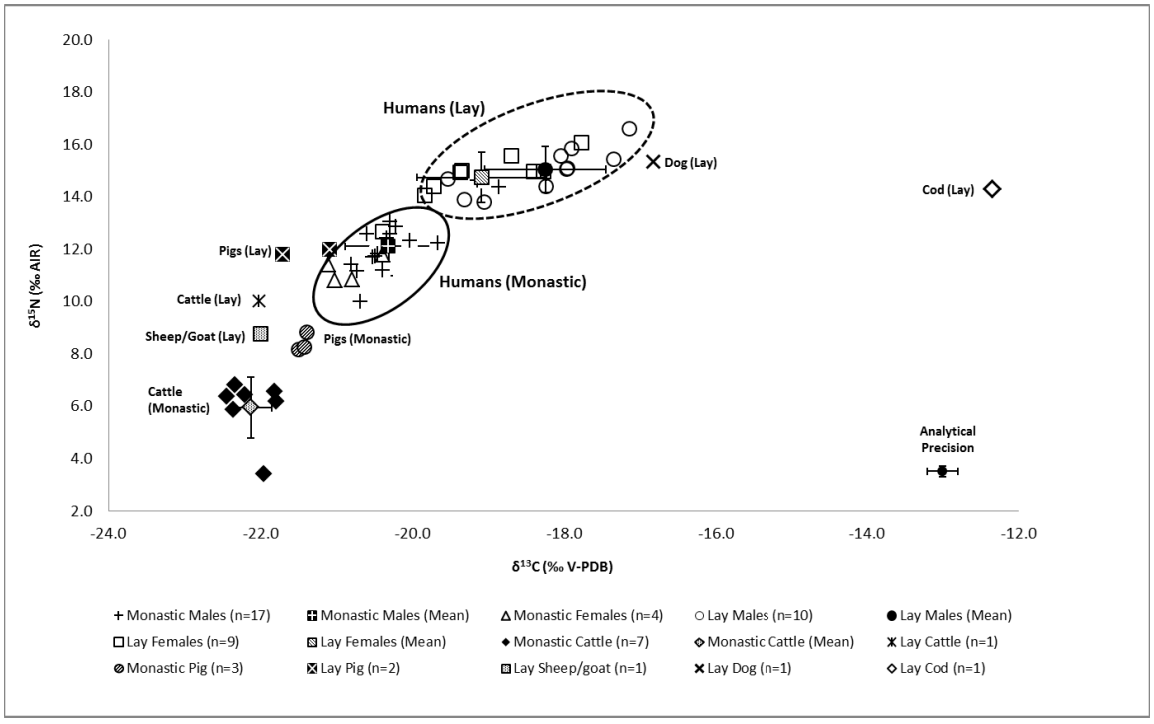

FIG 2
Plot of human and faunal bone collagen $\delta^{13}C$ and $\delta^{15}N$ and mean values from Portmahomack (analytical precision: ± 0.2‰).

HUMAN BONE COLLAGEN DATA

The monastic human (n=21) $\delta^{13}C$ values range between -21.2‰ and -18.9‰ (Δ = 2.3‰), with a mean of -20.4‰ ± 0.6‰ (1σ). The $\delta^{15}N$ values range between 10.0‰ and 14.6‰ (Δ = 4.6‰), with a mean of 12.2‰ ± 1.2‰ (1σ). Medieval lay human (n=19) $\delta^{13}C$ values range between -20.4‰ and -17.1‰ (Δ = 3.3‰), with a mean of -18.8‰ ± 0.9‰ (1σ). Medieval human $\delta^{15}N$ values range from 12.7‰ to 16.6‰ (Δ = 3.9‰), with a mean of 14.8‰ ± 1.0‰ (1σ). The $\delta^{13}C$ and $\delta^{15}N$ values are therefore higher in the lay individuals compared to the earlier monastic individuals (Fig.3), representing a diachronic change in diet over these periods at Portmahomack. Unpaired, independent two-sample t-tests revealed the difference between the monastic and lay bone collagen isotope results were highly significant for both carbon (t_{38} = -7.97, p = 0.000***) and nitrogen (t_{38} = -9.92, p = 0.000***) ratios.

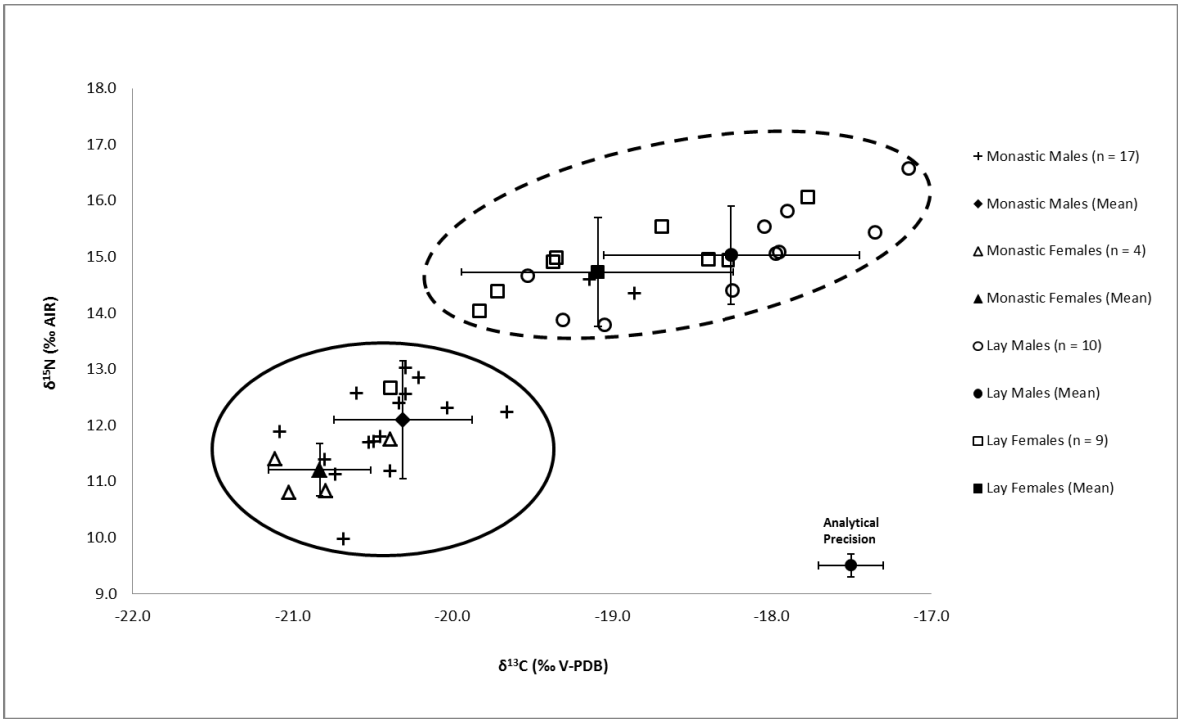

FIG 3
Plot of human bone collagen $\delta^{13}C$ and $\delta^{15}N$ and mean values for Monastic (bold circle) and Lay (dashed circle) groups at Portmahomack (analytical precision: ± 0.2‰).

Within the Monastic group (Periods 1-3), the proto-monastic (Period 1) burials (SK166, SK169 and SK172) showed similar $\delta^{13}C$ values compared to the Monastic burials (Period 2). One adult male from Period 1 (SK169) had slightly lower $\delta^{15}N$ values than the rest of the monastic group, although not of sufficient magnitude to suggest a trophic level difference. Two adult males from Periods 2 (SK144) and 3 (SK112) had atypical isotope results, with $\delta^{13}C$ and $\delta^{15}N$ values within the range of the Period 4 inhabitants (Fig.4). When compared to the mean $\delta^{13}C$ and $\delta^{15}N$ values of Period 2, the differences in carbon (Δ = 1.2‰, 1.1‰) and nitrogen (Δ = 2.4‰, 1.3‰) for SK144 and SK112 respectively suggest these individuals' diets may have included some marine protein. The difference in carbon (Δ = 2.2‰) and nitrogen (Δ = 2.5‰) between the two adult males from Period 3 (SK136 and SK112) further attests to this difference in diet. Atypical isotope results were also found in one adult female (SK105) from Period 4 who had the lowest $\delta^{13}C$ (-20.4‰), and $\delta^{15}N$ (12.7‰) values of this group. The isotope results from this individual fell within the Period 2 group and differed to the other lay individuals in both $\delta^{13}C$ (Δ = 1.3‰) and $\delta^{15}N$ (Δ = 2.0‰), suggesting a more terrestrial-based diet.

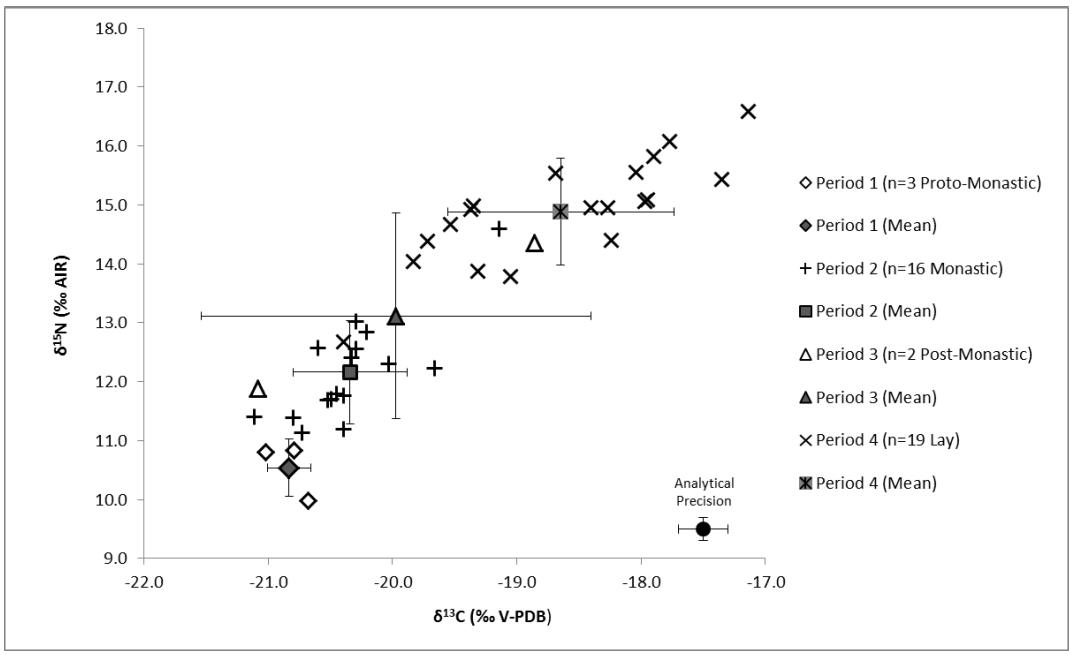

FIG 4
Plot of human bone collagen $\delta^{13}C$ and $\delta^{15}N$ and mean values for Periods 1-4 at Portmahomack (analytical precision: ± 0.2‰).

Two-sample *t*-tests were performed to determine age and sex differences in diet within the lay group and age differences within the monastic groups. Gendered-divisions in diet between the monastic groups could not be statistically tested due to uneven male-female sample numbers, although the $\delta^{13}C$ and $\delta^{15}N$ isotope values suggest a relatively homogeneous diet. Apart from one outlier (SK105), mean $\delta^{13}C$ and $\delta^{15}N$ isotope values for lay male and female bone collagen revealed little difference in $\delta^{13}C$ ($\Delta = 0.9‰$) and $\delta^{15}N$ ($\Delta = 0.3‰$) values. Statistical *t*-test results for $\delta^{13}C$ were slightly significant ($t20 = 2.39$, $p = 0.027$*), although the $\delta^{15}N$ data revealed no significant difference ($t18 = 0.59$, $p = 0.565$ n.s.).

Mean $\delta^{13}C$ and $\delta^{15}N$ isotope values for the 26-45 years and 46+ years age groups from the monastic periods revealed little difference in $\delta^{13}C$ ($\Delta = 0.1‰$) and $\delta^{15}N$ ($\Delta = 0.7‰$) values. Statistical *t*-test results found no significant difference for $\delta^{13}C$ ($t18 = 0.17$, $p = 0.864$ n.s.) and $\delta^{15}N$ ($t18 = -1.09$ P-Value = 0.289 n.s.). The 17-25 years age groups from both the monastic and lay periods has not been statistically tested due to low sample numbers (*n*=2).

Mean $\delta^{13}C$ and $\delta^{15}N$ isotope values for the 26-45 years and 46+ years age groups from the lay period revealed little difference in $\delta^{13}C$ ($\Delta = 0.4‰$) and $\delta^{15}N$ ($\Delta = 1.0‰$) values. Statistical *t*-test results for $\delta^{13}C$ found no significant difference ($t20 = 1.13$, $p = 0.273$ n.s.), although for $\delta^{15}N$, there was a fairly significant difference ($t20 = 2.76$, $p = 0.012$**).

HUMAN DENTINE COLLAGEN DATA

No tooth samples were provided for females from the monastic phase at Portmahomack, thus no dentine collagen has been analysed for this group. The mean $\delta^{13}C$ and $\delta^{15}N$ values for the monastic males (*n*=6) are -20.4‰ ± 0.7‰ (1σ), and 13.0‰ ± 1.1‰ (1σ) respectively. Individual $\delta^{13}C$ and $\delta^{15}N$ values for the lay females (*n*=2) are -19.2‰ and

13.8‰ (SK88) and -19.1‰ and 15.8‰ (SK100). The individual $\delta^{13}C$ and $\delta^{15}N$ value for the lay male sample (SK113) is -20.0‰ and 13.1‰ respectively (Table 3).

TABLE 3

Comparison of bone and dentine $\delta^{13}C$ and $\delta^{15}N$ values (measured in ‰) from Portmahomack.

Skeleton (burial) No.	Sex/Phase	Bone $\delta^{13}C$	Dentine $\delta^{13}C$	($\Delta_{dentine-bone}$ $\delta^{13}C$)	Bone $\delta^{15}N$	Dentine $\delta^{15}N$	($\Delta_{dentine-bone}$ $\delta^{15}N$)
88	F/Lay	-18.4	-19.2	0.8	15.0	13.8	1.2
100	F/Lay	-19.3	-19.1	0.2	15.0	15.8	0.8
113	M/Lay	-19.0	-20.0	1.0	13.8	13.1	0.7
112	M/Monastic	-18.9	-19.5	0.6	14.3	14.1	0.3
124	M/Monastic	-20.8	-21.2	0.4	11.4	11.7	0.3
144	M/Monastic	-19.1	-19.9	0.7	14.6	14.6	0.0
147	M/Monastic	-20.4	-20.5	0.1	11.2	12.2	1.0
152	M/Monastic	-20.5	-20.9	0.4	11.7	12.6	0.9
158	M/Monastic	-20.3	-20.5	0.2	12.4	12.8	0.4

DISCUSSION

Relative to the faunal data, human $\delta^{13}C$ values for the monastic periods reflect a predominantly terrestrial C_3-based diet with no input of C_4 or marine resources. $\delta^{15}N$ values for these individuals are a trophic level higher (+2-5‰) higher than the corresponding cattle and pigs. This, along with the archaeological faunal remains, suggests the early medieval monastic community were consuming a significant amount of terrestrial animal protein, such as pork, beef and dairy products. The earliest burials at Portmahomack (Period 1) have $\delta^{13}C$ and $\delta^{15}N$ values similar to the monastic phase (Period 2), suggesting they consumed terrestrial animal protein and C_3 plant foods but no marine protein consumption.

The atypical isotope results for three individuals from Periods 2 (SK144), 3 (SK112) and 4 (SK105), attest to the dietary variation that can occur within a community. Two adult males (SK144 and SK112) from the monastic periods had higher $\delta^{13}C$ and $\delta^{15}N$ values than their contemporaries, suggesting that as well as consuming terrestrial animal protein and C_3-based plant foods, they had access to marine protein. Conversely, the adult female (SK105) from the lay period had $\delta^{13}C$ and $\delta^{15}N$ values more in line with the majority of the monastic group. When the isotope values for this individual are compared to herbivores from the same period at Portmahomack, a diet of C_3-based plant foods and animal protein is suggested, with no marine protein consumed.

As previously discussed, the faunal baseline shift, which is reflected in the human isotope ratios, suggests that contrary to the earlier periods, $\delta^{13}C$ and $\delta^{15}N$ values from the lay individuals reflect a significant trophic level increase in $\delta^{15}N$ and a shift towards higher $\delta^{13}C$ ratios. Based on archaeological and isotopic evidence, the lay inhabitants at Portmahomack had a diet that probably included beef, cereals (e.g. bread, pottage), pork, lamb, dairy foods and marine fish.

Although it has been suggested that manuring significantly increases $\delta^{15}N$ values in cereals,[44] a major component of cereal grain in the late medieval individual's diet would be needed to reflect such high $\delta^{15}N$ values, which does not appear evident. Other explanations for greater $\delta^{13}C$ and $\delta^{15}N$ values in these individuals include increased $\delta^{13}C$ values in herbivores that grazed on seaweed,[45] or on salt marshes, which can increase $\delta^{15}N$ values.[46] Such occurrences would result in a shift in human carbon and nitrogen isotope ratios, through consumption of these animals. Human isotope results from both the main periods of burial at Portmahomack appear to correlate with associated faunal isotope baselines, suggesting

normal trophic level increases and isotopic shifts, due to the consumption of animal and possibly marine protein.

DIETARY DIFFERENCES RELATING TO SEX

The two adult females from Period 1 (SK172 and SK166) were buried in long cist graves, which may suggest their burials were of a status higher than that of a servant. However, the isotope values of these individuals (Fig.5) suggest that they were consuming similar foods to the monks who succeeded them. The female sample numbers for Period 1 (n=2) and Period 2 (n=2) were too small to provide an informative statistical comparison against the corresponding males. As previously mentioned, mean $\delta^{13}C$ and $\delta^{15}N$ isotope values for the medieval lay male and female bone collagen (Fig.6) revealed little significant statistical difference suggesting both men and women from this group consumed similar foods of C_3 plants and terrestrial and marine protein. Therefore, a gendered-division in diet at Portmahomack cannot be ascertained from this data alone.

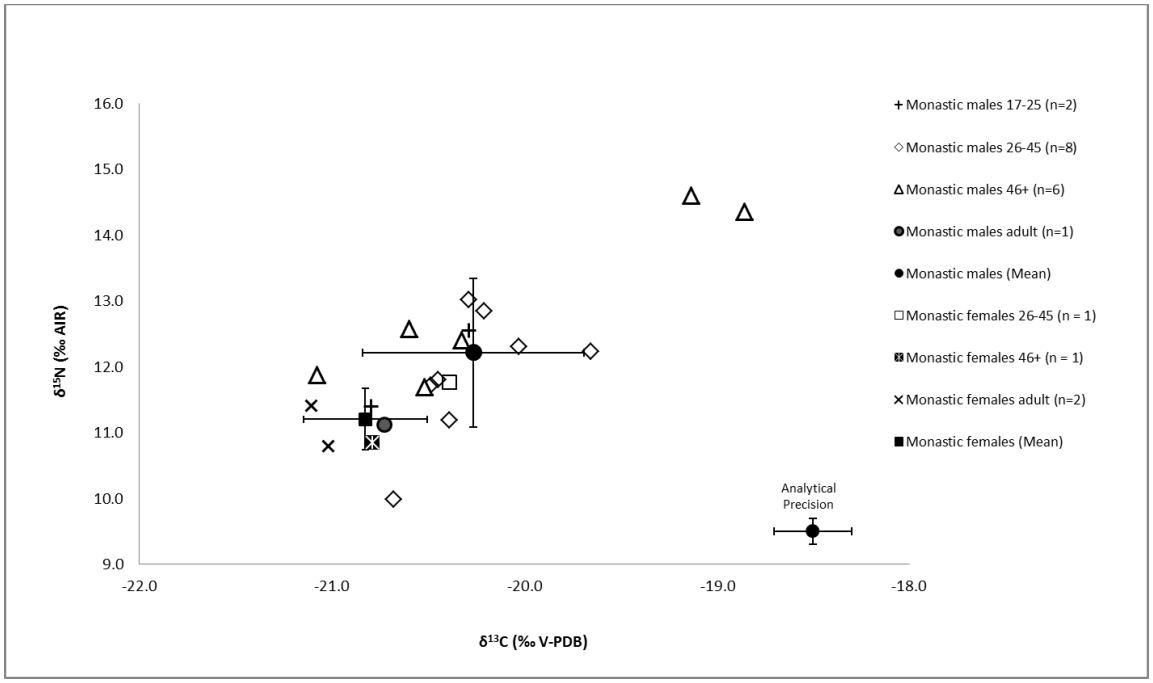

FIG 5
Plot of human bone collagen $\delta^{13}C$ and $\delta^{15}N$ and mean values from monastic periods at Portmahomack (analytical precision: ± 0.2‰).

DIETARY DIFFERENCES RELATING TO AGE

When individual $\delta^{13}C$ and $\delta^{15}N$ values are plotted for the 26-45 years and 46+ years age groups from the monastic burials (Fig.5), no significant difference in diet relating to age is apparent for the corresponding males, apart from the two outliers (SK112 and SK144) previously discussed. The 26-45 female (SK127) from Period 2 had slightly higher $\delta^{13}C$ and $\delta^{15}N$ values than the other females, although larger sample numbers would be needed to provide any conclusive interpretations. Statistical results previously mentioned revealed no significant difference for either $\delta^{13}C$ or $\delta^{15}N$ values between these two age groups, suggesting individuals of different ages consumed similar foods although the long-term average of diet represented in the adult human bone collagen measured here may hide short-term dietary fluctuations that may have occurred at particular periods of life.

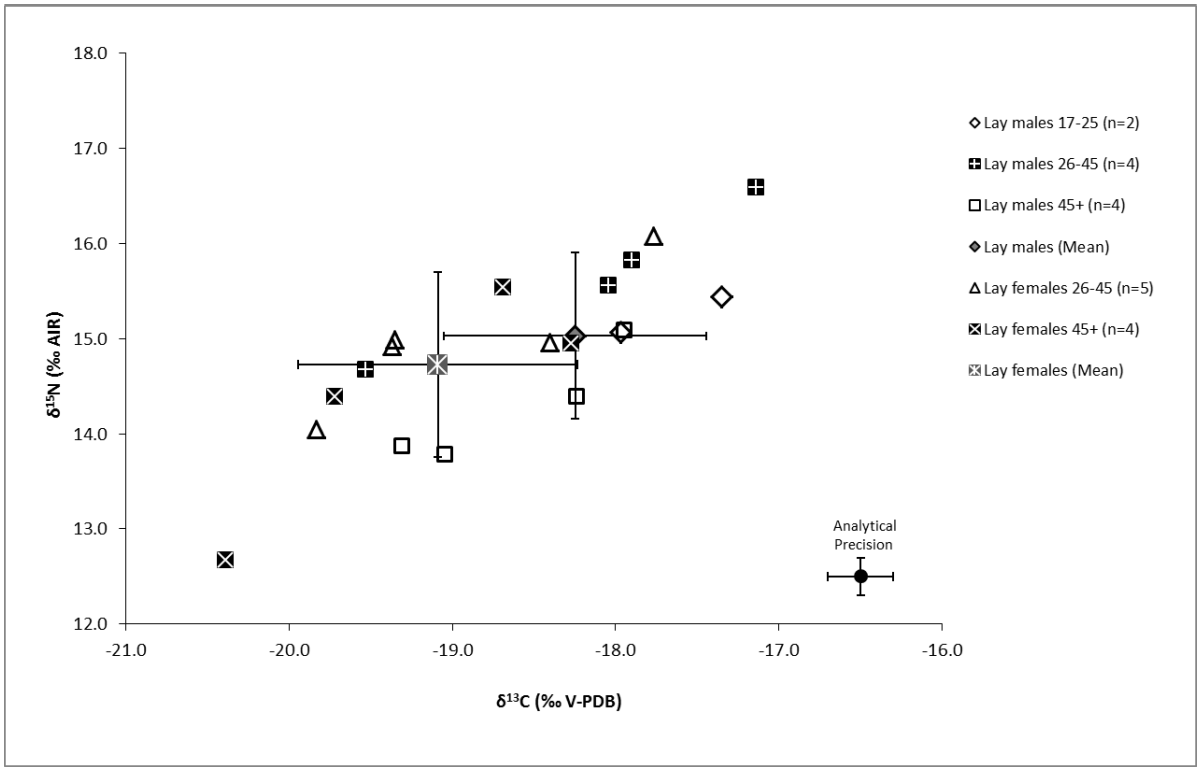

FIG 6
Plot of human bone collagen $\delta^{13}C$ and $\delta^{15}N$ and mean values from the lay period at Portmahomack, (analytical precision: ± 0.2‰).

Mean $\delta^{13}C$ and $\delta^{15}N$ isotope values for the 26-45 years and 46+ years age groups from the lay period suggest no difference in diet, although the aforementioned statistical *t*-test results for $\delta^{15}N$ showed a fairly significant difference between the two age groups. This suggests that some of the 26-45 years individuals had a higher intake of animal protein than some of the 46+ years individuals (Fig.6). This is most notable in the 26-45 male (SK93) that has the highest $\delta^{13}C$ and $\delta^{15}N$ isotope values out of the whole group and a whole trophic level difference compared to, for example, the two 45+ males (SK64 and SK113) that have the lowest $\delta^{15}N$ isotope values out of the males from this group. This may reflect a division in the types of animal protein that was being consumed, with some of the younger individuals possibly consuming different types of marine protein than the older individuals. Whether this difference was due to a labour-division in diet, where the younger individuals' ability to work required a better or different diet, requires further investigation.

BONE AND DENTINE COLLAGEN COMPARISONS

Any differences between dentine and bone collagen isotope values ($\Delta_{dentine\text{-}bone}$) may reflect a change in diet from adolescence to adulthood.[47] An increase in animal and/or marine protein consumption during adulthood may produce higher $\delta^{13}C$ and $\delta^{15}N$ values in bone collagen than in dentine collagen. $\delta^{13}C$ and $\delta^{15}N$ values for bone and dentine collagen were obtained for nine individuals.

The greatest difference in dentine to bone ($\Delta_{dentine\text{-}bone}$) $\delta^{13}C$ was found in sample SK113 at 1.0‰ and SK88 had the greatest $\Delta_{dentine\text{-}bone}$ in $\delta^{15}N$ at 1.2‰. Although bone collagen $\delta^{13}C$ and $\delta^{15}N$ values are varied between individuals, the tooth dentine collagen $\delta^{13}C$ and $\delta^{15}N$ values were within the same trophic level (e.g. <3‰ in $\delta^{15}N$ and <1‰ in $\delta^{13}C$). This suggests that the adult diets had not changed greatly since childhood. However, SK88 and SK113 may have had a slightly altered diet with possibly greater proportions of animal

protein consumption during adulthood. No $\Delta_{dentine\text{-}bone}$ for $\delta^{15}N$ was found in SK144, suggesting this individual had no significant change in protein intake during their lifetime. Apart from SK144, all $\delta^{15}N$ values for dentine collagen from the monastic phase were higher than bone collagen and $\delta^{13}C$ values were within the C_3 terrestrial range of -20‰ to -35‰.[48] Conversely, two individuals (SK88 and SK113) from the lay period had higher $\delta^{13}C$ and $\delta^{15}N$ values in bone collagen, than in dentine collagen. These differences may suggest a slightly higher or different protein intake during adulthood for these lay individuals and conversely, during childhood for the monastic individuals. The latter may imply that the monks at Portmahomack accepted oblates (children presented to monasteries to become monks or nuns) and their diet conformed to that of the monks by adulthood. However, although the practice of accepting oblates was common at many medieval monasteries,[49] no child burials were found from the monastic levels 400 years earlier at Portmahomack, suggesting that oblates either survived to adulthood or this practice was not performed at this site.

SITE COMPARISONS: AN OVERALL PERSPECTIVE

When the early medieval/monastic and high to late medieval/lay isotope data from Portmahomack are compared with a selection of comparable sites (Fig.7), a pattern emerges that is consistent with recent studies, which suggests a diachronic change in diet from the Iron Age to medieval periods in Britain.[50]

The isotope data from the Pictish/monastic phases at Portmahomack, Lundin Links[51] and Newark Bay[52] reflect a predominantly terrestrial-based diet, with significant levels of animal protein intake. Although these three sites are situated on the coast, isotopic values do not reflect a significant input in marine consumption, suggesting these coastal dwellers chose not to exploit resources from the sea. Conversely, Viking inhabitants from Newark Bay began

to exploit marine resources and consume greater proportions of fish than in earlier periods, which are reflected in their isotopic ratios.[53]

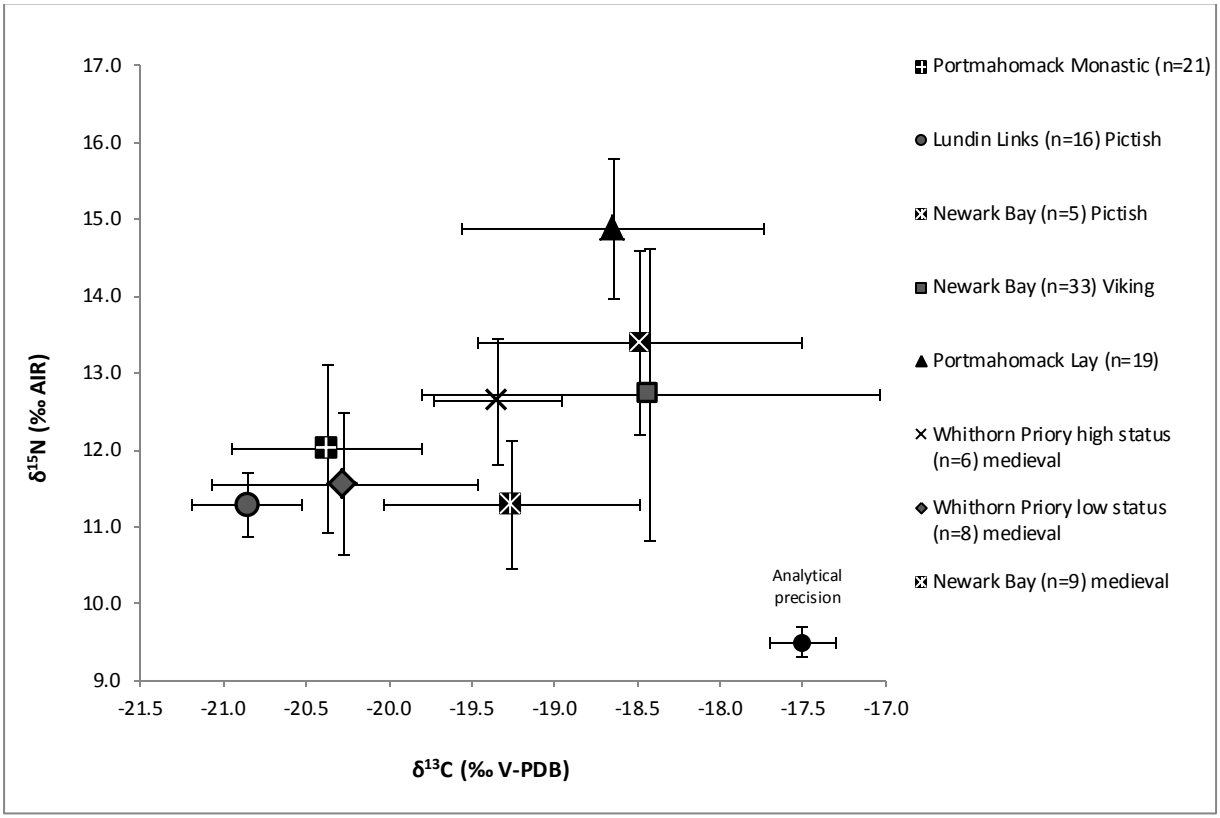

FIG 7
Plot of $\delta^{13}C$ and $\delta^{15}N$ mean values from selected Pictish, Viking and medieval sites in Scotland (analytical precision: ± 0.2‰). (After Barrett and Richards 2004; Modzelewski 2008; Müldner *et al*. 2009).

In the medieval period there is a significant increase in marine consumption, with higher $\delta^{15}N$ values reflecting a trophic level increase and $\delta^{13}C$ values shifting towards the marine range. Clerics at Whithorn Cathedral Priory were consuming a greater proportion of marine foods compared to the low status lay population.[54] However, the greatest shift towards marine protein consumption is evident from the medieval inhabitants of Newark Bay.[55] Isotopic evidence from the monastic and lay inhabitants at Portmahomack support this pattern of a predominantly C_3 terrestrial-based diet during the early medieval period and an increase in marine consumption in the high - late medieval period. This increase in marine

consumption has been associated with growing populations and an increase in the fish trade, as well as a widespread adherence to Christian fasting practices.[56]

It is suggested that in medieval Scotland the predominant dietary intake of terrestrial protein, such as lamb, beef and pork, reflected a high status diet; whereas marine foods, such as salted herring or cod, were consumed by lower status individuals, with terrestrial animals rarely killed for meat consumption.[57] This appears to be the case at Portmahomack, where the monastic groups consumed terrestrial protein but no marine foods, whereas the subsequent lay group had a wider dietary intake of foods including both terrestrial and marine protein. This is in contrast to some studies from Scottish monastic sites that suggest monks' consumption of fish reflected a high status diet, whereas terrestrial protein was consumed by lower status individuals.[58] Cod fishing had increased in Tarbat by AD 1670 and by AD 1845 the *New Statistical Account of Scotland* recorded that herring curing became so important at Portmahomack that the population doubled in size seasonally with people coming from all over the Highlands to assist with the herring curing,[59] suggesting that marine fish had become an important commodity for trade as well as consumption at Portmahomack.

Generally, all faunal samples from Portmahomack appear to have $\delta^{13}C$ and $\delta^{15}N$ values that are consistent with those from comparable sites,[60] although some isotopic differences between the two groups are evident. For example, $\delta^{15}N$ values are higher for lay (Medieval) versus monastic (Pictish) phased cattle ($\Delta = 4.1‰$) and for lay versus monastic phased pigs ($\Delta = 3.5‰$) at Portmahomack. However, there was no real difference in cattle and pig $\delta^{13}C$ values from both phases. Interestingly, the medieval lay dog sample from Portmahomack differs greatly, compared to same species isotope result at East Lothian[61] in both its $\delta^{13}C$ ($\Delta = 8‰$) and $\delta^{15}N$ ($\Delta = 4‰$) values. Pigs and dogs have been found to have

high $\delta^{15}N$ values, suggesting they may have consumed foods similar to that of humans and possibly scavenged marine foods from the coastline.[62] High pig $\delta^{15}N$ values at Portmahomack may be due to humans consuming a different diet compared to those in the earlier monastic phase, resulting in ^{15}N enrichment in pigs, who may have fed on human refuse.[63]

Higher herbivore $\delta^{15}N$ values from the medieval lay period at Portmahomack, compared to those from other sites discussed here may suggest possible differences in husbandry strategies, although due to low faunal sample numbers, further investigation is needed here. Although herbivore $\delta^{15}N$ values from the British Iron Age to medieval period ranges from around +4‰ to +7‰,[64] differences in regional resources and socio-economic practices may produce isotopic differences. The herbivores from the lay period at Portmahomack may have grazed around coastal areas, such as salt marshes, which have been found to produce higher herbivore $\delta^{15}N$ values compared to inland sites.[65] The Tarbat peninsula is near some of the most extensive areas of salt marsh in Britain,[66] which may explain the lay cattle $\delta^{15}N$ value, which is higher ($\Delta = 2‰$) than those reported by Britton et al[67] This however does not explain why herbivores from the monastic phase at Portmahomack have lower $\delta^{15}N$ values, although a different socio-economic strategy may simply be the cause, with herbivores from this phase being confined to inland grazing.

CONCLUSIONS

This study has provided new faunal and human stable isotope data from Portmahomack on the Tarbat peninsula, thereby contributing to current themes on reconstructions of medieval diets. There is a statistically significant diachronic change in diet between the early medieval monastic community who ate predominantly terrestrial plant and animal protein and the subsequent parish church family community at Portmahomack who

also ate terrestrial plant and animal protein plus marine fish. This temporal increase in carbon and nitrogen isotope ratios was also found in the faunal baseline and may reflect a change in husbandry practices in the later medieval period, such as increased manuring[68] and/or salt marsh grazing.[69] No dietary differences relating to sex was found in the lay population but younger adults had higher $\delta^{15}N$ values and although this finding was only weakly significant, it may suggest they ate more marine protein than the older individuals. No significant change in diet from childhood to adulthood was found for either the monastic or lay populations.

Overall, the results are suggestive of a monastic community who reared animals for a number of uses, including human consumption but chose not to exploit nearby marine resources relying heavily on terrestrial-based foods. In contrast, the isotope evidence suggests the mid-late Medieval/lay (c.AD 1100-1600) inhabitants at Portmahomack consumed a wide variety of foods, including animal protein from pork, beef, lamb and fish, which is supported by the faunal remains present. These individuals exploited marine resources, either by choice or through necessity. This may have been partly due to emerging Christian influences on fasting, which proscribed meat for up to three days a week[70] and partly due to an increase in the fishing trade, which supplied a cheap and plentiful food resource.[71] Archaeological evidence[72] along with stble isotope data presented here suggests the diets of the lay individuals at Portmahomack reflect a homogeneous community, who farmed the land and exploited the sea.

The isotope data presented here are consistent with other isotope studies that suggest a change in diet, from early medieval terrestrial food consumption, through to later medieval marine exploitation in Scotland.[73] Dietary reconstructions using stable isotope analysis from Scottish sites is still quite sparse compared to English sites. This pilot-study not only provides

new stable isotope data from the first excavated Pictish monastery, but offers new insights into medieval diet overall, thereby contributing to a greater understanding of social, religious and economic influences on diet in Scottish antiquity.

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