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Frequency Analyses of Historical and Archaeological Datasets Reveal the Same Pattern of Declining Sociocultural Activity in 9th to 10th Century CE Ireland

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Abstract

This paper discusses how the production rate of historical and archaeological data might contain unique information about past societies. The case study is the frequency of entries in the *Annals of Ulster*, a primary early medieval source from Ireland, which was compared to the frequency of archaeological material from early medieval Ireland. The two datasets were found to contain similar trends, namely a rapid increase in activity in the 7th Century, followed by a decline in the Early 9th Century, low levels of activity in the 10th Century, until recovery in the Late 10th / Early 11th Centuries. This overall pattern of activity had not been noticed before. Turning to the archaeological record of Britain, although there are certain similarities between Ireland and Scotland especially in the early part of the period, we find that the 9th and 10th centuries there were a stable period, and thus contrast with Ireland. We argue that environmental pressures are unlikely to be driving the signal, and instead various socio-cultural factors in the past coalesced in Ireland, leading to circumstances powerful enough to attenuate the enduring evidence for human activity, but expressing themselves silently, perhaps even in a way that was not immediately obvious to those witnessing them in the past. The simplest explanation, we contend, is that population levels fell throughout the period. This finding offers insight into the relationship between long-term change and the primary production of history, and supports the idea that the *quantity* of certain historical data can contain information about past realities.

Introduction

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The intensity of human behaviour—how much energy is invested by people in a given time and place—is constantly changing as a consequence of demographic and cultural factors such as population levels, farming practices, and economic activities (e.g. Freeman et al. 2017). Understanding past changes in the intensity of human behaviour over the long-term provides insight into evolutionary trajectories that societies have taken. To gain this understanding, a significant body of evidence needs to be amassed and somehow analysed; in this paper we argue a relatively simple but potentially important proxy for past intensity are the frequencies that historical data were written and archaeological materials were buried in the ground. Using early medieval Ireland (Figure 1) as our case-study, we set out to investigate whether similar trends can be seen in historical and archaeological data, and if so, what insight this provides on early medieval society.

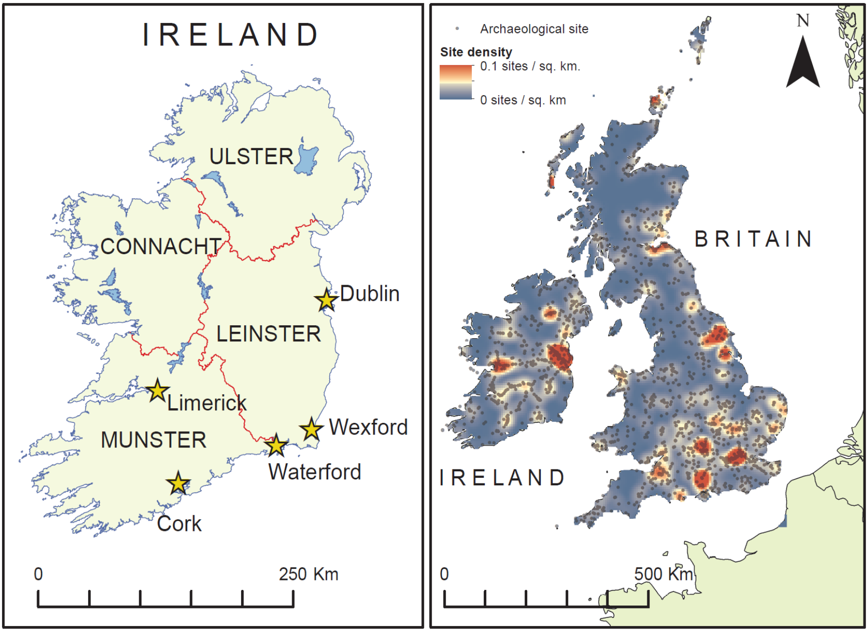

Figure 1. Location Map showing Britain and Ireland and the archaeological sites whose radiocarbon samples are meta-analysed in this paper. The density of the sites in the landscape is modelled in ArcGIS 10.2 using kernel density and a search radius of 30 km. Sites from Britain are plotted using data provided by Bevan et al. (2017).

Historians of early medieval Ireland are fortunate in having at their disposal a large number of contemporary records known as annals. Indeed the quantity of these sources can pose a challenge, as few suitable historical methods have been developed to deal with them. In an introductory textbook on early medieval Ireland, Dáibhí Ó Cróinín lays down a challenge (Ó Cróinín 2017: 8) that will pique the interest of readers of *Cliodynamics*:

> The question…is not where to find such records but how to cope with their sheer profusion; for historians, in trying to extract meaning from the hundreds of annalistic entries, are presented with the phenomenon that modern computer specialists describe as 'data overload.'

Drawing inspiration from recently-developed archaeological methods, in this paper we analyse the frequency of entries in Irish annals. Archaeological evidence from the early medieval period in Ireland is particularly rich, and is a rich source of information in its own right as well as being an independent check on the significance of patterns revealed by the analysis of annals. Indeed, although the use of statistics to help uncover long-term trends in the past has not yet been applied to the history of early medieval Ireland, such methods are increasingly and routinely being explored by archaeologists of the period (e.g. Kerr and McCormick 2014). Much contemporary, data-driven archaeology involves the analysis of the frequency of dated archaeological material through time as a proxy for levels of human activity in the past (e.g. Bevan et al. 2017; Brown 2017; Shennan et al. 2013; Timpson et al. 2014; Williams 2012). Pioneered by Haynes (1969) and Rick (1988), this is an established—if somewhat sill problematic—way to investigate large-scale fluctuations in human populations and/or cultural sequences (cf. Contreras and Meadows 2014). Radiocarbon dates—the ages of once-living biological samples—are particularly suitable for this treatment because they are frequently sought and widely published, have associated contextual information, and are numerical data in the sense that they consist of a repeatable measurement and associated error term, or (when calibrated) an age range defining the interval of time that a sample's age is most likely to fall within. Dendrochronological dates—wood samples dated using the pattern of growth rings common to all trees of a given era, species, and region—also offer these qualities, with the added advantage of enhanced chronological resolution. Other dating methods used in archaeology are either highly relative, imprecise, or not used frequently enough to be of use in analyses of this kind. Historical data, however, contain a wealth of contextual and chronological information, although ancient primary source material is not forthcoming for all regions that also have a large number of archaeological sites spanning the same period. This makes

Ireland (Figure 1) an ideal case study, as in addition to the availability of historic and archaeological sources, there is also a well-researched body of palaeoecological evidence for past environmental changes to the island, adding another dimension to the analysis. For these reasons our main focus is on Ireland, although in this paper we also draw comparisons with Britain as a first step in developing this work more broadly in space and time.

Historical Context

Spanning eight centuries, the early medieval period in Ireland began in the 430s CE with the arrival of Christian missionaries Palladius in 431 CE and, more notably, St. Patrick in 432 CE. By the 7th Century, Christianity was firmly established and religious institutions were organised into *paruchia*—a network of major monastic complexes overseeing lesser houses (Ó Cróinín 2017). Politically, the landscape was divided into over one-hundred and fifty *túatha*, essentially small kingdoms, with interactions between social classes based largely around a lord-client relationship (Kelly 1997). Integral to this was the milch cow, which formed the basis of wealth; social standing was measured by the number of cattle in one's possession, either owned or borrowed (Kelly 1988; 1997). From 7th-Century law tracts, such as the *Críth Gablach*, it is known that society was comprised of noble classes, various grades of farmer, free and unfree persons, as well as slaves (Kelly 1988). The hierarchical nature of society is reflected to an extent in the settlement archaeology of the period, with low-status farmsteads (ringforts) and higher-status, royal residences and island settlements (*crannógs*) widely dispersed in the rural landscape. The ringfort, a defended farmstead thought to be for the protection of cattle, was considered the quintessential domestic residence in Ireland previously, but through archaeology the known settlement forms in existence in Ireland at that time has changed quite drastically in recent years (O'Sullivan et al. 2014).

Britain's history differs greatly from Ireland. The early medieval world emerged from the Anglo-Saxon migrations of the 5th and 6th Centuries into the remnants of Roman-Britain, from which the Romans had withdrawn around 400 CE (Hills 2011). This was a time of major transition in Britain, and indeed elsewhere in Europe. Near-contemporary documentary sources survive, namely Gildas' writings from the 6th Century which denotes the history of Britain before and during the migrations (Brugmann 2011). Later texts include the Venerable Bede's 8th-Century '*Ecclesiastical History of the English People*', the Anglo-Saxon Chronicles and the 10th-Century *Annales Cambriae* of Wales. Politically, Britain came to be organised into a handful of larger kingdoms, in contrast to Ireland's numerous *túatha*. A rise of kingship from the 7th Century was reflected increasingly in both settlement forms and mortuary practices (Ulmschneider 2011; Welch 2011). Coins were produced by Anglo-Saxon rulers from this point, long before their use in Ireland. Trading centres known as *wics* and *emporia* were established at this time also, with no Irish equivalent this early (Ó Cróinín 2017). Christianity was not officially introduced until 597 CE, when St. Augustine's mission in Kent was first recorded. Its subsequent spread was aided by royal patronage (Blair 2005). It was not until the late 8th Century that the Scandinavian attacks began and were recorded in the various annals and chronicles of Ireland and Britain. These persistent incursions were soon followed by the long-term settlement of the invaders, establishing various towns such as York in England and Dublin in Ireland.

The Picts—presumed descendants of Iron Age inhabitants, occupied Scotland during early medieval times. The early history of the Picts is unclear but certainly distinctive from that of Southern Britain and Ireland, especially in terms of culture, social organisation, and economy. Western Scotland was the setting of an important 'Irish' monastery, the Abbey of Iona, and from the 6th Century the base for missionary work in Pictland and also a celebrated centre for learning and writing, and probably the place where some of the original source material for the *Annals of Ulster* was composed (McCarthy 1998). The Picts dominated Scotland in the 8th Century but by the 9th Century they were united with the Dal Riata Scottish dynasty, a neighbouring kingdom already spanning much of western Scotland and parts of north-eastern Ireland (James 2001). Viking conquests in northern Britain in the latter part of the 9th Century ensured that much of the former Pictish territories were no longer under their control (*ibid*). Viking influence in Scotland was felt in the islands especially, but unlike in Ireland or Southern Britain, there were no Viking towns established during the early medieval period.

Archaeological Context

The early medieval period in Britain and Ireland has been relatively well explored by archaeologists; traditionally these studies have focused on relatively high-status settlements and ecclesiastic centres. In Ireland, recent decades especially have seen a large amount of archaeological work being carried out in advance of infrastructural and other development. This has led to the availability of unprecedented numbers of excavation reports (e.g. O'Sullivan et al. 2014), large numbers of associated radiocarbon dates (e.g. Armit et al. 2014, Becker et al. 2011), and environmental archaeological evidence from all periods (e.g. McClatchie et al. 2015; McClatchie et al. 2016). Much more data are now available than were before and, crucially, these datasets have been collected with much less influence from the research bias that can strongly effect the patterning of archaeological data (see McLaughlin et al. 2016). This is because the work is dictated by the pressures of development rather than previous surveys or the presence of above-ground-level indicators such as megalithic tombs, castles, etc.; many thousands of sites have been discovered simply by maintaining a watching brief on the topsoil stripping in advance of building work or road construction. Although the deluge of data generated by this activity is still being processed, the overall trends emerging from the work have already become apparent (Armit et al. 2014; McLaughlin et al. 2016). In particular, there is a growing realisation that past levels of activity were highly dynamic, which stands in contrast to traditional models of growth. Such models viewed the past as gradual increases in social and technological complexity, punctuated with revolutions such as the Neolithic introduction of agriculture or the Industrial Revolution of the 19th Century (e.g. Childe 1925). By contrast, the highly resolved discoveries of archaeological work in recent decades reveal many episodes of fluorescence and long-term recession and therefore some time periods are associated with many more sites than others.

Within the eight-century span of early medieval Ireland, fluctuating levels of activity have been detected in various aspects of its archaeology, although a straightforward synthesis of the data is difficult to achieve. Ringfort chronology has been and still is a subject frequently under discussion and revision, with the current consensus view being that there was a peak in ringfort construction between 650 and 900 CE (Kerr and McCormick 2014), although many sites continued to be used for many centuries thereafter (Fitzpatrick 2009). Significantly, more nuanced changes are also detectable, as seen in the work of Kerr (2007), which has identified chronological differences within ringfort types, particularly in the 9th and 10th Centuries. Simple 'univallate' and higher-status 'multivallate' types were broadly contemporary and constructed in the period between ca. 650 and 900 CE, but 'platform rath' construction was in general later, occurring from around 950 CE through to the 11th Century (ibid.). This change has been linked to an economic shift towards arable production in the 8th and 9th Centuries (Kerr et al. 2009). Aside from ringforts, Kenny's (2010) study of charcoal production features in Ireland shows a distinct peak in this activity in the latter part of the early medieval period, between the 9th and 13th Centuries.

A complicating factor is the evidence for regional differences seen in a number of recent studies. For example, animal bones from one important site, Knowth, show evidence for a decline in cattle from the late 8th Century, but an increase in other kinds of livestock (McCormick and Murray 2007). However, McCormick et al.'s (2014) examination of over 100 other sites concluded that this pattern was not evident throughout the whole of Ireland—it is expressed more strongly in the north. Similarly, the chronology of corn-drying kilns is substantively different across the island, featuring in midland regions early in the 7th Century, and only becoming widespread in the south in the 10th Century, and significantly later still in western regions (Monk and Power 2012). In summary, available archaeological evidence from early medieval Ireland points to fluctuating activity and economic change—although the overall pattern is not quite clear from the literature—and recent discoveries of large numbers of settlement sites presents the opportunity for quantitative analysis of the data using newly-developed methods.

Methods

Historical Sources

The Annals of Ulster are a contemporary record of events in early medieval Ireland listing incidental events such as the deaths of chieftains, wars, Viking raids, and unusual meteorological and astronomical phenomena. Although named after Ulster, the northern province (Fig. 1), they refer to events throughout Ireland and beyond. The *Annals* were inscribed in 'Easter tables'—official communications received from Rome that set out the Christian calendar for worship each year. They were transcribed from their original source material in the late 15th Century and translated from Irish and Latin to English in the 19th and 20th Centuries. The version of the *Annals* used for this study is the English language electronic edition compiled by Bambury and Beechinor (2000) and freely available online. Other Irish annals, such as the 17th Century *Annals of the Four Masters* were compiled retrospectively for the early medieval period. Although they did draw on primary source material (including the *Annals of Ulster*) they cannot be considered for analysis of this kind due to distance that separated the annals and the events they describe. Similarly, there are too few entries in the British *Annales Cambriae* to permit a meaningful frequency analysis.

Each entry in the annals is dated, so using standard tools in the computer programming environment *R*, the text of the annals was used to construct a time series, with a measurement frequency equal to one calendar year, each containing an 'observation' equal to the number of entries in that year. The first entry each year, which simply declares time to be 1st January of the new year, was not included. To decompose the time series and identify the trends, a simple moving average (SMA) model was used with an order parameter of 30 years. Similarly, a 30-year moving standard deviation modelled any changing variance in the data. For comparison with the archaeological sources, a kernel density estimator (KDE) was computed using a Gaussian kernel and a bandwidth of 30 years. A confidence interval for this KDE was bootstrapped using random sampling with replacement, using standard tools in *R*.

Archaeological Sources

Radiocarbon dating measures the age of carbon in a sample of once-living tissue. The method is based on the premise that all living things exist in carbon equilibrium with the atmosphere and because a trace fraction of atmospheric CO_2

contains the cosmogenic radioactive ^{14}C isotope, which decays to ^{14}N with a half-life of ca. 5730 years, age can be estimated from the relative proportion of ^{14}C in a sample (Arnold and Libby 1949; Libby 1946. See also e.g. Bronk Ramsey 2008 for an overview). A complicating factor is that the ^{14}C content of the atmosphere has not remained constant over time, but rather it has oscillated unpredictably, meaning that all ^{14}C measurements must be 'calibrated' against a database of measurements of known age. The resolution of the technique is therefore somewhat limited, with the 95% confidence interval of a typical age determination sometimes spanning several centuries, although through recent improvements to the calibration dataset (e.g. Reimer et al. 2013) and in Bayesian analysis of the results (e.g. Bronk Ramsey 2009) this situation can sometimes be improved to a decadal-scale. Radiocarbon dating is routinely applied to archaeological sites, especially where the material culture associated with the site is not particularly distinctive. A database of radiocarbon dates from Ireland was compiled using publically accessible sources of data (CBA 2012; Chapple 2015) and supplemented with additional information from relevant publications and site reports as part of on-going wider projects (by Rowan McLaughlin and Emma Hannah) that are currently synthesising and analysing these data. The database included earlier (Iron Age) data and later (medieval) data, and therefore suffered no edge effects because these were collected with the same research intensity as the early medieval data. Comparative data for Britain were provided by Bevan et al. (2017). Associated with each Irish date was some metadata indicating the site location and whether the sample was derived from a settlement site, an enclosure, a human burial, or another kind of feature, and what material constituted the sample. As noted above, the archaeological data derive mainly from modern-day development pressure, rather than research tradition, although a degree of bias is inevitable in databases of this kind. Modern-day population centres and the natural route-ways between them are where development tends to take place, and therefore where 'rescue' archaeological excavations happen. However, as shown in Figure 1, even remote areas are covered quite well. To check that no one particular region or site type was dominating the results, analysis was performed independently on each, and the results compared.

The radiocarbon dates were calibrated in *R* using the IntCal13 and Marine13 databases as appropriate (Reimer et al. 2013) and the standard normal distribution density function (e.g. see Blaauw 2010). This typically gives rise to a multimodal probability density distribution. At this point, many studies sum the probability densities for all the radiocarbon dates under analysis, although this often leads to unwanted spikes and the amplification of noise from the calibration data. An alternative approach was taken here; the calibrated probability density function of each radiocarbon date was sampled, and their temporal distribution modelled using Kernel Density Estimation with a bandwidth of 30 years. Using bootstrapping, 500 iterations of this process were used to estimate the standard deviation of the KDE caused by the uncertainty of the calibration process (for further details, see McLaughlin 2018). The results were compared to a summed probability distribution of all the dates under analysis. The use of KDEs for summarizing radiocarbon data has been discussed at length recently by Bronk Ramsey (2017) and the method is rapidly gaining momentum (e.g. Pilø et al. 2018).

One feature of calibrated radiocarbon dates is that if the confidence interval of a radiocarbon date overlaps a change in the steepness of the calibration curve, the sampled radiocarbon probability densities used to estimate the kernel density are more likely to fall within the steep part of the curve, thus causing slightly higher density estimates for certain periods, and greater uncertainty in others. Some periods are more susceptible to this, which is ultimately due to the uneven history of ^{14}C production and cycling in the atmosphere and therefore beyond our control. However, to demonstrate that this was not an issue hampering the current study, we calculated an expected ^{14}C KDE for material evenly deposited through time by 'reverse-calibrating' then 're-calibrating' 3000 randomly chosen 'years' between 300 and 1300 CE (a method similar to that described by Timpson et al. 2014). This simulated set of radiocarbon data was used as a 'null model' of steady-state activity, and compared to the archaeological data.

A database of dendrochronological measurements was obtained in the manner described above and also modelled using a KDE, using bootstrapping to calculate its confidence interval in the same manner as the annals data. This undertaking was somewhat simpler than the process for radiocarbon, as dendrochronological dates are obtained on the calendar time scale. There are fewer dendrochronological dates available because the requisite samples of preserved wood, which must be quite substantial in size, are only found in certain types of site and typically only in waterlogged conditions. By contrast, the majority of radiocarbon dates from the period are obtained from small samples of charcoal, charred seeds or animal bones, all of which are ubiquitous.

Results

The density models and SMA time series for the historical and archaeological data are shown in Figure 2. From ca. 400 CE until ca. 680 CE the annals and the radiocarbon data both show the similar trend of rapid increase; the number of entries in the annals increases on average every year, as does the frequency of archaeological materials. Increase in activity in this period is well known from studies of cereal drying kilns and ringforts (cf. Bronk Ramsey 2017; Kerr and McCormick 2014; Monk and Power 2012). The trends in the radiocarbon data are highly significantly different from the 'null model' (Figure 2, bottom-left). The KDE of dendrochronogical dates peaks twice, once around 600 CE and again around 800 CE, the latter caused in part by the large number of grain mills built in the early 9th Century (Brady 2006).

From around 700 to 825 CE the density of entries in the annals indicates relative stability, whereas the radiocarbon activity begins to fall from its peak level. That said, more detailed examination of the radiocarbon signal from different contexts (Figure 3) reveals however that this pattern was driven by declining activity at enclosures and in human burials. Settlement debris—material found in shallow pits, rubbish middens, and domestic hearths—does not decline, nor does the frequency of cereal dates through time—a proxy for agricultural activity. This matches the pattern found in the *Annals*.

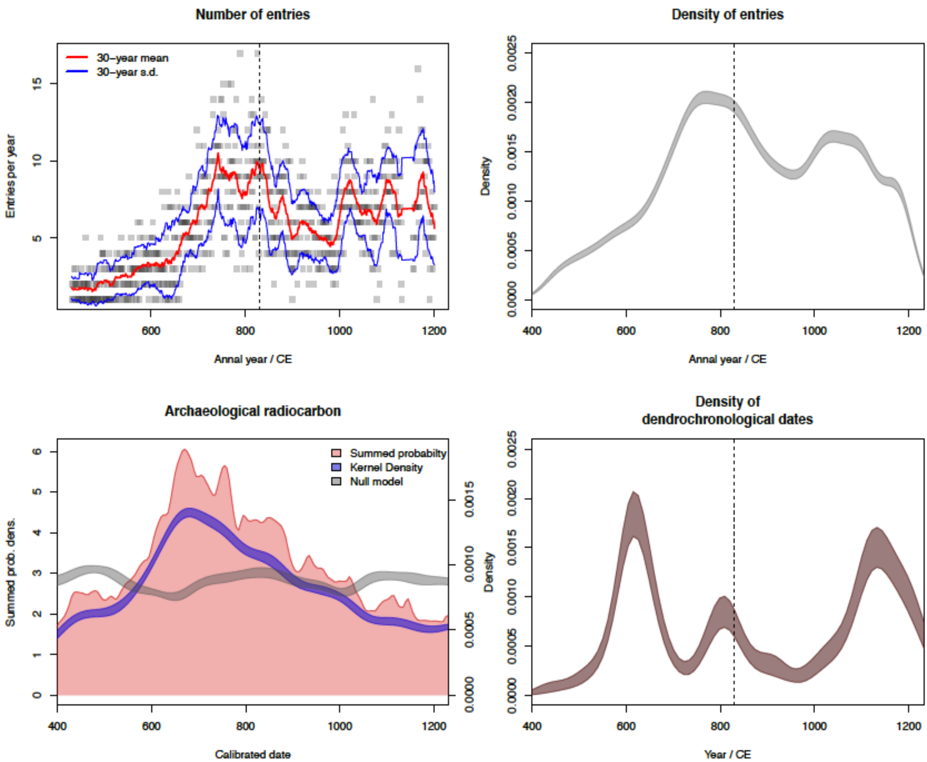

Figure 2. Graphs visualising the number of entries in the *Annals of Ulster* each year; a model of the relative frequency of entries in the *Annals of Ulster* using a KDE with bootstrapped confidence; the density of radiocarbon dates on archaeological samples modelled using summed probability and a KDE; and the KDE of dendrochronogical dates on archaeological wood samples. In all cases the kernel bandwidth is 30 years.

From 800/825 CE until 1000 CE—the 9th and 10th Centuries, all the indications point to reduction in activity. This continues a pre-existing trend in the radiocarbon data, but in the annals and dendrochronological data, it is a pronounced episode of reducing activity. Once again, the pattern in the annals is reflected in the radiocarbon data from settlement debris and radiocarbon dates from all contexts obtained from cereal grains. From 1000 CE, the annals and the archaeological data show fluctuating levels of activity, expressing itself differently depending on context, but in general the downward trend halts at this time. A summary of these trends is given in Table 1.

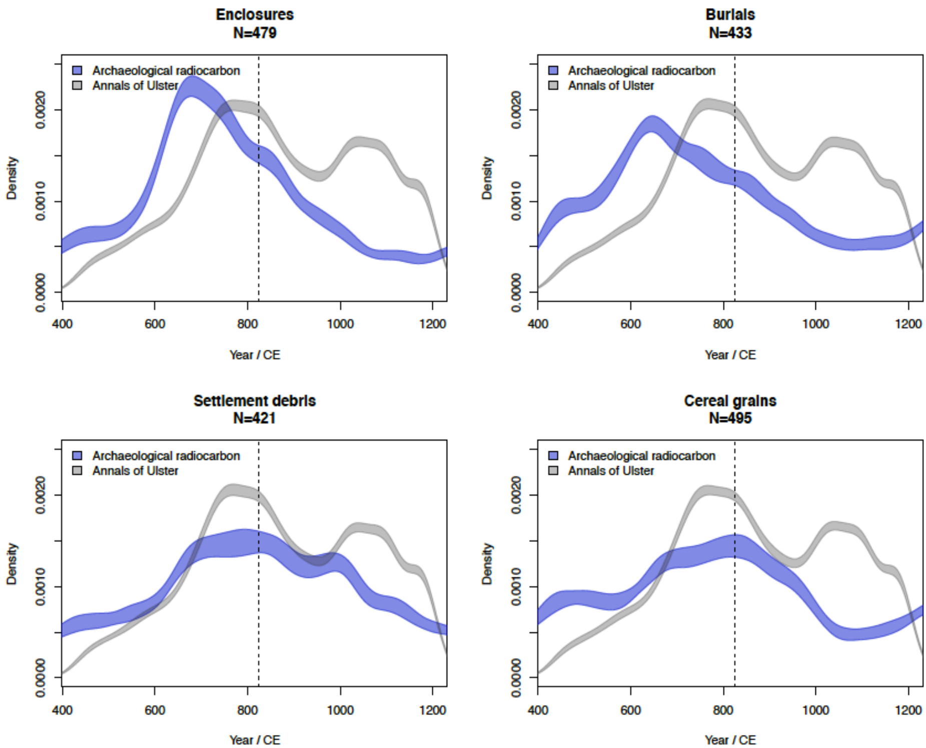

Figure 3. Comparison of archaeological radiocarbon density models from enclosures (ringforts and other kinds), human burials, settlement debris, and ecclesiastical sites.

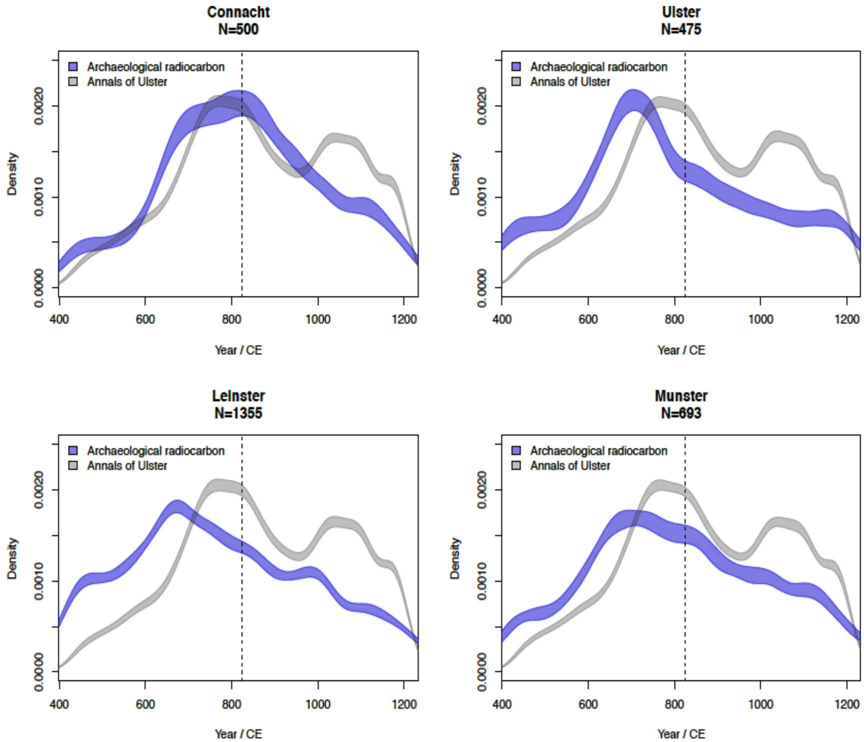

Figure 4. Comparison of archaeological radiocarbon density models from the four provinces of Ireland.

Further evidence for the strength of these patterns can be read in the archaeological data when we limit the analysis to individual provinces (Figure 4), although there are some significant differences between these too. The timing of peak activity level differs by region; for example in Leinster (the eastern province) radiocarbon activity increases most quickly, whereas in Connacht (the western province) there is a sustained high level of activity spanning 700 and 825 CE. As per the overall radiocarbon intensity across the island, this difference is caused mainly by regional variation in the intensity of burial activity and in ringfort construction and use. Although detailed cross examination of context and region is beyond the scope of this paper, the supplementary data may be analysed by readers curious about what may be driving these signals. We can however point out that in all cases, and in all regions, the 9th and 10th Centuries were a period of decline, irrespective of what aspect of the data is examined.

Table 1. Summary of trends in the datasets under analysis

Period	Annals	^{14}C (settlement)	^{14}C (cereal economy)	Other ^{14}C	Dendro-date
Up to 700 CE	Increase	Increase	Increase	Increase	Increase
Up to 825 CE	Stable	Stable	Stable	Decrease	Fluctuating
825 to 1000 CE	Decrease	Decrease	Decrease	Decrease	Decrease
1000 to 1200 CE	Fluctuating	Fluctuating	Fluctuating	Stable	Fluctuating

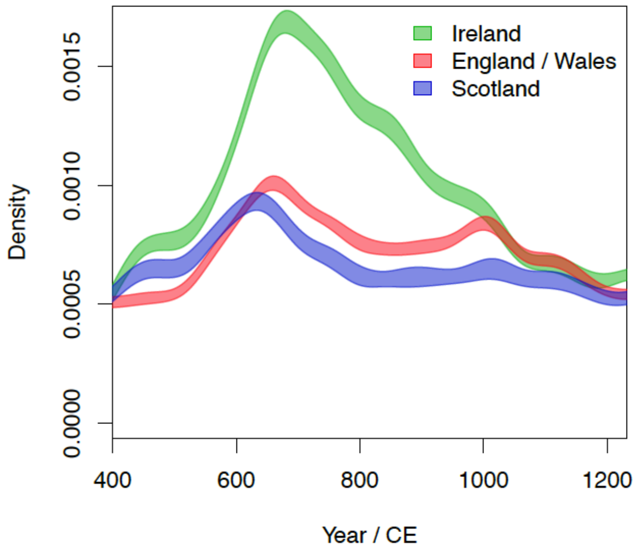

Figure 5. A comparison of KDE models of the early medieval archaeological-radiocarbon datasets from Ireland, England / Wales (Southern Britain), and Scotland (Northern Britain). KDEs for England / Wales (N=3926), and Scotland (N=1496) were calculated using data published by Bevan et al. (2017).

Comparing Ireland with Britain illustrates the uniqueness of the Irish patterns in activity across the wider region. In all three regions (Ireland, England / Wales, and Scotland; Figure 5), the radiocarbon evidence indicates that maximum activity occurred in the 7th Century. In Britain this seems to be caused by a large number of burials dating to around that time, although details on context are not available in the source dataset (Bevan et al. 2017), so exploring this further is beyond the scope of this paper. From the 9th Century, different trajectories were followed in Britain and Ireland: Britain was stable, indeed in southern Britain there was a small increase in activity, whereas Ireland saw decline.

Discussion

Limitations in the Data

Trends in the production rate of historical data are made difficult to interpret because little is known about what motivated the original authors of the *Annals of Ulster*, nor the true significance of the events they recorded. Similarly, the loss of some historical data and the embellishment or downright invention of much history renders it problematic when subjected to this kind of analysis. Trends in these data could simply be a signal of the circumstances under which the Annals were originally recorded then later recompiled—a 'quota' of events that the ancient historians felt inclined to meet, and this quota drifted with time, causing the patterns in the time series. Although little unequivocal information exists on how the annals were originally compiled, the sheer size of the dataset should be sufficient to average-out any factor that randomly affected each entry.

All archaeological data is inevitably subjected to random filtering, *i.e.*, the loss of sites from the landscape and the biased selection of others for excavation. However, we believe that the unprecedented size of the archaeological dataset from Ireland puts aside any fear that the data are biased towards any one point in time or space; the vast majority of the data discussed in this paper derive from small-scale sites discovered accidentally during modern-day development. It could be argued that there is a bias introduced by modern-day patterns of settlement and land use. Although it is true that this dictates where fieldwork has taken place, we would also point out that in the context of the current study, modern-day settlement patterns are not independent to those of early medieval Ireland. The major urban centres of Dublin, Cork, Limerick, and Waterford were founded in the 9th and 10th Centuries; the modern routeways between these places have been much explored by archaeologists, and much early medieval archaeology has been uncovered as a result (see Figure 1). The important point is that there is little difference in broad terms between trends in the archaeological data from parts of the landscape that have been intensively studied, and regions where research has been less intense.

Another important point is the issue of spurious calibration 'wiggles' in the radiocarbon data; it is simply not possible to distinguish certain short-term blips from calibration effects, although the use of the KDE goes a long way to remove this noise from the time series, and simulation can be used to verify the significance of the results (cf. Bronk Ramsey 2017; Contreras and Meadows 2014; Timpson et al. 2014).

The results indicate that the time-series produced though analysis of both the historical and archaeological data contain trends or 'autoregressive processes' whereby the activity level each year can generally be predicted based on average activity levels over previous years. Furthermore, the historical and archaeological time series share many characteristics, reaching local maxima and minima simultaneously and changing at similar rates, which suggests that there were relationships between their original causes. Counterbalancing this observation are other points in history where the two time series are out of step. However, given how well-expressed certain trends are in both historic and archaeological time series, especially how activity levels by 1000 CE are a fraction of what they were at 825 CE, we must now turn to face the difficult questions of why there are trends in these data, and their likely cause.

Climate as a Driving Force

Environmental and climate change is at face value an attractive explanation, and has been put forward as an explanation of economic change in Ireland in the 8th to 10th Centuries (e.g. McCormick 2015), but we would caution against its uncritical use. Throughout this period, hydroclimate proxy records indicate an overall trend of increasing wetness (Swindles et al. 2010), and there is a general indication that temperatures are cooler too—indeed the *Annals* themselves mention several extreme snowstorms in the 9th Century (Kerr et al. 2009). To investigate whether this impacted on activity levels in the landscape, we can turn to vegetation reconstruction using pollen analysis of sediment core samples taken from bogs and lakes (cf. Coyle-McClung 2013; Plunkett 2009). A recent review of 36 published pollen records from across Ireland covering this period gave contrasting results (Coyle-McClung 2012). At 19 sites, arable and pastoral agriculture expanded after ca. 800 CE on a scale not seen before (e.g. Hirons 1984; Heery 1998). Only three sites actually show a reduction in human activity while the rest remain unchanged. That said, sites where activity declines are quite widespread and pronounced, such as increasing scrub (birch and hazel) at sites in the north and west of Ireland (Hall et al., 1993; Huang 2002). Chique et al. (2017) record a break in cereal cultivation and a reduction in pastoral indicators surrounding Lough Muckno in county Monaghan dated to ca. 830 CE, which they attribute to disputes with the Vikings following the plundering of Muckno Monastery in 832 CE, as documented in the Annals.

If this seems promising, a useful illustration of the complexities of interpreting data of this kind is Mongan Bog, near the centre of Ireland. At this large wetland complex, conflicting pollen investigations have been made; Parkes and Mitchell (2000) have recorded increasing arable weeds and hence the expansion of farming, whereas Hall (2005) has identified a break in cereal pollen and a reduction in pastoral activity. As the bog's catchment is large, the two sets of records could in fact reflect a population movement from one area to another—and if such complexities exist within one system, how can broader changes in settlement patterns or agricultural intensity be disentangled? Palaeoevniromental work has much to contribute to our understanding of the scale of human impact in the landscape, and the consequences of social and demographic change, especially over the long term, and especially if we can restrain the discussion to the geographical and temporal bounds of the data. However, as a universal explanation of how human behaviour in particular is determined it is simply insufficient. We are reminded of Butzer's (2012: 2) warning that

> a primary fascination with climatic change and environmental degradation….[comes]…at the cost of less attention to the necessary cross disciplinary integration. Indeed, the recent return to environmentalism is not about a fresh interest in the environment–society interface, but a continuing failure to appreciate the complexity of such interrelationships.

With this in mind, other more intricate factors such as demographic and socio-economic trends and political turmoil must be taken into consideration as the catalysts for change.

Disease or Plague

Demographic change for example can be wrought by disease and famine. The Annals themselves quite frequently describe outbreaks of such events that led to loss of life on a large scale. As it happens, an entry for 825 CE reads:

> A great pestilence in the island of Ireland affected the old, the children and the weak; there was great famine and shortage of bread.

No such event is mentioned in *Annals of the Four Masters*, nor in the *Annales Cambriae*, so if there was a major disease and famine event around 825 CE, there seems to have been little subsequent historical awareness that it had significant consequences in terms of subsequent activity levels.

Political Instability

History portrays the 9th and 10th Centuries as a rather eventful time. In Britain, Scotland and England are attacked and settled to varying extents by Viking invaders. This began with sporadic attacks, which eventually led to more permanent attempts at settlement, followed by expulsions which, ultimately, led to a lasting return. Notably, in England, the East Midlands came to be known as the Danelaw, an area which was agreed to be settled and ruled under Scandinavian leadership. Against this backdrop, the unification of England took place, attributed to Æthalstan in 927 CE (James 2001). A similar pattern occurred in Ireland—attack, settlement, expulsion, and resettlement. Norse invaders were expelled from Dublin by the Irish in 902 CE but only for a short time before their return in 917 CE when the second phase of settlement began, and thereafter took off (Ó Cróinín 2017). There was also great political re-organisation related to the issue of High Kingship, which was an unsettled affair. Even by the 10th Century, there were still various claimants to the Kingship as well as a number of on-going and long-drawn hostilities between contenders for various local kingdoms too (e.g. Byrne 2005: 857). From modest origins, the church played an increasingly dominant role in early medieval society and by the 9th Century, it had amassed significant wealth, power and political influence (Hughes 2008). The principal monasteries, which were major economic centres and a focus of settlement in themselves, also became strongly associated with the ruling elite, and even became embroiled in warfare with each other as a result (Ó Corráin 2005).

The *Annals* mention these events, and some of this turmoil is probably represented in the time series data. Although few in number, around 920 CE there is a brief period of rather lengthy entries, typically accounts of battles between native Irish forces and Viking armies and often embellished with poetry and verse; for example at the Battle of Islandbridge in 919 CE:

> The heathens won a battle against the Irish at Duiblinn in which fell Niall Glúndub son of Aed, king of Ireland…. Where now are the princes of the western world / Where now the horror of every clang of arms / Since valiant Niall of Cnucha / Has brought desolation to his great cantred?

An important observation however concerns trends common to both historical and archaeological data—these began their decline *earlier* than the tumultuous events described by the historic sources. From certain perspectives, like the total sum of archaeological data, the decline begins in the late 7th Century, and by ca. 825 CE it can be observed across the various datasets.

Economic Change and the Confluence of Factors

In the absence of a plausible model derived solely from environmental or historical factors, we can suggest that the 9th and 10th Centuries in Ireland saw a general reduction in broadly construed sociocultural activity. Certain details of the archaeological record in Ireland bear this out. Kerr et al. (2009) argue that during the 8th and 9th Centuries there was an economic shift towards arable production, which could have focused activity upon certain points in the landscape—mills and other infrastructure—which were often associated with, or controlled by, ecclesiastic centres (Rynne 2009). Increased intensity could, paradoxically, lead to fewer archaeological sites, because for example provisioning growing towns requires a degree of organisation and co-operation in society in general, and therefore fewer randomly dispersed smaller-scale rural settlements. McCormick (2008) sees the economic shift as a move towards a surplus-based economy featuring significant amounts of trade. All this points to an on-going re-organising of society at some basic level. Add to this the political instability caused by 9th-/10th-Century wars with the Vikings, which could have driven down economic and agricultural productivity, because these events distracted from primary production. This may explain the apparently contradictory fact that the radiocarbon data from cereals found on early medieval sites, like virtually everything else, decline in frequency in the 9th Century (Figure 3).

There may be a simpler, demographic explanation for the observed trends that relates to human population levels. The relationship between radiocarbon dates and populations has been widely debated in prehistoric archaeology (e.g. Contreras and Meadows 2014; Shennan et al. 2013) and although there are undoubtedly many problems in assuming a simple relationship between the two, it is an attractive and parsimonious explanation of why we see declining activity in Ireland, especially in the 9th and 10th Centuries. Interestingly, recent analysis of the genetic structure of contemporary human populations in Ireland has revealed that there was a significant migration event in or throughout the 9th and 10th Centuries, leading to many Irish people today sharing genetic signatures of affinity with Scandinavian people (Byrne et al. 2018). In light of this, the declining activity seen in the annals and in the archaeological record could be interpreted as evidence that Viking settlement occurred when the indigenous Irish population was much reduced from an apogee centuries before. Irrespective of population level and the role of immigration, we can state with confidence that the geographic extent of human activity contracted during this period, leading to far fewer archaeological sites being occupied than before and fewer noteworthy activities being inscribed in the *Annals of Ulster*. The rate at which this occurred seems relatively rapid from the vantage point of today, but in terms of lived experience, change over the course of a 175 years would map onto eight or nine different human generations. A gradual change in circumstances over that time may not even have been noticed, despite it being of significant magnitude.

Conclusions

The relatively recent availability of large sets of archaeological data has led many archaeologists to develop their frequency distributions as models for past demographics or broad trends. In general terms, archaeological data tend to be the signal of human presence, relatively unbiased and broadly construed, in contrast to a common critique of history that it is concerned with the actions of élite groups and hence potentially blind to the truly significant forces that influenced the past and gave rise to the circumstances prevalent in the world today. In the case of early medieval Ireland, perhaps because of the underlying random nature of how the *Annals* were written, it seems that there could be new information embedded in the rate at which history was recorded. Discovering other cases where this idea is applicable will make for interesting future research.

Despite the limitations of the data, which we acknowledge, these observations are derived from significant datasets, each containing thousands of entries with an underlying stochastic structure. Each Viking battle, or each noble death recorded in the *Annals* makes no reference to an overarching metanarrative. Similarly, archaeological data derive mainly from the everyday remnants of settlement, and were buried in the ground and subsequently recovered accidentally. When random forces dominate day-to-day life, but nonetheless make manifest similar trends in the evidence, we cannot help but imbue them with a meaning that reflects on some level the dominant trends that shape the world. In the case of early medieval Ireland, the analysis has revealed a significant period of widespread reduction in cultural activity spanning at least 175 years, and this finding adds a significantly to our knowledge of the dynamics of the period.

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