From the Mountains to the Sea: The View from Stable Isotope Data on Humans and Animals in Mesolithic Northern Spain

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Abstract

In this paper we summarise the available human radiocarbon dates and stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope data for the Mesolithic of Northern Spain. This reinforces a strong division between inland and coastal locations, with the two separated by a distance of as little as *ca.* 10 km. There is considerable time depth to this division, which appears to exist from at least the second half of the eighth millennium BC, representing the region's earliest Holocene human results. We also present new $\delta^{13}C$ and $\delta^{15}N$ data for terrestrial fauna from the inland site of Los Canes, as well as for a small number of marine and estuarine fish species from coastal sites.

1 Introduction

The Mesolithic archaeology of the Cantabrian region of Northern Spain has long been known for its strong coastal focus (Obermaier 1924; Clark 2000; Arias 2005; Arias and Fano 2005; Fano 2019; Clark and Barton 2022). This is perhaps not surprising, given the relatively constricted coastal plain, backed by the steeply rising Picos de Europa and the rest of the Cantabrian Mountain range. Nevertheless, the nature of the subsistence and settlement pattern has been a matter for debate, centred on the question of whether the coastal sites – often quite small – were special purpose camps occupied seasonally as part of a single, integrated system linking the coast and the interior (Clark 1989; Clark and Barton 2022); or, alternatively, whether two distinct subsistence-settlement systems existed, one with a coastal orientation and the other with an inland, terrestrial focus (González Morales 1989). Stable isotope analysis of human remains brings an independent line of evidence to bear, with accumulating results from the region strongly supporting the existence of distinct coastal and inland adaptations (Arias 2005; Arias and Fano 2005; Arias 2013; Fano 2019). Here, we present additional data pertaining to this question, including a substantial Mesolithic faunal dataset from the inland cave of Los Canes (Asturias) to provide a terrestrial isotopic baseline, and a small number of archaeological fish values reflecting marine and estuarine habitats. The human sample size is still not large, but the existence of separate coastal and inland groups continues to be strongly supported. We also briefly address the methodological question of inter-laboratory comparability in stable isotope measurements.

2 Stable carbon and nitrogen isotope analysis

In a prehistoric Western European context, carbon stable isotope (δ^{13}C) measurements on bone collagen can distinguish between terrestrial and marine sources of protein (well-known feeding experiments have demonstrated that ^{13}C abundance in bone collagen is strongly influenced by the protein component of the diet (Ambrose and Norr 1993)). The δ^{13}C endpoint of bone collagen for a human consuming an entirely marine diet would generally be *ca.* -12‰, while for a human subsisting on an entirely terrestrial, C_3-based diet this endpoint would be *ca.* -20‰ (Richards and Hedges 1999; Schulting 2018; 2021). A complicating factor in the terrestrial endpoint when comparing values across large geographical scales is the existence of a latitudinal gradient as a result of climate effects (Richards and van Klinken 1997; Schulting 2018). Thus, a purely terrestrial value for a human consumer in Northern Europe would be *ca.* -21‰, while a purely terrestrial value in Southern Europe would be *ca.* -19‰. There are further nuances in this overall pattern relating to factors including local microclimates, degree of forest cover, etc. Another complicating issue relates to estuarine ecosystems. Because of the greater contribution of terrestrial carbon sources, these often exhibit δ^{13}C values intermediate between terrestrial and marine systems (Petersen *et al.* 1985). Resident species/individuals will thus also exhibit intermediate values, as will human consumers relying upon such resources. Other species might be caught in estuaries, but be migratory, spending most of their time in the sea proper, and so will yield values consistent with fully marine organisms. At the same time, marine species themselves can exhibit considerable variability in δ^{13}C (ranging over *ca.* 4‰) depending on where in the ocean they spend most of their time feeding. Pelagic species, for example, are often ^{13}C-depleted relative to benthic species (Hobson *et al.* 2002).

Although there are other considerations, nitrogen stable isotope abundance values (δ^{15}N) refer mainly to trophic level enrichments up the 'food chain', of on average 3–5‰ for each step (Bocherens and Drucker 2003; McCutchan *et al.* 2003; Fry 2006; Hedges and Reynard 2007). This is particularly so for non-food-producing societies, with relatively minimal modification of the environment compared to farming societies (e.g. through the application of animal manure to fields (Bogaard *et al.* 2013)). Marine food webs have the potential for many more trophic levels than the terrestrial mammalian systems that humans tend to operate within. As a consequence, they can provide corroborating evidence (alongside δ^{13}C values) for the use of marine resources, and also suggest what kinds of resources were being utilised, e.g. whether shellfish, fish or marine mammals, as these generally operate at increasingly higher trophic levels.

Finally, it should be noted that stable isotope measurements on adult human bone collagen reflect an average of (mainly) protein consumed during the last decade or more of life in adults (Pearson and Lieberman 2004; Hedges *et al.* 2007; Meier-Augustein and Kemp 2012). Thus, seasonal variability in diets – which certainly might be expected to feature in Cantabrian Spain, and indeed across Mesolithic Europe more widely – is averaged out.

The majority of faunal measurements reported here, from the site of Los Canes, were measured in duplicate by Mike Richards, then at the Department of Archaeological Sciences, University of Bradford. As part of an on-going programme of inter-laboratory comparisons, a subset of faunal samples from Los Canes was also run by Wolfram Meier-Augenstein while at the Environmental Engineering Research Centre (EERC), Queen's University Belfast. The fish and new human measurements were made at the Research Laboratory for Archaeology and the History of Art (RLAHA), University of Oxford.

All radiocarbon dates have been re-calibrated using the Intcal20 (Reimer *et al.* 2020) and Marine20 (Heaton *et al.* 2020) curves and presented at 95.4% confidence. For coastal individuals, mixed terrestrial and marine curves are employed in OxCal 4.4 (Bronk Ramsey 2001), with the percentage of marine protein estimated from the δ^{13}C values, with an assumed ±10% error. The local ΔR offset is estimated to be -109 ± 55 yr, based on the five nearest data points to coordinates 43.5568 latitude and -4.4152 longitude in the Marine20 database (*http://calib.org/marine/*).

3 The mountains

The inland sites in Northern Spain with directly dated Mesolithic human remains are Chan do Lindeiro, La Braña, Aizpea, Arangas, Paré de Nogales and Los Canes (Figure 1). Of these, Los Canes is particularly important as it lies closest to the coast and contains multiple individuals.

Chan do Lindeiro (Lugo) is located in the Serra do Courel of Galicia, some 100 km from the modern coast. The skeleton of an adult female ('Elba') has been dated to 7321–7053 cal BC (Ua-13398/38115: 8154 ±42 BP, 95.4% confidence) (Grandal d'Anglade and Vidal 2017), although this is a combined result for two radiocarbon determinations that actually differ significantly by *ca.* 200 ^{14}C years (χ^2: df=1, T=7.6(5%, 3.8); Table 1). The δ^{13}C and the δ^{15}N values of -20.7‰ and 8.2‰, respectively, are as expected for an entirely C_3 terrestrial diet.

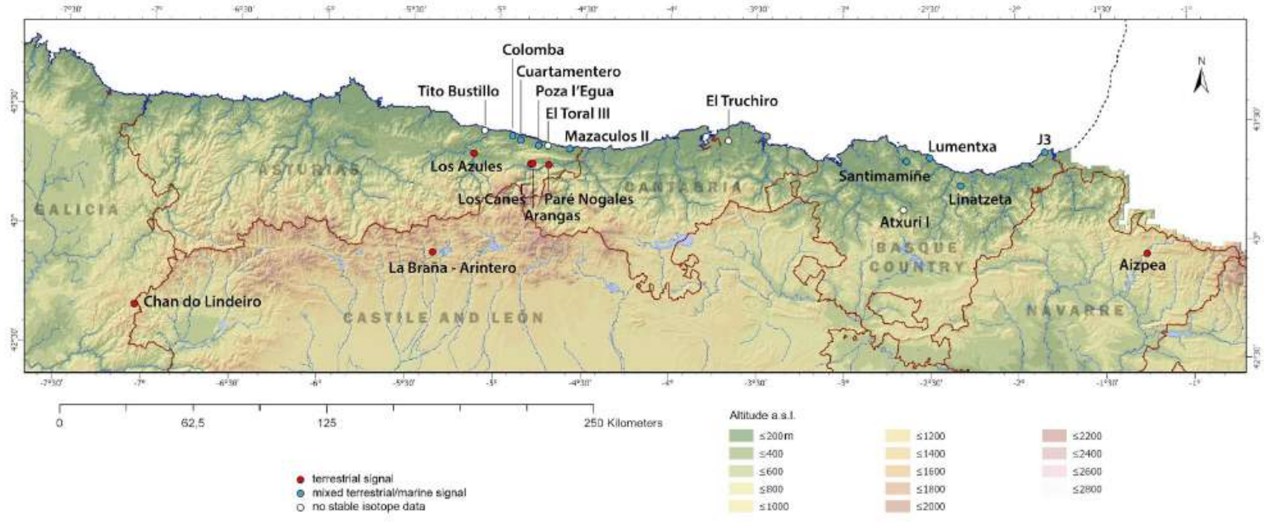

Figure 1: Map of northern Spain showing locations of sites mentioned in the text (map: Luis C. Teira).

The cave of La Braña-Arintero (León) is located on the southern slopes of the Cantabrian Cordillera, some 60 km from the sea. The two adult male skeletons found here have been directly dated to the Mesolithic, 5983-5741 cal BC (Beta-226472: 6980 ± 50 BP) and 6015-5790 cal BC (Beta-226473: 7030 ± 50 BP) (Vidal and Prada 2010). Given their distance from the coast, the stable isotope values would be expected to provide a wholly terrestrial signal. However, both the δ^{13}C and the δ^{15}N results are slightly elevated compared to those from the other inland sites, though only significantly so (despite the small sample size) for δ^{15}N (δ^{13}C: Student's t-test, $t = 1.355$, $p = 0.213$; δ^{15}N: $t = 3.292$, $p = 0.011$). Indeed, the δ^{13}C values of -18.8‰ and -18.9‰ for La Braña 1 and La Braña 2, respectively, would be

Table 1: ^{14}C dates and stable isotope data (where available) for Mesolithic humans from Northern Spain. All dates have been recalibrated in OxCal 4.4 (IntCal20 and Marine20 curves). Marine reservoir corrections for coastal sites employ estimated marine protein contributions (± 10%) based on δ^{13}C values and assuming marine and terrestrial endpoints of -12‰ and -20‰, respectively, with ΔR of -109 ± 55 years (see text). Note that the marine reservoir corrections for Tito Bustillo, Atxuri-I, and El Toral III have been estimated (assuming 50% marine diets) in the absence of δ^{13}C data. For Lumentxa (CNA-5114.1.1), the correction is made using the δ^{13}C value for OxA-18236, assuming they are the same individual. χ^2 tests are provided for combined dates (using `R_combine` in OxCal 4.4) for duplicate determinations on ostensibly the same individual (those in red fail the test; Ward and Wilson 1978). M = male; F = female; I = indeterminate.

Site	**Age**	**Sex**	**Lab no.**	**^{14}C BP**	**±**	**cal BC (95.4%)**	**δ^{13}C**	**δ^{15}N**	**C:N**	**Source**
Inland										
Arangas	Adult	I	OxA-24799	8240	40	7456–7079	-18.8	9.1	3.3	Arias et al. 2014; this paper
Chan do Lindeiro	Adult	F	Ua-13398	7995	70	7073–6647	-20.5	8.4	3.1	Grandal d'Anglade and Vidal 2017
Chan do Lindeiro			Ua-38115	8235	51	7457–7076	-20.8	8.1	3.1	Grandal d'Anglade and Vidal 2017
Chan do Lindeiro			Combined	8154	42	7321–7053	-20.7	8.2	3.1	χ^2: df=1, T=7.6(5% 3.8)
Paré de Nogales	Adult?	I	OxA-X-23999-26	7365	36	6389–6083	-19.2	8.2	3.2	Arias 2012
La Braña 1	Adult	M	Beta-226472	6980	50	5983–5741	-18.8	10.4	3.2	Vidal and Prada 2010
La Braña 2	Adult	M	Beta-226473	7030	50	6015–5790	-18.9	10.5	3.2	Vidal and Prada 2010
Los Canes 1A	Adult	F	AA-5294	6265	75	5464–5012	-20.0	7.9	n.d.	Arias 2005; Drak 2016
Los Canes 1A			OxA-7184	6160	55	5292–4949	-19.5	8.2	3.2	Arias 2013
Los Canes 1A			Combined	6197	45	5300–5012	-19.8	8.1	3.2	χ2: df=1, T=1.3(5% 3.8)
Los Canes 2A	Adol.	M	AA-11744	7025	80	6029–5735	-19.7	8.0	n.d.	Arias 2005; Drak 2016
Los Canes 2A			OxA-23185	7208	38	6218–5990	-19.7	7.8	3.3	Arias 2013
Los Canes 2A			Combined	7171	36	6082–5984	-19.7	7.9	3.3	χ2: df=1, T=4.21(5% 3.8)
Los Canes 2B	Adult	M?	OxA-23184	7118	24	6066–5913	-19.2	8.1	3.3	Arias 2013; Drak 2016
Los Canes 3A	Adult	M	AA-6071	6930	95	5991–5645	-19.2	9.4	n.d.	Arias 2005; Drak 2016
Los Canes 3B	Child	I	OxA-19918	7210	40	6219–5990	-18.3	11.3	3.3	Arias 2013; Drak 2016; this paper
Los Canes 3C	Adult	I	OxA-23181	6243	35	5308–5067	-19.7	7.6	3.2	Arias 2013; Drak 2016
Los Canes 3D	Indet	I	OxA-X-2395-20	7315	40	6237–6073	-20.7	7.5	3.3	Arias 2013; Drak 2016; this paper
Aizpea	Adult	F	GrA-779	6600	50	5622–5478	-20.3	7.2	3.5	Barandiarán and Cava 2001
Coastal										
Poza l'Egua	Adult	M	TO-10222	8550	80	7592–7189	-16.7	12.2	n.d.	Arias et al. 2007; Drak 2016
Tito Bustillo	Adult	M	Beta-197042	8470	50	7503–7083	n.d.	n.d.	n.d.	Drak 2016; Drak et al. 2008
J3	Adult	M	GrA-23733	8300	50	7352–6917	-16.7	11.5	n.d.	Arias 2005; Iriarte et al. 2005
Cuartamentero	Adult	M	OxA-18230	8395	40	7293–6772	-12.8	14.3	3.3	Drak 2016; This paper
Mazaculos	Adult	M	OxA-18237	7840	40	6592–6258	-14.8	11.6	3.2	This paper
Linatzeta	Infant	I	OxA-18231	7362	37	6207–5832	-15.7	12.9	3.2	This paper
Linatzeta			KIA-33193	7315	35	6073–5799	n.d.	n.d.	n.d.	Tapia Sagarna et al. 2008
Linatzeta			Combined	7337	26	6079–5811	-15.7	12.9	3.2	χ2: df=1, T=0.9(5% 3.8)
Atxuri-I	Adult?	I	Beta-442236	7290	30	6066–5800	n.d.	n.d.	3.3	García-Sagastibelza et al. 2020
El Toral III	Adult?	I	UGAMS-5400	7080	30	5884–5622	n.d.	n.d.	n.d.	Noval 2014
Colomba	Adult	M	TO-10223	7090	60	5963–5567	-15.8	12.6	n.d.	Arias 2005; Arias and Fano 2005
Lumentxa	Adult	I	OxA-18236	6122	38	5001–4682	-17.2	10.0	3.2	This paper
Lumentxa			CNA-5114.1.1	6110	35	4990–4670	n.d.	n.d.	n.d.	García-Sagastibelza et al. 2020
Lumentxa			Combined	6116	26	4986–4704	-17.2	10.0	3.2	χ2: df=1, T=0.1(5% 3.8)
Santimamiñe	Adult	M	Beta-307665	6130	40	4960–4590	-16.3	10.4	n.d.	López Quintana et al. 2015

seen as reflecting some minor marine component in more northerly parts of Europe (e.g. no values higher than -19.1‰ (itself an outlier) have been observed in over 300 Neolithic humans from Britain and Ireland (Schulting and Borić 2017)). Possible explanations for the elevated δ^{13}C and δ^{15}N values at La Braña have been explored elsewhere, with the frontrunner being variability in the local baseline isotope ecology related to climatic differences on the southern side of the Cordillera, which is considerably more arid than its northern slopes (Arias and Schulting 2010). In the absence of associated faunal remains, this cannot currently be confirmed.

Aizpea (Navarre) is a rockshelter located in the foothills of the Pyrenees at 720 masl, also some 60 km from the coast. A well-preserved adult female yielded a radiocarbon date of 5622–5478 cal BC (GrA-779: 6600 ± 50 BP) (Barandiarán and Cava 2001; Cava 1997). A separate bone from the same individual yielded δ^{13}C and δ^{15}N values of -20.3‰ and 7.2‰, respectively; the latter is unusually low for the Mesolithic, with a Bayesian model suggesting a substantial contribution of plant foods in the diet of this individual, despite the presence of substantial numbers of freshwater fish bones at the site (Fernández-Crespo *et al.* 2020). Zapata (2000) has noted the potential importance of plant foods – particularly hazelnuts, acorns and Pomoideae fruits – in the Mesolithic of the Basque Country. Sequential isotopic measurements on dentine (M2) explored this individual's childhood dietary life history between the ages of 3 and 15, showing decreasing δ^{15}N values in the last years represented (Fernández-Crespo *et al.* 2020). Other isolated human remains from the site proved to be Chalcolithic when radiocarbon dated (Fernández-Crespo *et al.* 2020).

The cave of Los Canes (Asturias) is located on a steep, south-facing slope in the Sierra de Cuera, facing the Picos de Europa massif. Today, its distance from the sea is *ca.* 11 km, and it would not have been much further in the Middle Holocene because of the steep drop-off along the Cantabrian Sea. Excavations revealed three funerary structures (I–III) each containing one well-preserved primary individual (Arias and Garralda 1996; Arias *et al.* 2009), although in each structure the remains of additional individuals also occurred, ranging from isolated teeth to a pair of articulated feet (Drak 2016).

The most recent burial is Los Canes 1A[1], an older adult female, dated to 5300–5012 cal BC (AA-5294 and OxA-7184 combined: 6197 ±45 BP; Table 1), potentially falling within the period of the Mesolithic-Neolithic transition in Cantabria, beginning in the second half of the sixth millennium BC (Fano *et al.* 2015). However, palaeogenomic results have confirmed an entirely Western Hunter-Gatherer ancestry for this individual (González-Fortes *et al.* 2017). This supports a period of overlap between indigenous hunter-gatherers and incoming farmers, at least on a regional scale, though the details of their interactions are still unclear.

Los Canes 2A is an adolescent male, and 2B are the disturbed, partial remains of a probable male adult. The original dates for 2A (AA-5296: 6770 ±65 BP) and 2B (AA-5295: 6860 ± 65 BP) have been replaced by more recently made, and significantly earlier, determinations of 6082–5984 cal BC for 2A (AA-11744 and OxA-23185 combined: 7175 ±35 BP) and 6066–5913 cal BC for 2B (OxA-23184: 7118 ±24 BP) (Table 1) (Arias 2005; 2013). It should be noted that the duplicate radiocarbon dates for Los Canes 2A marginally fail to combine (χ^2: df=1, T=4.21(5% 3.8)). The reason for this is unclear, and may just be a statistical anomaly.

Funerary structure III is by far the most complex burial deposit at the site. The *in situ* adult male designated Los Canes 3A has been dated to 5991–5645 cal BC (AA-6071: 6930 ± 95 BP). Los Canes 3B is represented by the disturbed remains of a young child aged 3-4 years (Drak 2016: 192) found overlying 3A, and dated to 6219–5900 cal BC (OxA-19918: 7210 ± 40 BP), implying that 3A had disturbed an older grave (Arias 2013). A slightly earlier date of 6416–6233 cal BC (OxA-19919: 7450 ±45 BP), also attributed to 3B, was made on what was originally identified as a child's rib fragment (Arias 2013: Table 1); however, this is now considered as faunal based on its associated δ^{15}N value of 4.6‰ (δ^{13}C = -19.3‰), lying well below the range observed for Mesolithic humans across Europe (Schulting 2018) and far below the value of 11.3‰ associated with OxA-19919. Another date on child remains attributed to Los Canes 3B (TO-11218: 7640 ±210 BP; Arias 2013) is excluded from consideration here due to its high error term. Los Canes 3C – dated to 5308–5067 cal BC (OxA-23181: 6243 ±35) – is represented only by two adult-sized cuboids that cannot be from any of the other adults (Drak 2016: Figure 81). Thus, they must represent a distinct individual, further highlighting the degree of disturbance at the site. Finally, an isolated permanent molar designated Los Canes 3D has yielded a date of

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[1] The individual designations follow Drak (2016: Table 1).

6237–6073 cal BC (OxA-X-2395-20: 7315 ± 40 BP) that is the earliest Mesolithic human result from the site, though whether a single tooth should be considered as a separate individual on this basis is debatable. Nevertheless, its associated stable isotope values have been included in calculating the site mean presented below.

When first discovered and excavated, there was a question over whether Los Canes represented a specialised hunting camp for groups that might have spent a considerable time on the coast, or whether the people buried in the cave were part of a community entirely focussed on inland resources. From previous isotopic analyses, it is clear that the latter is the case (Arias 2005; Arias and Fano 2005), and this has been confirmed by more recent analyses. The putative six individuals from Los Canes directly dated to the Mesolithic show little or no evidence of the consumption of marine protein, averaging -19.7 ± 0.6‰ for δ^{13}C and 8.1 ± 0.7‰ for δ^{15}N (Table 1; Figure 2). This excludes the young child 3B with a high δ^{15}N value of 11.3‰, reflecting a nursing signal (Schurr 1998). The δ^{13}C values are perhaps slightly elevated from what might be expected for a purely C_3 terrestrial diet, and there is a hint of a corresponding increase in δ^{15}N ($r^2 = 0.432$; $p = 0.056$), raising the possibility of a small contribution of marine protein. Alternatively, however, there may be sufficient variation in the terrestrial faunal and floral isotopic ecology to account for this correlation. The isotopic results for La Braña show that both δ^{13}C and δ^{15}N values can be elevated in inland locations.

A considerably earlier Mesolithic date of 7456–7079 cal BC (OxA-24799: 8240 ±40 BP) has been obtained on an isolated human vertebra from a closely related cave system at Arangas (Arias *et al.* 2014), with newly measured duplicate δ^{13}C and δ^{15}N values of -18.8‰ and 9.1‰, respectively. These are closely comparable to the values associated with the radiocarbon date, of -18.4‰ and 9.3‰; as noted below, this is not always the case.

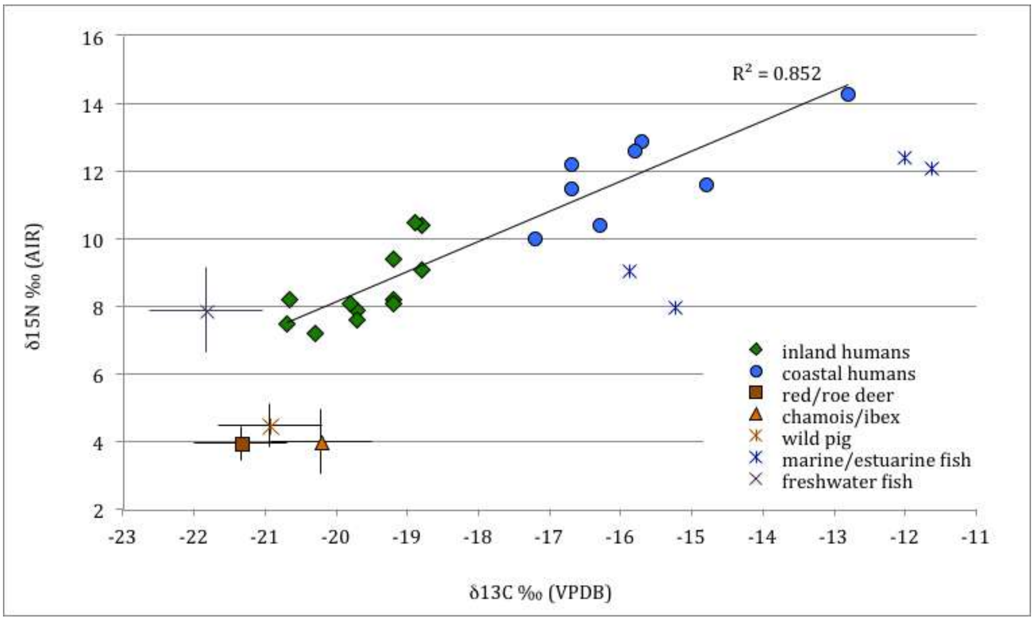

Figure 2: Plot of human and faunal δ^{13}C and δ^{15}N values (data from Tables 1 and 2; freshwater fish from Aizpea (n = 22; Fernández-Crespo et al. 2020). There is a strong positive correlation between the two isotope systems for humans ($r^2 = 0.852$, $p < 0.001$, $df = 1,18$). That the correlation seems to also apply to the inland humans is unexpected, but may relate more to the environmental settings of the sites (e.g. the highest δ^{13}C and δ^{15}N values are from the inland site of La Braña where coastal resources are very unlikely to have contributed to diets).

Finally, a poorly preserved burial from Paré de Nogales (Arias 2012) has yielded a Mesolithic date of

6389–6083 cal BC (OxA-X-23999-26: 7365 ±36 BP). The site is located *ca.* 10 km to the east of Los Canes and Arangas, and also presents a terrestrial stable isotope signal (-19.2‰, 8.2‰), albeit slightly elevated in δ^{13}C. It should be noted that the isotopic values for Paré de Nogales are those obtained alongside the AMS measurement rather than independently for palaeodiet. Nevertheless, and despite frequently expressed cautions, comparative analyses have shown that in the Oxford radiocarbon facility these generally do not differ significantly (cf. Schulting *et al.* 2014), though ideally this sample would be re-analysed for greater confidence.

A substantial faunal assemblage was recovered from Los Canes, much of it contemporary with the burials, though both earlier and later material was also present. The main species present were sampled for isotopic analysis, with the results summarised in Table 2 and Figure 2 (full results are supplied in Appendix 1). Four samples with C:N values above the accepted range of 2.8–3.6 (DeNiro 1985) are excluded. As would be expected, the δ^{13}C results are consistent with an entirely C_3 terrestrial ecosystem, though elevated by *ca.* 1–2‰ above values for Northern European herbivores due to the aforementioned latitudinal gradient in δ^{13}C. The cervids (red and roe deer) are slightly but significantly depleted compared to the ibex and chamois (-21.3 vs. -20.1‰, Mann-Whitney U-test, $p = 0.009$). This is presumably related to the preferred habitats for these species, with the deer found in more forested conditions, and hence subject to a 'canopy effect' (Bonafini *et al.* 2013), whereas ibex and chamois would be found in higher, more open elevations. The δ^{15}N values from the two wild pigs are not significantly elevated compared to those of herbivores, suggesting limited consumption of animal protein (Figure 2). It can be noted that the red deer from Los Canes show similar δ^{13}C and δ^{15}N values to those from the Mesolithic levels at El Mirón cave, with respective means of -21.5 ±0.7‰ and 3.9 ±0.4‰ (n = 4) (Stevens *et al.* 2014).

Table 2: Summary of $\delta^{13}C$ and $\delta^{15}N$ data for fauna from Los Canes.

Species	Latin	δ^{13}C	± 1SD (δ^{13}C)	δ^{15}N ‰	± 1SD (δ^{15}N)	n
Red deer	*Cervus elaphus*	-21.5	0.4	4.0	0.6	6
Roe deer	*Capreolous capreolus*	-20.9	0.9	3.9	0.1	3
Ibex	*Capra pyrenaica*	-20.2	0.6	3.9	0.9	5
Chamois	*Rupicapra pyrenaica*	-20.1	1.0	4.6	0.6	4
Ibex/chamois	*Capra/Rupicapra*	-20.0	NA	2.8	NA	1
Wild pig	*Sus scrofa*	-20.8	1.0	4.1	0.2	2
Bear	*Ursus* sp.	-20.4	NA	2.5	NA	1

As part of an inter-laboratory comparison exercise, a subset of 11 faunal samples were also measured by Wolfram Meier-Augustein, then at the EERC, Queen's University Belfast. The resulting correlations are high ($r^2 = 0.96$ for both δ^{13}C and δ^{15}N), though the regression equations indicate a slight offset, with EERC measurements on average being elevated by 0.1‰ for δ^{13}C and 0.2‰ for δ^{15}N (Figures 3 and 4; full results are supplied in Appendix 2). This could be due to the use of different internal calibration standards, or to the use of an ultrafiltration step at the Bradford laboratory. In either case, the differences are minor, and do not affect the interpretations; if anything, they impart greater confidence in the results (cf. Pestle *et al.* 2014).

The 19 herbivores average -20.7 ± 0.9‰ and 4.1 ± 0.7‰ in δ^{13}C and δ^{15}N, respectively. This provides a baseline for comparison with the human results from Los Canes. Taking into account a *ca.* 1‰ trophic level shift for δ^{13}C (prey to predator bone collagen), and 4‰ shift for δ^{15}N, the expected human bone collagen values would be -19.7‰ and 8.1‰, which is in fact identical (to one decimal) to the observed means of -19.7‰ and 8.1‰ (excluding the infant), suggesting that there are no missing major food sources (e.g. freshwater fish). The comparison is further improved if the EERC faunal values are used, since, as noted above, these are slightly elevated in both isotopes. However, this very simple calculation would be called into question if plant foods – with generally lower δ^{15}N values – contributed significant dietary protein as suggested for Aizpea. Further work is required to investigate this matter.

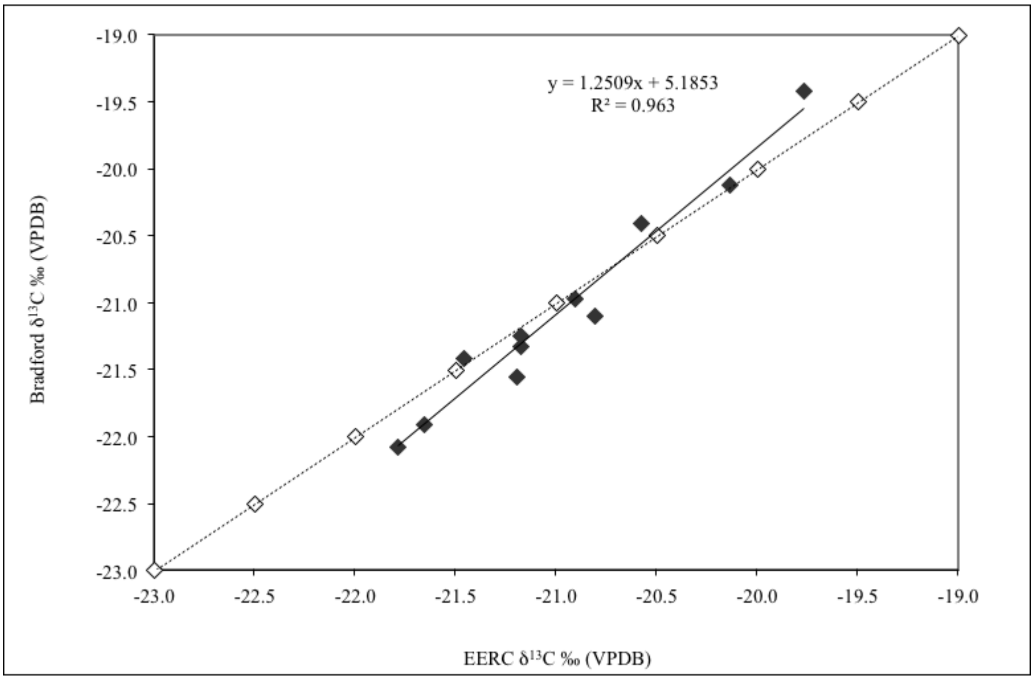

Figure 3: Comparison of δ^{13}C measurements on faunal from Los Canes at EERC and Bradford. The open diamonds define a perfect 1 to 1 correlation.

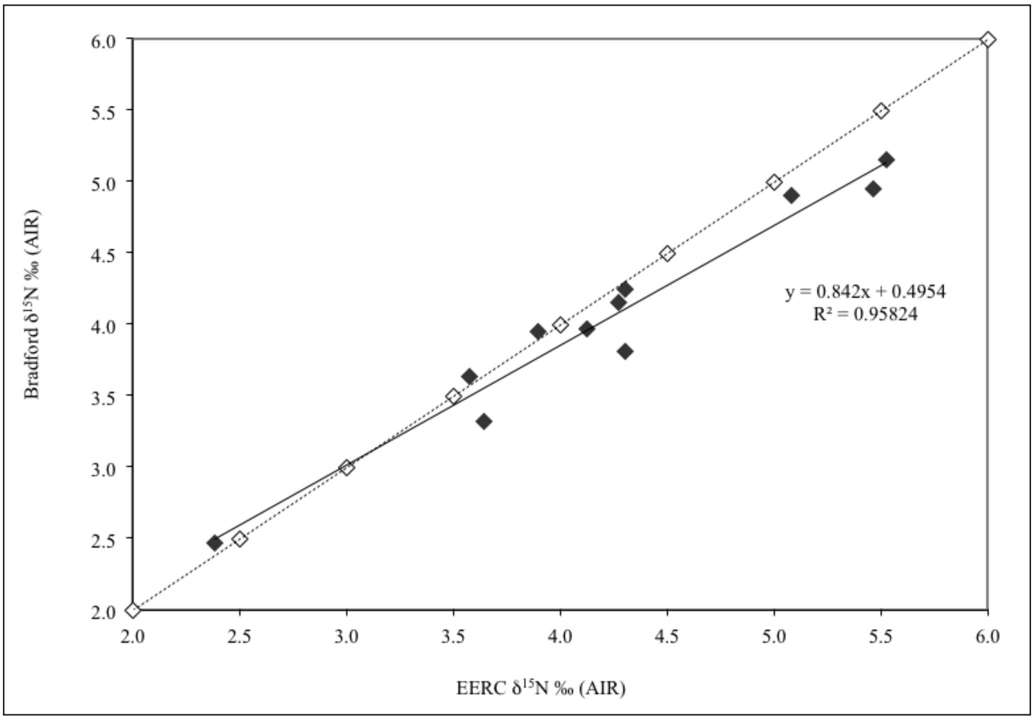

Figure 4: Comparison of δ^{15}N measurements on faunal from Los Canes at EERC and Bradford. The open diamonds define a perfect 1:1 correlation.

4 The sea

While many small shell middens inside caves and rockshelters are known from the Cantabrian coastal strip, relatively few human remains have been recovered (Arias *et al.* 2009; Meiklejohn 2009). The available isotopic data often derive from single skeletons or isolated elements that have been found at these sites, and directly radiocarbon dated to confirm their Mesolithic attribution. Previously reported isotopic results from the near-coastal (within 5 km) sites of Colomba, La Poza l'Egua, Santimamiñe, and Jaizkibel (J3) all exhibit moderately elevated δ^{13}C and δ^{15}N values (Arias 2005; Arias *et al.* 2007; López Quintana *et al.* 2015) (Table 1). The remnant shell midden in a small cave at Colomba (Asturias) yielded three lower limb bones, probably from the disturbed burial of a single adult male. Isolated adult male mandibles were recovered from the shell midden in the cave of La Poza l'Egua (Asturias) and from the cave of Santimamiñe (Biscay). Jaizkibel J3 (Gipuzkoa) is a shell midden inside a sandstone rockshelter, in which was found the complete skeleton of an adult male, buried in a flexed position (Iriarte *et al.* 2005; 2010).

Three additional dates are available on coastal Mesolithic individuals, but without associated stable isotope data. The earliest is a tooth from a skeleton from Tito Bustillo (Asturias) dated to 7503–7083 cal BC (Beta-197042: 8470 ± 80 BP) (Drak *et al.* 2008). From the same stretch of coast, human remains from the cave of El Toral III (Asturias) have yielded a date of 5884–5622 cal BC (UGAMS-5400: 7080 ±30 BP) (Noval 2014). Finally, an isolated rib fragment from the destroyed cave of Atxuri-I (Biscay) has yielded a date of 6066–5800 cal BC (Beta-442236: 7290 ± 30 BP), while a complete femur gave a considerably later date of 2020–1774 cal BC (Beta-493406: 3560 ±30 BP) (García-Sagastibelza *et al.* 2020). All three Mesolithic individuals would be expected to show considerable reliance on marine foods, though δ^{13}C and δ^{15}N measurements are required for confirmation and quantification. As a provisional approximation, the calibrated dates for these individuals (Table 1) assume a contribution of 50 ±10% marine protein (the mean of coastal Mesolithic humans excluding Cuartamentero as an outlier).

To these can be added 'new'[2] AMS ^{14}C dates and stable isotope values on human remains from Mazaculos, Cuartamentero and Linatzeta (Figure 1). All three are cave/rockshelter sites. An isolated mandible belonging to an adult male was recovered from excavations at Mazaculos II (Asturias) (González Morales and Márquez Uría 1978; Garralda 1981), while amateur excavations at Cuartamentero (Asturias) revealed an adult calotte (Garralda 1982). The burial from Linatzeta cave (Gipuzkoa) is that of an infant less than six months old. It has been previously dated to the Mesolithic (KIA-33193: 7315 ± 35 BP; Tapia *et al.* 2008), but without an associated δ^{13}C value it was uncertain to what extent a marine reservoir correction might apply. The new date reported here is comparable, with a δ^{13}C value of -15.7‰, for a combined date of 6079–5811 cal BC (7337 ± 26 BP, χ^2: df=1, T=0.9 (5% 3/8)), with an estimated 54 ±10% marine protein (Table 1). It is likely that the relatively elevated δ^{15}N value of 12.9‰ partly reflects a nursing signal (Schurr 1998).

An adult fibula from Lumentxa (Biscay) has been dated to 5001–4628 cal BC (OxA-18236: 6122 ±38 BP) placing it within the still poorly defined Mesolithic-Neolithic transitional period, although it does exhibit moderately elevated δ^{13}C and δ^{15}N values of -17.2‰ and 10.0‰, respectively. Moreover, collagen from this sample was measured in triplicate with good agreement, including two new measurements made in 2024, since in this case (unlike Arangas), the previously published 'radiocarbon' values δ^{13}C and δ^{15}N values of -16.7‰ and 12.0‰ (Arias 2012) were notably different, especially for δ^{15}N. The isotopic results suggest that, whatever the cultural attribution of this individual, marine foods still played an important role. An adult human vertebra from Lumentxa has been recently dated to 6610 ±35 BP (CNA-5114.1.1) (García-Sagastibelza *et al.* 2020), though no stable isotopic data are reported. Given their similarity in date, this may be from the same individual represented by the fibula (OxA-18236). Combining the two measurements (χ^2: df=1, T=0.1(5% 3.8)) results in a date of 4986–4704 cal BC, assuming 35 ± 10% marine protein. Scattered Neolithic to Early Bronze Age human remains are also present at both sites (López Quintana *et al.* 2015; García-Sagastibelza *et al.* 2020).

An adolescent/young adult mandible from the relatively nearby cave of Santimamiñe (Biscay) is dated to approximately the same period, 4960–4590 cal BC (Beta-307665: 6130 ± 40 BP), with a somewhat stronger marine signal as indicated by a δ^{13}C value of -16.3‰, though again with only a moderate δ^{15}N value of 10.4‰ (López Quintana *et al.* 2015). This suggests that the marine foods being consumed at both Lumentxa and Santimamiñe were primarily at a low trophic level, e.g. shellfish.

Attempts to obtain collagen from a poorly preserved Mesolithic burial at El Truchiro (part of the La Garma cave complex) as part of this project were unsuccessful. A previous date of 5560–5310 cal BC (TO-10912: 6470 ± 70 BP; Arias *et al.* 2009) on an immature skeleton is seen as suspect since the bone was charred. An earlier date of 5997-5790 cal BC (OxA-23190: 8296 ± 31 BP) on associated charcoal is thought to be more reliable (Àlvarez-Fernández *et al.* 2013)[3].

The isotopic results from Mazaculos and Linatzeta are in line with those previously reported for other Cantabrian coastal Mesolithic sites. Cuartamentero is particularly interesting, in that it presents the highest δ^{13}C and δ^{15}N values thus far obtained from the region, -12.8‰ and 14.3‰, respectively. These

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[2] The dates were first presented at the MESO2010 conference in Santander. They have since been cited (with permission) in other publications (e.g. Drak and Garralda 2009), but without the associated chemistry details.

[3] Note that a date of 7165 ± 65 (OxA-7300) was originally attributed to another skeleton from the complex, La Garma B (Arias and Álvarez Fernández 2004: 233), but this was in error. The date should be 4165 ± 65 BP and refers to Chalcolithic use of this part of the cave system, which contains no evidence for Mesolithic activity.

approach what might be expected for an individual consuming almost entirely marine protein. Even when corrected for the marine reservoir effect, the calibrated date of 7293–6772 cal BC (OxA-18230: 8395 ± 40 BP) from Cuartamentero is among the four earliest Mesolithic humans from the coast of Northern Spain (Table 1).

Taken at face value, the stable isotope results from coastal sites in Northern Spain suggest – with the exception of the stronger marine signal from Cuartamentero – a mixed marine-terrestrial diet, with each contributing approximately 50% (using δ^{13}C end members of -12‰ and -20‰, respectively; the latter figure being based on the mean of the inland humans excluding La Braña). However, recalling the above discussion regarding isotopic ecology of estuaries, this may significantly under-represent the contribution of marine resources. Few contemporary fish samples are available from Cantabrian Spain, but four specimens from Mesolithic sites analysed as part of this study demonstrate considerable variability in both δ^{13}C and δ^{15}N (Table 3). Single vertebrae identified as horse mackerel (*Trachurus trachurus*) and seabream (*Sparidae diplodus*) provided δ^{13}C values of -15.9‰ and -15.2‰, respectively; these are very similar to the coastal human values in Table 1. Another vertebra identified as horse mackerel, however, gave a δ^{13}C value of -11.6‰. A comparable range of variability has been found in modern Atlantic mackerel (*Scomber scombrus*) and horse mackerel in the Bay of Biscay (Le Loc'h and Hily 2005; Logan 2009). Additional isotopic measurements on a much wider range of archaeological fish samples from the region would be extremely useful in understanding the degree to which coastal communities exploited these resources (stable carbon and nitrogen isotopic values for two freshwater fish species – trout and barbel – have been published from the Mesolithic site of Aizpea (Fernández-Crespo *et al.* 2020); see Figure 2). We are also hampered by the very limited number of human remains that have been found, with only a single individual represented at each coastal site. At present we can say that Mesolithic coastal communities certainly relied heavily on the sea for their subsistence, but it is difficult to explore the details of this relationship further.

Table 3: Stable carbon and nitrogen isotope data for archaeological fish remains from Mesolithic deposits.

Site	Species	Latin	δ^{13}C ‰	δ^{15}N ‰	C:N
Balmori	Horse mackerel	*Trachurus trachurus*	-11.6	12.1	3.1
Poza l'Egua	Horse mackerel	*Trachurus trachurus*	-15.9	9.1	3.2
Colomba	Sea bream	*Sparidae diplodus*	-15.2	8.0	3.1
Colomba	Salmonid	*Salmonidae*	-12.0	12.4	3.2

5 Two separate lifeways

While sample size remains low, there is a clear distinction in isotopic values, and hence diets, between individuals from inland and coastal sites (Table 4). The inland group averages -19.6 ±0.7‰ for δ^{13}C and 8.5 ±1.1‰ for δ^{15}N ($n = 12$, excluding the Los Canes infant), compared to -15.8 ±1.4‰ for δ^{13}C and 11.9 ±1.4‰ for δ^{15}N ($n = 8$) for the coastal group. In both cases the differences are statistically significant (Student's t-test, δ^{13}C $t = 8.166$, $p < 0.001$; δ^{15}N $t = 6.168$, $p < 0.001$).[4] What makes this particularly striking is the location of Los Canes, with an inland adaptation, only some 11 km from the coast. This adds to growing evidence for small-scale isotopic variation in the Mesolithic, which in turn

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[4] Neither distribution departs significantly from a normal distribution as assessed by Shapiro-Wilks tests, permitting the use of the parametic Student's t-test.

suggests limited mobility (both physical and social) between coastal and inland communities (Schulting 2010). In a recent review of the Mesolithic of Atlantic coastal Spain, Clark and Barton (2022: 55) refer to the ‘near absence of inland sites’ other than burials, and suggest that one possible explanation for this is that the dense forests made hunting too costly, leading people to congregate on the coast. This fails to take into account the clear isotopic evidence for viable subsistence adaptations focussed entirely on terrestrial resources, as well as the sizeable faunal assemblage at Los Canes.

It can also be noted that the division into inland and coastal adaptations seems to persist throughout the period for which data are available, beginning in the second half of the eighth millennium BC and continuing to the end of the Mesolithic in the fifth millennium BC (Figure 5). Once corrected for the marine reservoir effect, the late dates combined with elevated δ^{13}C values for Lumentxa and Santimamiñe could suggest the late survival of a Mesolithic hunter-fisher-gatherer economy overlapping with the arrival of domesticated plants and animals that is the hallmark of the Neolithic in Western Europe.

Table 4: ummary of human δ^{13}C and δ^{15}N data for inland (excluding Los Canes infant) and near-coastal locations in Northern Spain.

Site location	δ^{13}C ‰	± 1SD (δ^{13}C)	δ^{15}N ‰	± 1SD (δ^{15}N)	n
Inland	-19.6	0.7	8.5	1.1	12
Coastal	-15.8	1.4	11.9	1.4	8

Obviously additional samples –both human and faunal, particularly additional archaeological marine fish – would be of great benefit in refining the picture presented here. Given the emerging evidence for the use of relatively constrained territories for day-to-day subsistence activities (cf. González Morales *et al.* 2004; Schulting 2010), we would anticipate considerable variability along the coast of Northern Spain, given the different configurations of the coastline, the presence of estuaries, etc. The isotopic results also need to be seen in conjunction with material culture studies, concerning which some predictions might now be made (e.g. for differences in lithic traditions or raw material use), in order to further our understanding of Middle Holocene hunter-gatherer adaptations along the Atlantic façade.

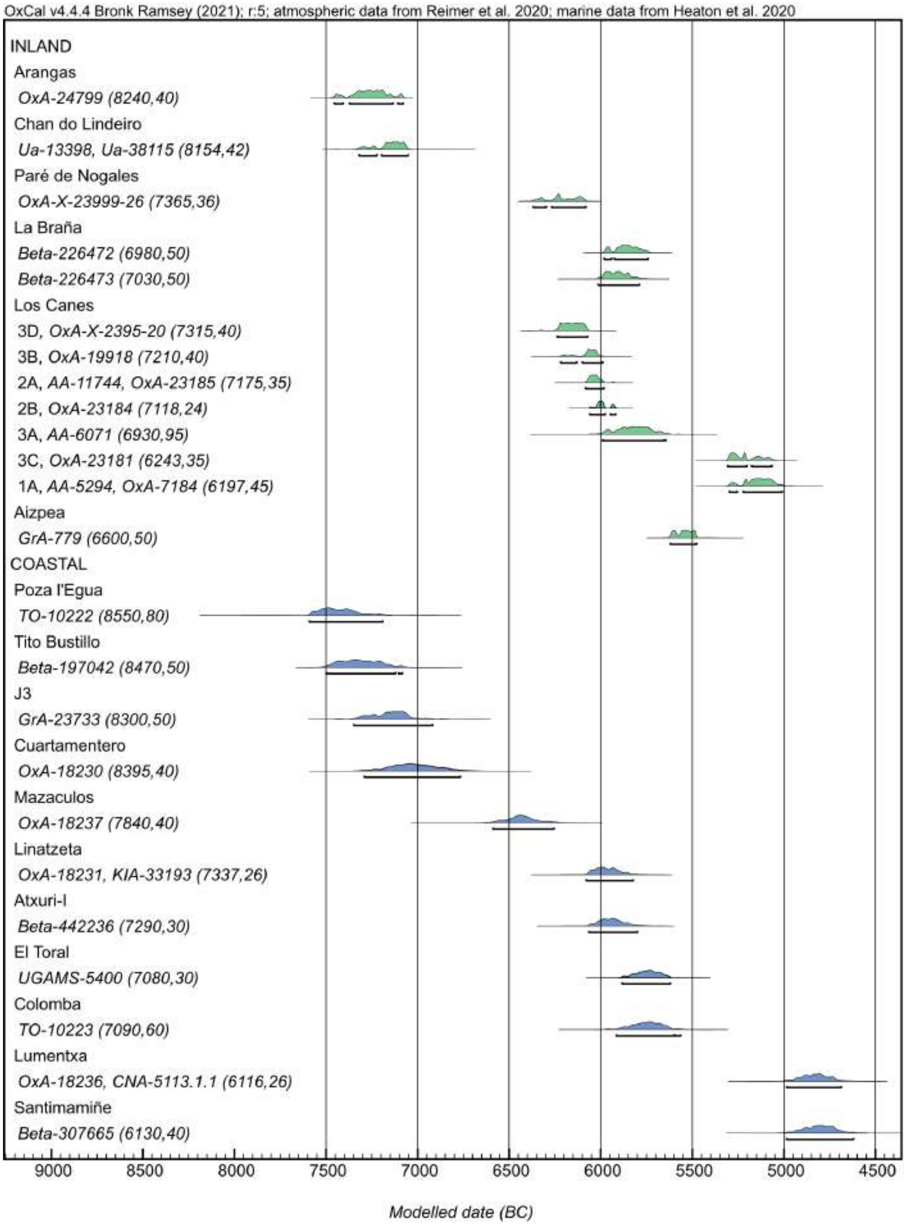

Figure 5: Calibrated radiocarbon dates for inland and coastal Mesolithic/Mesolithic-Neolithic transitional humans from Northern Spain. Note that the marine reservoir corrections for Tito Bustillo, Atxuri-I and El Toral III have been estimated (assuming 50% marine diets) in the absence of $\delta^{13}C$ data.

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Appendices

Site	Sample	Latin name	Common	Element	Age	$\delta^{13}C$	$\delta^{15}N$	C:N	%C	%N
Balmori	15	*Capra/Rupicapra*	Ibex/chamois	Mandible	Adult	-20.0	2.8	3.53	41.20	13.62
Los Canes	21	*Capra pyrenaica*	Ibex	Metatarsal	Adult	-20.1	4.3	3.42	41.99	14.30
Los Canes	22	*Capra pyrenaica*	Ibex	Metapodial	Subadult	-20.1	2.9	3.41	42.91	14.67
Los Canes	30	*Capra pyrenaica*	Ibex	Scapula	Adult	-20.1	4.2	3.45	21.57	7.31
Los Canes	35	*Capra pyrenaica*	Ibex	Metapodial	Adult	-19.4	5.0	3.28	38.71	13.79
Los Canes	40	*Capra pyrenaica*	Ibex	Rib	Adult	-21.2	4.0	3.24	42.63	15.37
Los Canes	16	*Capreolus capreolus*	Roe deer	Scapula	Adult	-21.5	4.0	3.25	43.69	15.67
Los Canes	28	*Capreolus capreolus*	Roe deer	Rib	Adult	-19.9	3.9	3.32	41.05	14.44
Los Canes	39	*Capreolus capreolus*	Roe deer	Radius	Adult	-21.3	3.8	3.25	43.30	15.57
Los Canes	17	*Cervus elaphus*	Red deer	Phalanx	Adult	-21.9	3.6	3.35	43.35	15.12
Los Canes	18	*Cervus elaphus*	Red deer	Phalanx	Adult	-21.7	3.8	3.28	42.36	15.05
Los Canes	19	*Cervus elaphus*	Red deer	Tibia	Adult	-21.2	5.1	3.32	43.35	15.23
Los Canes	27	*Cervus elaphus*	Red deer	Rib	Adult	-22.1	4.2	3.40	26.06	8.94
Los Canes	32	*Cervus elaphus*	Red deer	Flat bone	Adult	-21.3	3.8	3.36	39.99	13.88
Los Canes	37	*Cervus elaphus*	Red deer	Metatarsal	Adult	-21.0	3.3	3.33	41.98	14.73
Los Canes	25	*Rupicapra pyrenaica*	Chamois	Mandible	Adult	-19.2	5.1	3.31	42.74	15.05
Los Canes	26	*Rupicapra pyrenaica*	Chamois	Mandible	Adult	-20.2	4.4	3.63	40.08	12.87
Los Canes	31	*Rupicapra pyrenaica*	Chamois	Metapodial	Adult	-21.4	4.9	3.25	42.63	15.30
Los Canes	33	*Rupicapra pyrenaica*	Chamois	Phalanx	Adult	-19.6	3.9	3.21	43.60	15.87
Los Canes	38	*Rupicapra pyrenaica*	Chamois	Rib	Adult	-20.8	2.3	3.94	43.45	12.85
Los Canes	23	*Sus scrofa*	Wild boar	Metapodial	Adult	-21.6	4.0	3.45	35.54	12.01
Los Canes	29	*Sus scrofa*	Wild boar	Phalanx	Adult	-20.1	4.3	3.22	40.95	14.82
Los Canes	34	*Sus scrofa*	Wild boar	Metapodial	Adult	-21.1	5.2	3.81	30.76	9.41
Los Canes	20	*Ursus* sp.	Bear	Phalanx	Adult	-20.4	2.5	3.37	41.26	14.27
Failed										
Balmori	14	*Cervus elaphus*	Red deer	Long bone	Adult	-22.5	3.4	4.5	46.57	12.03
Los Canes	36	*Cervus elaphus*	Red deer	Scapula	Adult	-21.7	4.1	4.5	36.55	9.44
Los Canes	41	*Sus scrofa*	Wild boar	Metapodial	Adult	Insufficient collagen yield				
Los Canes	24	*Sus scrofa*	Wild boar	Calcaneous	Adult	Insufficient collagen yield				

Appendix 1: *Stable carbon and nitrogen isotope results on fauna from Los Canes and Balmori.*

						EERC			Bradford			Difference		Absolute diff	
Sample	**Latin name**	**Common**	**Element**	**Age**	**Context**	$\delta^{13}C$	$\delta^{15}N$	C:N	$\delta^{13}C$	$\delta^{15}N$	C:N	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
35	Capra pyrenaica	Ibex	Metapodial	Adult	Burial	-19.8	5.5	3.0	-19.4	5.0	3.3	-0.4	0.5	0.4	0.5
40	Capra pyrenaica	Ibex	Rib	Adult	Burial	-21.2	4.1	2.9	-21.2	4.0	3.2	0.1	0.1	0.1	0.1
17	Cervus elaphus	Red deer	Phalanx	Adult	Layer 8	-21.7	3.6	2.8	-21.9	3.6	3.3	0.2	-0.1	0.2	0.1
27	Cervus elaphus	Red deer	Rib	Adult	Burial	-21.8	4.3	3.0	-22.1	4.2	3.4	0.3	0.1	0.3	0.1
32	Cervus elaphus	Red deer	Flat bone	Adult	Burial	-21.2	4.3	2.9	-21.3	3.8	3.4	0.1	0.5	0.1	0.5
37	Cervus elaphus	Red deer	Metatarsal	Adult	Burial	-20.9	3.6	2.9	-21.0	3.3	3.3	0.1	0.3	0.1	0.3
31	Rupicapra pyrenaica	Chamois	Metapodial	Adult	Burial	-21.5	5.1	2.9	-21.4	4.9	3.3	-0.1	0.2	0.1	0.2
23	Sus scrofa	Wild pig	Metapodial	Adult	Layer 8	-21.2	3.9	3.1	-21.6	4.0	3.5	0.4	-0.1	0.4	0.1
29	Sus scrofa	Wild pig	Phalanx	Adult	Burial	-20.1	4.3	2.9	-20.1	4.3	3.2	0.0	0.0	0.0	0.0
34	Sus scrofa	Wild pig	Metapodial	Adult	Burial	-20.8	5.5	3.0	-21.1	5.2	3.8	0.3	0.4	0.3	0.4
20	Ursus	Bear	Phalanx	Adult	Layer 8	-20.6	2.4	3.1	-20.4	2.5	3.4	-0.2	-0.1	0.2	0.1

Appendix 2: *Subset of faunal samples from Los Canes measured at both Queen's University Belfast (EERC) and the University of Bradford.*