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## **Traveling Monastic Paths: Mobility and Religion at Medieval Irish Monasteries**

Elise Alonzi, Niamh Daly, Gwyneth Gordon, Rachel E. Scott, Kelly Knudson

### **1. Introduction**

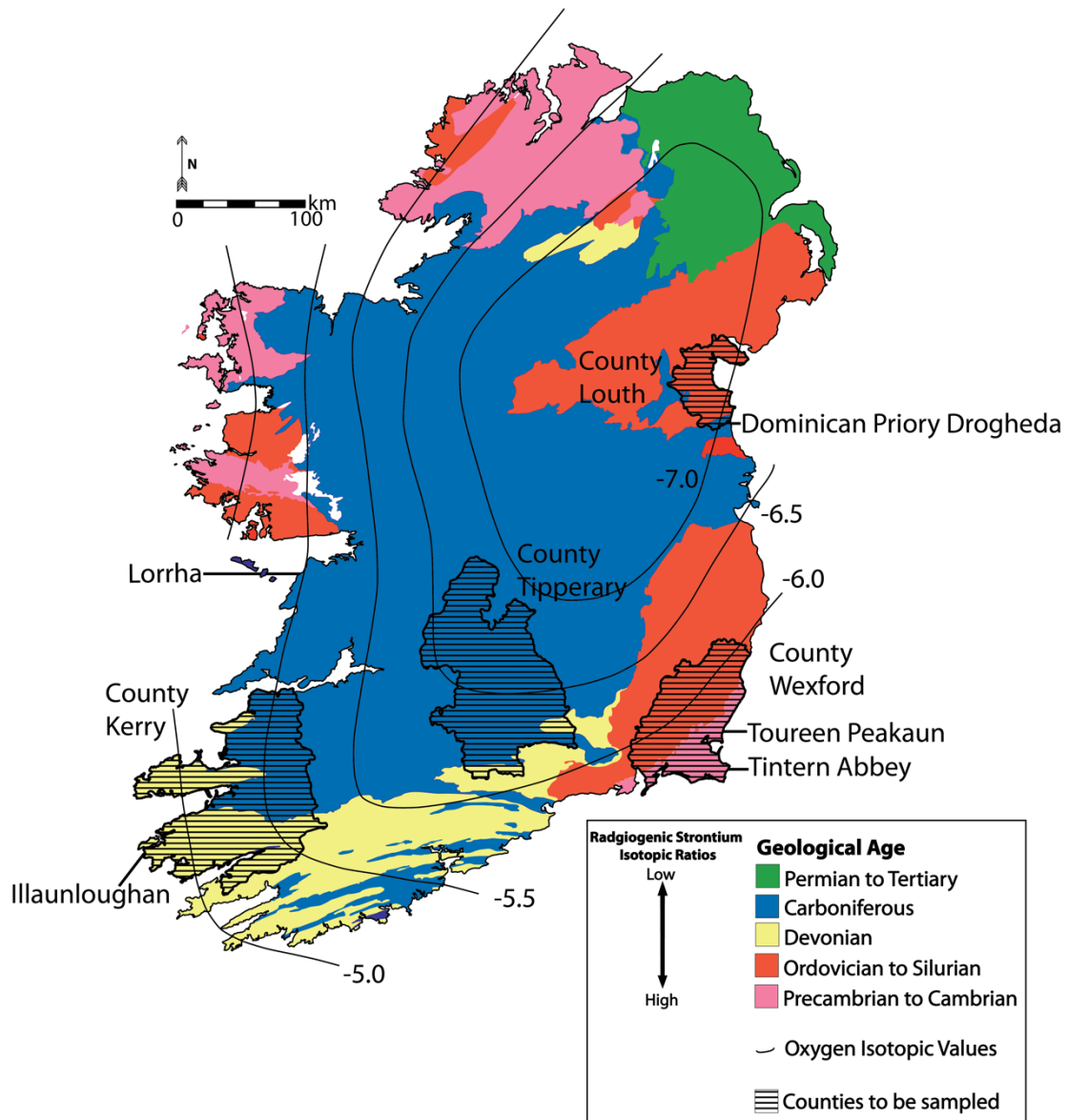
Travel is recorded as a notable event in the lives of many high-status Irish monks and nuns, and according to medieval Irish texts, they traveled extensively in continental Europe, Ireland, Scotland, Wales, and England to lead and found monastic communities (Charles-Edwards, 2000; Flechner and Meeder, 2016; Hughes, 1966; Johnston, 2016; Loveluck and O'Sullivan, 2016). In the early medieval period (5<sup>th</sup>-12<sup>th</sup> centuries AD), mobility is cited as part of the mechanism for spreading and popularizing Christian practice in a previously pagan society (d'Arcy, 1974; Hughes, 1966). In the late medieval period (12<sup>th</sup>-16<sup>th</sup> centuries AD), monastic orders from elsewhere in Europe, such as France and England, founded abbeys in Ireland (O'Keeffe, 2003; Stalley, 1987). Mobility is a mechanism that can introduce new cultural practices through relatively long and definitive moves between communities (Anthony, 1990; Baker and Tsuda, 2015; Burmeister, 2000; Tilly, 1978), and religious institutions are formed and changed by the cultural practices of the members who participated in the religion (Stark, 1996). However, medieval texts do not indicate how common it was for medieval Irish people to be mobile if they were not one of the venerated saints or part of the elite class, and it is unclear what role mobility truly played in the spread and practice of Christianity. Did people who lived monastic lives in medieval Ireland experience mobility differently than those in lay communities?

In this study, mobility in medieval Ireland is examined through the biogeochemical analysis of eighty-eight individuals who were buried at five early and late medieval (8<sup>th</sup>-16<sup>th</sup> centuries AD) Irish ecclesiastical and monastic sites to elucidate to what extent mobility was practiced by medieval Irish people (see Figure 1). These sites include: Illaunloughan, Co.

Kerry; Toureen Peakaun, Co. Tipperary; Lorrha, Co. Tipperary; Tintern Abbey, Co.

Wexford; and Dominican Priory, Drogheda, Co. Louth. This paper addresses the following questions: (1) How did the patterns of mobility for lay and religious people compare between the early and late medieval period? and (2) How frequently did ecclesiastical people move away from their natal communities to live at a monastery? Archaeological context is used to estimate which individuals were likely members of the religious and lay communities, and rates of mobility in these groups are compared to add to the narrative of the development and practice of Christianity in medieval Ireland. This study will supply a better understanding of the lived experience of medieval Irish monasticism and will further develop the contextualization of monasticism within everyday life in medieval Ireland.

**Figure 1.** Map of  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}_{\text{D-VSMOW}}$  distributions, site locations, and counties sampled for the bioavailable radiogenic strontium isotope baseline (Darling 2003; Geological Society of Ireland 2017).



## 2. Early and late medieval monasticism in Ireland

### 2.1. *Early and late medieval Ireland: An introduction*

Early (5<sup>th</sup>-12<sup>th</sup> centuries AD) and late (12<sup>th</sup>-16<sup>th</sup> centuries AD) medieval Ireland are distinct time periods during which Irish culture changed politically, socially, and religiously. Ireland was divided into over one hundred chiefdoms of kingdoms, or *túatha*, during the early medieval period (Jaski, 2000; Kelly, 1988; Wailes, 1995). Christianity was introduced by missionaries from the continent and Britain in the fifth century, and the elite invested in ecclesiastical buildings and monastic communities in part to bolster their political influence (d'Arcy, 1974; Manning, 1995; Ó Carragáin, 2011). Scholarship flourished as law tracts, religious texts, and poetry were written in monastic, ecclesiastical, and secular contexts (Duncan, 2016; Kelly, 1988:232-236; Stout, 2017:93). Around the ninth century, Vikings began raiding Irish monasteries and starting colonies in Ireland such as Dublin (Barrett, 2003; Etchingham, 1996, 2001; Knudson et al., 2012). During the early medieval period, institutionalized power in the form of kingdoms and the Church became more prevalent in Ireland than it had been in the preceding Iron Age (Kelly, 1988).

The Anglo-Normans arrived in Ireland in AD 1169, beginning the late medieval period (Barry, 1987; Otway-Ruthven, 1968). Smaller kingdoms were consolidated into larger territories and provinces, and continental monastic orders, such as the Dominicans and Cistercians, founded monastic houses in Ireland (Barry, 1987; O'Keeffe, 2003; Otway-Ruthven, 1968; Potterton, 2005). During this period, Ireland became more politically connected to England, and families who claimed origins outside of Ireland owned significant areas of land (Otway-Ruthven, 1968). Late medieval Ireland differs from early medieval

Ireland in the increase of formalized political, social, and religious ties to groups outside of the island of Ireland.

Life in medieval Ireland can be examined through archaeological data, and much information about medieval Ireland is recorded in contemporary texts. These include annals which were typically written at ecclesiastical sites (Hennessy, 1871; Mac Airt and Mac Niocaill, 1983; Manning, 2000; McCarthy, 2008; O'Donovan, 1851; Warner, 1990), narratives of saints' lives called hagiographies (Campbell, 1968; Edwards, 2002; Sharpe, 1991, 1995), and law texts (Kelly, 1988, 1997). These texts are useful sources, but they often portray the idealized lives of the elite rather than the daily experiences of average people living in medieval Ireland. Also, these texts were influenced by the political and religious contexts of the authors, who were members of monasteries that held elite places in society that relied on the economic and political support of secular patrons (Johnston, 2013:95). For instance, the text of the Life of St. Brigit was used by Cogitosus to assert the dominance of the church in Kildare by suggesting that the Kildare church was part of a *paruchia* that spread throughout Ireland (Stout, 2017:73).

### **3. Christianity in early and late medieval Ireland**

Beginning in the early medieval period, Christianity rose to prominence in Ireland. In AD 431, Palladius was sent from Rome as a missionary, in response to the beginning of the conversion of Ireland that was subsequently continued by St. Patrick and others (Charles-Edwards, 2000; d'Arcy, 1974; Manning, 1995). A distinctly Irish version of Christianity began to develop, which over time caused differences in the practices undertaken by medieval Irish people and the doctrines promoted by the Church in Rome (d'Arcy, 1974;

Edwards, 1990; Manning, 1995; Ó Carragáin, 2011). These differences included issues such as the date of Easter and differences in monastic practices (Campbell, 1968; Ó Cróinín, 1982; O'Hagan, 2012).

Early medieval Irish monasteries often followed ascetic doctrines, which emphasized withdrawing from society to follow austere ways of life. Some of these communities were influenced by the practices of St. Anthony, who founded a community of ascetic monks in the Egyptian desert (Bitel, 1994; Follett, 2006; Rousseau, 1978). Often these solitude-seeking communities or individual hermits sought out harsh and isolated locals such as island in the Atlantic and sparsely inhabited areas (Ó Carragáin, 2013). Other monasteries, known as *civitas*, were founded in populous areas and ministered to the community of lay people (Bolger and Moloney, 2012, 2014; Charles-Edwards, 2000:119; Valante, 1998). Saints' lives suggest that some powerful saints founded several monasteries across Ireland and Scotland that were allied as *paruchia* or federations of monasteries (Charles-Edwards, 2000; Hughes, 1966:63; Ó Carragáin, 2011:9). For instance, the influential St. Columba, who is also known as Colum Cille, is reported to have founded monasteries in modern day Scotland, Northern Ireland, and the Republic of Ireland (Sharpe, 1995; Valante, 1998:6). However, the monastic *paruchia* may not have had as important a role in religious practice as it was suggested in these texts (Etchingham, 1993). These texts form a valuable starting place for inquiries about everyday life at a monastery, but they do not shed light on how the average monk or nun might have experienced mobility.

The Church in Ireland underwent significant changes in the eleventh and twelfth centuries. At the Synod of Ráth Breasil in AD 1111, regional dioceses were formed in an attempt to change the previously close relationship between the Church and the regional secular leaders (Hughes, 1966:258). This reorganization opened up the opportunity for monastic orders from the Continent and England to found Irish monasteries, which were

much larger and more formalized than the early medieval monasteries (Stalley, 1987). By the beginning of the twelfth century, Cistercian, Augustinian, Dominican, Benedictine, and other orders had founded monasteries in Ireland (Burton, 1994; Flynn, 1993; Hughes, 1966). These were often located in resource-rich areas on land granted by wealthy families or in the center of large towns. Politically powerful donors, some of whom were Anglo-Norman, socially and monetarily supported these monasteries (Potterton, 2005; Stalley, 1987). Non-wealthy people may have been excluded from some areas of religious practice, as the late medieval monastic communities were arranged hierarchically from lay brothers who were essentially agricultural workers, to the academically trained choir monks, to the powerful abbot (Hughes, 1966; Stalley, 1987). The system of Continental monastic orders and regional dioceses was in place until Henry VIII dissolved the monasteries in the sixteenth century (Ellis, 1990; Stalley, 1987). At this point the monastic buildings were sold to wealthy families and converted to domestic residences or demolished to be used as quarries (Lynch, 2010; Potterton, 2005; Stout and Stout, 2016).

#### **4. Archaeological studies employing isotope methods in Ireland**

Biogeochemical methods have been used to understand mobility in several medieval Irish contexts. Knudson et al. (2012) analyzed individuals buried in Viking Dublin (10<sup>th</sup>-13<sup>th</sup> centuries AD). The data indicate that the majority of the study population likely originated from near the burial site, although some may have moved to the area later in life (Knudson et al., 2012:317). Based on oxygen isotopic values ( $\delta^{18}\text{O}$ ), Cahill Wilson and Standish (2016) suggest that several of the twenty-seven individuals dating from the fourth to seventh centuries AD who were buried at sites in eastern Ireland were of non-local origin. Two

individuals buried at the early medieval monastery on High Island, Co. Galway were analyzed, and at least one appears to be non-local based on its  $\delta^{18}\text{O}$  (Cahill-Willson et al., 2014). However, large scale biogeochemical analyses of individuals buried at early and late medieval monastic sites in Ireland have not been attempted until this project.

## 5. Sites included in this study

*Illaunloughan, Co. Kerry (4 individuals, see Figure 1 and Tables 1 and 2):*

Illaunloughan is an island that lies between Valencia Island and the Iveragh Peninsula in County Kerry. The architectural remains on the island include a drystone oratory, several beehive huts known as *clóchans*, and a reliquary shrine (Marshall and Walsh, 2005). A monastic community was founded on this small island in the mid-seventh century, and it was likely a proprietary site that was run by and passed down within a family (Marshall and Walsh, 2005; Mytum, 1992; Ó Carragáin, 2003b). Of the seventeen individuals who were buried on Illaunloughan during the early medieval monastic phase, three were juveniles, twelve were adult males, sex could be identified for two individuals (Buckley, 2005:3). This has been interpreted as evidence for fosterage at the monastery (Buckley, 2005; Marshall and Walsh, 2005). The burials analyzed in this study were excavated from the area around the drystone oratory on the eastern end of the island. The island was used for burial after the monastic community had dissolved in the late ninth century, and one burial tested here is from the later phase (Marshall and Walsh, 2005).

*Toureen Peakaun, Co. Tipperary (8 individuals, see Figure 1 and Tables 1 and 2):*

This monastic site was founded in the Glen of Aherlow in County Tipperary by St. Abban in the mid seventh century, and it is named after St. Béccán, who is recorded as the monastery's

first abbot by the *Annals of Ulster* and the *Annals of Inishfallen* (Charles-Edwards, 2002; Mac Airt and Mac Niocaill, 1983; Ó Carragáin, 2016). A twelfth century church is extant on the site, but excavations have revealed that this may have been preceded by an earlier church building (Ó Carragáin, 2016). Also, excavations have revealed a possible hermitage area adjacent to the monastic site that appears to be built in the middle of a stream or small waterway (Ó Carragáin, 2016). The site is notable for housing a large engraved high cross and around thirty early medieval inscribed stones, many that appear to be grave markers inscribed with names. The individuals buried at this monastery compose two early medieval burial phases, and some may have Anglo-Saxon ties (Ó Donnabháin and Ní Mhurchadha, 2010). One stone appears to be “signed” by an artisan with an Anglo-Saxon name (Charles-Edwards, 2002:118), and St. Béccán was one of those addressed in a letter from St. Cummian, an Anglo-Saxon saint who was supported the Roman Church’s date for Easter over the Celtic Church’s date of Easter in the famous Easter Controversy (Ó Cróinín, 1982; O’Hagan, 2012).

*St. Ruadhán’s Church, Lorrha, Co. Tipperary (10 individuals, see Figure 1 and Tables 1 and 2):* The monastic site at Lorrha was likely founded in the sixth century AD, based on annalistic evidence for St. Ruadhán and archaeological excavations of the ecclesiastical enclosure (Bolger and Moloney, 2012, 2014; Linnane, 2002). In the early medieval period, the *Annals of Inishfallen* and the *Annals of Ulster* record both bishops and abbots at Lorrha, which suggests that it had both ecclesiastical and monastic functions (Bolger and Moloney, 2012: 113). Lorrha had links with the ascetic and fundamentalist Céili Dé movement, and the associated text known as the Stowe Missal was held at Lorrha from about the eleventh to fourteenth centuries AD (Bolger and Moloney, 2012; Follett, 2006). After the reorganization in the twelfth century at the Synod of Ráth Breasil, Lorrha lost its status as an episcopal center and was part of the Killaloe diocese (Bolger et al., 2012: 115).

Around this time, Augustinian monastic rule was adopted at the site, and a larger Augustinian priory was built within the original ecclesiastical enclosure (Bolger et al., 2012:113). The individuals included in this study were buried to the west of the western wall of the eleventh century stone church, and their dates of burial span the early and late medieval periods (Bolger and Moloney, 2012; Ó Carragáin, 2011). Other architectural remains at the site include two carved high crosses (8<sup>th</sup>-9<sup>th</sup> century AD) and the fifteenth century priory (Bolger and Moloney, 2012).

*Tintern Abbey, Co. Wexford (24 individuals, see Figure 1 and Tables 1 and 2):* This abbey was founded around AD 1200, when William Marshall, the Earl of Pembroke, survived a shipwreck on the southern coast of Ireland and vowed to found a monastery in thanks (Lynch, 2010:3). Monks from Tintern Abbey in Wales traveled to the newly founded monastery to populate it, and both monasteries were in the Cistercian order, which originated in France (Lynch, 2010:4). The monastic house remains largely intact today, as it was given to the Colclough family after its dissolution in 1536, who lived there until 1959 (Lynch, 2010:9). The burials in this study were excavated from within the monastic church, including the nave, chancel, transept, ambulatory, and chapel the churchyard (Lynch, 2010:39).

*Dominican Priory Drogheda, Co. Louth (42 individuals, see Figure 1 and Tables 1 and 2):* This priory was likely founded in AD 1224 (Bradley, 1978; Halpin and Buckley, 1995). It was a high-status monastic house, as two Archbishops of Armagh were buried at the site during the twelfth century, but it had largely fallen into ruin before the monastery was dissolved by King Henry VIII in AD 1540 (Bradley, 1978; Halpin and Buckley, 1995). There are few standing remains of the monastery, consisting only of a bell tower. The individuals in this study were buried in the churchyard during the late medieval period (12<sup>th</sup>-14<sup>th</sup> century AD) based on radiocarbon dating and artifactual evidence (Halpin and Buckley, 1995:193). One area of the site housed mainly male burials, perhaps belonging to members of the

Dominican religious community, while another part of the site has a sex distribution indicative of the lay community (Halpin and Buckley, 1995:193).

Table 1. Contextual Information, Elemental Concentration, and Isotope Data for Human Samples. Time periods are early medieval (EM) or late medieval (LM).

Laboratory Number	Specimen Number	Site	Age	Sex	Time Period	Ecclesi-astical (E) or Lay (L)	Skeletal Element	Ca/P	U/Ca	Sr (ppm)	$^{87}\text{Sr}/^{86}\text{Sr}$	$d^{18}\text{O}_{\text{VPDB}}$	$d^{18}\text{O}_{\text{dw}}$ [VSMOW]
ACL-8597	IRE-TP-0519	Toureen Peakaun	Younger adult	Probable male	EM	L	M1	1.9	1.63E-07	88	0.71067	-4.3	-6.7
ACL-8598	IRE-TP-0519						M3	1.9	1.22E-08	47	0.71063	-3.8	-6.1
ACL-8599	IRE-TP-0596	Toureen Peakaun	Younger or middle age adult	NA	EM	E	M1	1.9	1.64E-07	69	0.71002	-3.6	-5.8
ACL-8600	IRE-TP-0596						M3	1.9	1.31E-07	58	0.71014	-4.3	-6.8
ACL-8601	IRE-TP-0596						Femur	1.9	1.39E-05	86	0.71091	-4.2	-6.6
ACL-8602	IRE-TP-0417	Toureen Peakaun	Young adult	Female	LM	L	M1	2.0	1.96E-07	144	0.70934	-4.3	-6.7
ACL-8603	IRE-TP-0417						M3	1.9	5.20E-08	115	0.71095	-3.6	-5.8
ACL-8604	IRE-TP-0417						Femur	1.9	1.17E-05	78	0.71065	-6.9	-10.1
ACL-8605	IRE-TP-0494	Toureen Peakaun	Middle adult	Male	LM	L	M1	1.9	3.60E-07	72	0.70874	-2.5	-4.4
ACL-8606	IRE-TP-0494						M3	1.9	1.86E-07	63	0.70892	-5.5	-8.3
ACL-8607	IRE-TP-0494						Ribs	2.0	3.48E-05	80	0.71011	-5.4	-8.2
ACL-8608	IRE-TP-0421	Toureen Peakaun	Middle or older adult	Male	EM	L	M1	1.9	2.06E-07	92	0.71070	-4.7	-7.3
ACL-8609	IRE-TP-0421						Humerus	2.0	1.93E-05	130	0.71035	-8.1	-11.6
ACL-8610	IRE-TP-0384	Toureen Peakaun	Young adult	Female	LM	L	M1	1.9	1.28E-07	50	0.71003	-5.0	-7.6
ACL-8611	IRE-TP-0384						Ribs	2.0	2.66E-05	96	0.70998	-5.0	-7.6
ACL-8612	IRE-TP-0368	Toureen Peakaun	Adult	Male	LM	L	Femur	2.0	2.32E-05	96	0.71055	-6.7	-9.8
ACL-8613	IRE-TP-0490	Toureen Peakaun	14-16 yrs	Male	LM	L	M1	2.0	1.01E-08	150	0.71029	-6.3	-9.3
ACL-8614	IRE-TP-0490						M3	1.9	2.65E-08	82	0.71016	-6.0	-9.0
ACL-8615	IRE-TP-0490						Ribs	2.0	1.82E-05	133	0.71091	-5.6	-8.4
ACL-8616	IRE-TA-53	Tintern Abbey	Adult	Male or probable male	LM	E	M1	1.9	6.00E-07	159	0.70979	-4.7	-7.2
ACL-8617	IRE-TA-53						M3	2.0	3.96E-08	307	0.70976	-5.5	-8.3
ACL-8618	IRE-TA-53						Rib	2.0	2.88E-05	376	0.70963	-4.9	-7.5
ACL-8619	IRE-TA-54	Tintern Abbey	Adult	Female	LM	E	M1	1.9	5.47E-08	96	0.71107	-4.9	-7.5

ACL-8620	IRE-TA-54						M3	1.9	3.34E-08	100	0.71126	-3.6	-5.8
ACL-8621	IRE-TA-54						Rib	2.0	3.16E-05	268	0.70953	-5.0	-7.6
ACL-8622	IRE-TA-58	Tintern Abbey	Adult	Male or probable male	LM	E	Rib	2.0	4.11E-05	202	0.70972	-5.2	-7.9
ACL-8623	IRE-TA-59	Tintern Abbey	Adult	Male or probable male	LM	E	M1	1.9	3.44E-08	124	0.71019	-3.0	-5.1
ACL-8624	IRE-TA-59						M3	2.0	4.74E-08	281	0.71008	-5.8	-8.7
ACL-8625	IRE-TA-59						Rib	2.0	6.50E-05	441	0.70961	-5.9	-8.9
ACL-8626	IRE-TA-60	Tintern Abbey	Adult	Male or probable male	LM	E	M1	2.0	9.45E-08	295	0.71161	-6.1	-9.1
ACL-8627	IRE-TA-60						Rib	2.0	4.37E-05	385	0.70969	-6.0	-9.0
ACL-8628	IRE-TA-62	Tintern Abbey	Adult	Male or probable male	LM	E	Rib	2.0	3.20E-05	540	0.70966	-5.5	-8.2
ACL-8629	IRE-TA-48	Tintern Abbey	Younger adult	Male	LM	L	M1	2.0	1.29E-06	369	0.71048	-4.6	-7.1
ACL-8630	IRE-TA-48						Rib	2.0	1.77E-05	399	0.70974	-4.8	-7.4
ACL-8631	IRE-TA-26	Tintern Abbey		Female	LM	L	M1	2.0	2.07E-07	204	0.71013	-6.2	-9.2
ACL-8632	IRE-TA-26						M3	2.0	1.83E-07	329	0.70979	-6.6	-9.7
ACL-8633	IRE-TA-26						Rib	2.0	4.91E-05	604	0.70974	-5.0	-7.7
ACL-8634	IRE-TA-4	Tintern Abbey	Adult	Female	LM	L	Rib	2.0	9.87E-05	304	0.70986	-5.4	-8.2
ACL-8635	IRE-TA-36	Tintern Abbey	Younger or middle adult	Female	LM	L	Rib	2.1	3.11E-05	166	0.70951	-5.0	-7.7
ACL-8636	IRE-TA-85	Tintern Abbey	Adult	Male	LM	E	Long bone	2.1	2.01E-05	301	0.70970	-5.3	-8.0
ACL-8637	IRE-TA-89	Tintern Abbey	Adult	Male	LM	E	Rib	2.1	3.63E-06	337	0.71000	-5.5	-8.3
ACL-8638	IRE-TA-42	Tintern Abbey	Middle adult	Male	LM	L	M1	2.0	1.54E-07	295	0.71003	-5.1	-7.7
ACL-8639	IRE-TA-42						M3	1.9	2.07E-07	337	0.70998	-3.4	-5.6
ACL-8640	IRE-TA-42						Long bone	2.1	2.30E-05	664	0.70945	-4.9	-7.5
ACL-8641	IRE-TA-90	Tintern Abbey	Older adult	Male	LM	E	Rib	2.0	3.21E-05	631	0.70966	-5.6	-8.4
ACL-8642	IRE-TA-41	Tintern Abbey	Younger adult	Female	LM	L	M1	2.0	7.84E-08	123	0.71026	-5.0	-7.7
ACL-8643	IRE-TA-41						M3	2.0	6.51E-07	151	0.71043	-4.5	-7.0
ACL-8644	IRE-TA-41						Rib	2.0	4.66E-05		0.70986	-5.7	-8.6
ACL-8645	IRE-TA-12	Tintern Abbey	Middle adult	Female	LM	L	M1	2.0	2.55E-07	298	0.70984	-4.0	-6.4
ACL-8646	IRE-TA-12						M3	2.0	2.48E-07	352	0.70984	-4.6	-7.1
ACL-8647	IRE-TA-12						Rib	2.0	3.23E-05	195	0.70994	0.7	-0.2
ACL-8648	IRE-TA-5	Tintern Abbey	Adult	Male	LM	L	Rib	2.0	5.19E-05	266	0.70958	-5.2	-7.9
ACL-8649	IRE-TA-76	Tintern Abbey	Adult	Male	LM	L	M1	2.0	2.22E-07	223	0.70970	-5.6	-8.4
ACL-8650	IRE-TA-76						M3	2.0	1.90E-07	267	0.71012	-4.7	-7.2
ACL-8651	IRE-TA-76						Rib	2.0	5.25E-05	403	0.70977	-6.0	-8.9
ACL-8652	IRE-TA-93	Tintern Abbey	Adult	Male	LM	L	M3	2.0	6.07E-07	127	0.71059	-5.1	-7.8
ACL-8653	IRE-TA-93						Long bone	2.0	1.00E-05	325	0.70985	-4.7	-7.2
ACL-8654	IRE-TA-13	Tintern Abbey	Adult	Male	LM	L	M3	2.0	1.13E-07	96	0.71029	-5.9	-8.8
ACL-8655	IRE-TA-13						Rib	2.0	3.86E-05	396	0.70990	-6.9	-10.2
ACL-8656	IRE-TA-40	Tintern Abbey	Younger adult	Male	LM	L	Long bone	2.1	6.75E-05	732	0.70959	-6.5	-9.6
ACL-8657	IRE-TA-87	Tintern Abbey	Younger adult	NA	LM	L	M1	1.9	2.36E-08	151	0.71047	-4.3	-6.8

ACL-8658	IRE-TA-87						M3	2.0	3.71E-08	203	0.71031	-4.0	-6.4
ACL-8659	IRE-TA-87						Rib	2.0	3.00E-05	338	0.70934	-5.6	-8.5
ACL-8660	IRE-TA-47a	Tintern Abbey	NA	NA	LM	L	M1	2.0	5.67E-08	195	0.71091	-6.8	-10.0
ACL-8661	IRE-TA-47a						M3	2.0	2.99E-07	156	0.71053	-5.1	-7.7
ACL-8662	IRE-TA-47a						Long bone	2.1	3.51E-05	599	0.70980	-6.3	-9.3
ACL-8663	IRE-TA-F61	Tintern Abbey	NA	NA	LM	L	M3	2.0	1.17E-07	334	0.70998	-6.2	-9.1
ACL-8664	IRE-TA-F61						Rib	2.0	7.18E-05	499	0.70975	-7.2	-10.5
ACL-8665	IRE-IL-180	Illauloughan	Adult?	Male	EM	E	Rib	2.0	6.18E-07	549	0.70930	-6.6	-9.8
ACL-8666	IRE-IL-106	Illauloughan	Young adult	Female	LM	L	M1	2.0	3.73E-08	237	0.70972	-6.0	-8.9
ACL-8667	IRE-IL-106						M3	2.0	9.55E-08	567	0.70944	-5.7	-8.6
ACL-8668	IRE-IL-120	Illauloughan	Older adult	Male	EM	E	Rib	1.9	2.51E04	161	0.70927	-5.6	-8.4
ACL-8669	IRE-IL-172	Illauloughan	Juvenile 5-7 years	NA	EM	E	M1	2.0	2.40E-08	292	0.70933	-6.3	-9.3
ACL-8670	IRE-IL-172						M1 Decid.	2.0	1.04E-07	443	0.70933		
ACL-8671	IRE-LR-7	Lorrha	25-35	Female	LM	L	M1	2.0	9.53E-08	137	0.70857	-5.3	-8.0
ACL-8672	IRE-LR-7						Rib	2.1	1.71E-05	374	0.70824	-4.3	-6.8
ACL-8673	IRE-LR-48	Lorrha	40-45	Male or probable male	LM	L	Rib	2.0	1.43E-05	291	0.70826	-9.0	-12.8
ACL-8674	IRE-LR-37	Lorrha	60+	Female		L	M1	2.0	1.20E-08	116	0.70827	-6.0	-9.0
ACL-8675	IRE-LR-37						Rib	2.0	1.83E-05	209	0.70827	-7.3	-10.6
ACL-8676	IRE-LR-26	Lorrha	Preadult, 7-8	NA	LM	L	M1	2.0	2.33E-08	47	0.70873	-5.4	-8.2
ACL-8677	IRE-LR-26						Rib	2.0	1.76E-05	337	0.70828	-6.5	-9.6
ACL-8678	IRE-LR-3	Lorrha	16-20	NA	LM	L	M1	1.9	1.71E-08	128	0.70841	-7.2	-10.4
ACL-8679	IRE-LR-3						M3	2.0	3.55E-08	182	0.70843	-8.3	-12.0
ACL-8680	IRE-LR-3						Rib	2.1	1.06E-05	487	0.70823	-7.1	-10.3
ACL-8681	IRE-LR-34	Lorrha	Preadult, 5-6	NA	LM	L	Long bone	2.2	1.16E-05	520	0.70819	-5.7	-8.6
ACL-8682	IRE-LR-25	Lorrha	Preadult, 9-10	NA	LM	L	Rib	2.1	1.91E-05	371	0.70823	NA	-8.3
ACL-8683	IRE-LR-22	Lorrha	35-45	Female	LM	L	M1	2.0	6.74E-08	86	0.70908	-5.5	-10.1
ACL-8684	IRE-LR-22						M3	2.0	6.03E-08	65	0.70905	-6.9	-9.4
ACL-8685	IRE-LR-22						Rib	2.1	1.52E-05	439	0.70821	-6.4	-8.5
ACL-8686	IRE-LR-29	Lorrha	25-35	Male	LM	L	M1	2.0	5.74E-08	226	0.71249	-5.6	-9.1
ACL-8687	IRE-LR-29						M3	2.0	4.98E-08	370	0.71251	-6.2	-8.6
ACL-8688	IRE-LR-29						Rib	2.0	2.50E-05	262	0.70827	-5.8	-8.8
ACL-8689	IRE-LR-44	Lorrha	35-45	Male	LM	L	Long bone	2.1	1.67E-05	316	0.70967	-5.9	-6.9
ACL-8690	IRE-DPD-50	Dominican Priory Drogheda	Older Adult	Male	LM	E	M1	2.1	3.66E-07	238	0.70972	-4.4	-8.7
ACL-8691	IRE-DPD-50						Rib	2.1	8.29E-06	185	0.70973	-5.8	-6.9
ACL-8692	IRE-DPD-42	Dominican Priory Drogheda	Older Adult	Male	LM	L	M1	2.0	4.16E-07	201	0.70990	-4.4	-7.6
ACL-8693	IRE-DPD-42						M3	2.0	2.57E-07	273	0.70984	-5	-8.4
ACL-8694	IRE-DPD-40B	Dominican Priory Drogheda	Adult	Male	LM	L	Long bone	2.1	4.64E-05	313	0.71104	-5.6	-8.0
ACL-8695	IRE-DPD-2005	Dominican Priory Drogheda	NA	NA	LM	L	M1	2.0	3.20E-08	140	0.71010	-5.3	-9.2
ACL-8696	IRE-DPD-2005						M3	2.0	6.04E-08	120	0.70992	-6.2	-7.7

ACL-8697	IRE-DPD-2005						Long bone	2.1	1.45E-05	386	0.70959	-5.1	-8.7
ACL-8698	IRE-DPD-39	Dominican Priory Drogheda	Juvenile, 2-4 years	NA	LM	L	Rib	2.0	1.42E-04	221	0.70964	-5.9	-9.0
ACL-8699	IRE-DPD-18	Dominican Priory Drogheda	Adult?	Male?	LM	L	Long bone	2.1	7.59E-06		0.70918	-6.1	-9.0
ACL-8700	IRE-DPD-60	Dominican Priory Drogheda	Adult	Female	LM	L	Long bone	2.1	4.34E-05	275	0.71009	-6.0	-8.6
ACL-8701	IRE-DPD-41	Dominican Priory Drogheda	Adult	Female	LM	L	Long bone	2.1	2.42E-05	387	0.70999	-5.8	-8.3
ACL-8702	IRE-DPD-53	Dominican Priory Drogheda	NA	NA	LM	E	Rib	2.1	4.72E-05	320	0.71008	-5.5	-8.3
ACL-8703	IRE-DPD-47	Dominican Priory Drogheda	Juvenile, 6-8 years	NA	LM	L	Long bone	2.1	2.65E-05	423	0.70973	-5.5	-6.8
ACL-8704	IRE-DPD-24	Dominican Priory Drogheda	NA	NA	LM	L	M1	2.0	1.74E-07	112	0.70944	-4.3	-8.0
ACL-8705	IRE-DPD-24						M3	2.0	1.23E-07	141	0.70944	-5.3	-8.3
ACL-8706	IRE-DPD-19	Dominican Priory Drogheda	Juvenile, 11-13 years	NA	LM	L	M3	2.0	1.17E-07	224	0.71095	-5.5	-9.2
ACL-8707	IRE-DPD-19						Long bone	2.1	2.39E-05	263	0.70979	-6.2	-8.5
ACL-8708	IRE-DPD-25	Dominican Priory Drogheda	Adult	Probable Female	LM	L	M1	2.0	2.18E-08	115	0.71048	-5.7	-9.0
ACL-8709	IRE-DPD-25						M3	2.0	2.02E-08	251	0.71007	-6.0	-8.0
ACL-8710	IRE-DPD-27	Dominican Priory Drogheda	Adult	Male	LM	L	M1	2.0	2.18E-07	276	0.70985	-5.3	-9.8
ACL-8711	IRE-DPD-27						M3	2.1	4.89E-07	259	0.71007	-6.7	-9.1
ACL-8712	IRE-DPD-27						Rib	2.1	1.63E-05	478	0.70968	-6.1	-9.5
ACL-8713	IRE-DPD-38	Dominican Priory Drogheda	Adult	Female	LM	L	Rib	2.0	2.05E-05	317	0.70985	-6.4	-8.4
ACL-8714	IRE-DPD-40A	Dominican Priory Drogheda	Middle-aged Adult	Female	LM	L	M1	2.0	3.55E-07	97	0.70899	-5.6	-10.1
ACL-8715	IRE-DPD-40A						M3	2.0	3.59E-07	113	0.70896	-6.9	-8.8
ACL-8716	IRE-DPD-40A						Rib	2.1	3.54E-05	311	0.70961	-5.9	-9.2
ACL-8717	IRE-DPD-61	Dominican Priory Drogheda	Middle-aged adult	Male	LM	L	Rib	2.0	7.12E-05	225	0.70990	-6.2	-9.0
ACL-8718	IRE-DPD-10s	Dominican Priory Drogheda	NA	NA	LM	L	M1	2.0	2.72E-07	219	0.71037	-6.0	-9.0
ACL-8719	IRE-DPD-10	Dominican Priory Drogheda	Adult	Male	LM	L	Rib	2.0	5.65E-05	384	0.70958	-6.1	-9.2
ACL-8720	IRE-DPD-46	Dominican Priory Drogheda	Older Adult	Female	LM	L	Rib	2.0	5.08E-05	127	0.70995	-6.2	-6.8
ACL-8721	IRE-DPD-23	Dominican Priory Drogheda	Young Adult	Male	LM	L	M1	2.0	2.19E-07	113	0.70891	-4.3	-8.6
ACL-8722	IRE-DPD-23						M3	2.0	1.94E-07	161	0.70871	-5.7	-9.7
ACL-8723	IRE-DPD-23						Rib	2.0	2.03E-05	103	0.70964	-6.6	-7.3
ACL-8724	IRE-DPD-57	Dominican Priory Drogheda	Adult?	Female	LM	L	M1	2.0	7.51E-08	145	0.70995	-4.8	-8.9
ACL-8725	IRE-DPD-57						M3	2.0	8.50E-08	174	0.71007	-6.0	-9.9
ACL-8726	IRE-DPD-57						Rib	2.0	2.53E-05	292	0.70990	-6.8	-8.2
ACL-8727	IRE-DPD-52A	Dominican Priory Drogheda	NA	NA	LM	L	Long bone	2.1	1.60E-05	298	0.70993	-5.5	-9.6
ACL-8728	IRE-DPD-15	Dominican Priory Drogheda	Adult?	Male	LM	E	Long bone	2.1	5.65E-06	275	0.70996	-6.5	-9.3

ACL-8729	IRE-DPD-15*	Dominican Priory Drogheda	NA	NA	LM	L	Long bone	2.0	2.33E-05	594	0.70959	-6.3	-9.3
ACL-8730	IRE-DPD-36	Dominican Priory Drogheda	Juvenile, 16-19	NA	LM	L	M1	2.0	2.14E-07	212	0.71113	-6.3	-8.5
ACL-8731	IRE-DPD-36						Rib	2.1	1.00E-05	199	0.71025	-5.7	-9.3
ACL-8732	IRE-DPD-36+	Dominican Priory Drogheda	NA	NA	LM	L	Long bone	2.1	8.30E-06	351	0.71027	-6.3	-7.6
ACL-8733	IRE-DPD-F1B1	Dominican Priory Drogheda	NA	NA	LM	L	M1	1.9	3.01E-07	168	0.71001	-5.0	-9.1
ACL-8734	IRE-DPD-F1B1						M3	1.9	6.24E-08	415	0.71035	-6.1	-9.6
ACL-8735	IRE-DPD-F1B1						Rib	2.0	1.75E-05	341	0.71017	-6.5	-9.6
ACL-8737	IRE-DPD-B51	Dominican Priory Drogheda	Juvenile, 16-18 years	NA	LM	L	M1	2.0	1.60E-07	211	0.70990	-5.6	-8.4
ACL-8738	IRE-DPD-B51						M3	2.0	1.14E-07	158	0.70987	-6.4	-9.4
ACL-8739	IRE-DPD-28	Dominican Priory Drogheda	Adult?	Male	LM	L	M1	2.0	4.09E-08	241	0.71139	-5.6	-8.5
ACL-8740	IRE-DPD-28						M3	2.0	2.80E-08	227	0.71245	-6.9	-10.0
ACL-8741	IRE-DPD-28						Long bone	2.0	2.03E-05	263	0.71016	-5.8	-8.7
ACL-8742	IRE-DPD-58	Dominican Priory Drogheda	Adult	NA	LM	L	Rib	2.0	3.75E-05	306	0.70967	-5.8	-8.7
ACL-8743	IRE-DPD-52B	Dominican Priory Drogheda	Adult	Male	LM	L	M3	2.0	2.47E-08	187	0.71084	-5.9	-8.8
ACL-8744	IRE-DPD-52B						Rib	2.0	1.12E-05	242	0.70993	-5.9	-8.7
ACL-8745	IRE-DPD-34	Dominican Priory Drogheda	Adult	Female	LM	L	M1	2.0	3.34E-07	310	0.70977	-5.4	-8.2
ACL-8746	IRE-DPD-34						M3	2.0	1.57E-08	189	0.70968	-6.0	-9.0
ACL-8747	IRE-DPD-34						Long bone	2.1	2.34E-06	403	0.70979	-6.5	-9.5
ACL-8748	IRE-DPD-30	Dominican Priory Drogheda	Middle-aged adult	Male	LM	E	M1	2.0	6.85E-08	161	0.71008	-5.7	-8.5
ACL-8749	IRE-DPD-30						M3	1.9	1.02E-08	216	0.71015	-5.4	-8.2
ACL-8750	IRE-DPD-30						Rib	2.1	1.98E-05	322	0.71013	-5.4	-8.2
ACL-8751	IRE-DPD-56	Dominican Priory Drogheda	Middle-aged Adult	Female	LM	L	M1	2.0	2.02E-08	388	0.70930	-6.9	-10.1
ACL-8752	IRE-DPD-56						M3	2.0	4.77E-08	340	0.70921	-6.2	-9.2
ACL-8753	IRE-DPD-56						Long bone	2.1	2.44E-05	237	0.70981	-5.0	-7.7
ACL-8754	IRE-DPD-45	Dominican Priory Drogheda	Middle-aged Adult	Male	LM	L	M1	2.0	7.36E-07	105	0.70920	-7.9	-11.5
ACL-8755	IRE-DPD-45						M3	2.0	5.56E-08	107	0.70892	-6.3	-9.3
ACL-8756	IRE-DPD-45						Rib	2.1	1.15E-05	187	0.70973	-6.3	-9.3
ACL-8757	IRE-DPD-3	Dominican Priory Drogheda	Adult	Male	LM	E	Long Bone	2.2	1.20E-05	402	0.71001	-6.3	-9.3
ACL-8758	IRE-DPD-14	Dominican Priory Drogheda	Adult	Probable Male	LM	L	Long Bone	2.1	1.96E-05	300	0.7100	-7.1	-10.3
ACL-8759	IRE-DPD-4	Dominican Priory Drogheda	Adult	Female	LM	L	M1	2.0	2.30E-07	120	0.71035	-5.2	-7.8
ACL-8760	IRE-DPD-4						M3	2.0	3.26E-08	115	0.71001	-4.2	-6.7
ACL-8761	IRE-DPD-4						Rib	2.1	1.70E-05	136	0.70991	-5.1	-7.8
ACL-8762	IRE-DPD-59	Dominican Priory Drogheda	Adult	Male	LM	L	M1	2.0	1.52E-07	124	0.71128	0.0	-1.1
ACL-8763	IRE-DPD-59						M3	2.0	3.72E-08	100	0.71082	-6.1	-9.1

ACL-8764	IRE-DPD-59						Rib	2.0	2.73E-05	211	0.71001	-6.4	-9.5
ACL-8765	IRE-DPD-7	Dominican Priory Drogheda	Old Adult	Male	LM	L	M1	2.0	7.47E-07	150	0.71073	-4.2	-6.6
ACL-8766	IRE-DPD-7						M3	2.0	6.35E-08	190	0.71065	-6.5	-9.6
ACL-8767	IRE-DPD-7						Rib	2.1	4.53E-05	186	0.70970	-8.8	-12.6
ACL-8768	IRE-DPD-21	Dominican Priory Drogheda	Adult	Male	LM	L	M1	1.9	1.12E-07	160	0.71138	-4.6	-7.1
ACL-8769	IRE-DPD-21						M3	2.0	1.04E-07	215	0.71128	-7.0	-10.2
ACL-8770	IRE-DPD-21						Rib	2.0	1.96E-05	177	0.71001	-5.8	-8.7
ACL-8771	IRE-DPD-5	Dominican Priory Drogheda	Older Adult	Male	LM	L	M1	2.0	3.96E-08	186	0.70959	-3.0	-5.0
ACL-8772	IRE-DPD-5						M3	2.0	3.13E-08	129	0.70944	-5.6	-8.5
ACL-8773	IRE-DPD-5						Rib	2.1	7.46E-06	196	0.70961	-8.8	-12.6
ACL-8774	IRE-DPD-6	Dominican Priory Drogheda	Middle-aged adult	Male	LM	L	M1	2.0	7.31E-08	214	0.70973	-4.7	-7.3
ACL-8775	IRE-DPD-6						M3	2.0	1.47E-08	266	0.70954	-6.7	-9.9
ACL-8776	IRE-DPD-6						Rib	2.0	5.67E-06	288	0.70977	-5.9	-8.8

Table 2. Skeletal Population and Sample by Site. Information gathered from skeletal reports (Bolger and Moloney, 2012; Buckley, 2005; Halpin and Buckley, 1995; Ó Donnabháin and Ní Mhurchadha, 2010; O'Donnabhain, 2010).

Site Name	Location	Date of Burials	Number of Individuals Excavated	Age Distribution	Sex Distribution	Number of Individuals Sampled
Illaunloughan	Co. Kerry	7 <sup>th</sup> -9 <sup>th</sup> centuries, Late medieval	17	14 adults, 3 juveniles	12 males, 2 unknown	4
Toureen Peakaun	Co. Tipperary	7 <sup>th</sup> -12 <sup>th</sup> centuries	30 (14 are late phase <i>cillin</i> burials)	12 adults, 2 juveniles, 15 infants, 1 unknown	1 possible male, 6 males, 2 females, 6 unknown	8
Lorrha	Co. Tipperary	13 <sup>th</sup> -15 <sup>th</sup> centuries	72	49 adults, 38 juveniles, 4 infants	7 male, 9 female, 25 unknown	10
Tintern Abbey	Co. Wexford	13 <sup>th</sup> -15 <sup>th</sup> centuries	106	33 non-adults, 73 adults	42 males, 23 females, 8 unknown	24
Dominican Priory Drogheda	Co. Louth	13 <sup>th</sup> -16 <sup>th</sup> centuries	61, more fragmentary	50 adults, 11 juveniles	32 males, 14 females, 4 unknown	42

## 6. Identifying Monastic and Lay Individuals

The level of likelihood that each individual participated in monasticism as a monk, priest, or other religious person was estimated based on five categories of archaeological and historical factors (see Table 3). These factors are based on the burial surroundings and context, and they are derived from historical records about burial and early Christian practices (Fry, 1999; O'Brien, 2009; O'Brien, 1992; Scott, 2011; Stalley, 1987). Factors 1-3 are meant to distinguish monastic and lay individuals within a monastic cemetery, and Factors 4-5 are meant to ensure that individuals were buried at a monastic site during its active use by a monastic community. Both sets of factors are necessary because the Church began to require burial at church sites in the eighth century, meaning that burials on monastic sites could represent lay or religious individuals (O'Brien, 2009; O'Brien, 1992). The specific date or time period of each burial was considered in this process, and therefore individuals buried at a monastic site after the monastic occupation had ended were not considered to fulfill Factor 5-Historical information about the site (30 of 88 individuals, 34.1%). Also, only early medieval individuals at Illaunloughan were considered to fulfill Factor 4-Geographical setting of the site (3 of 88 individuals, 3.5%). A score of zero represents the lowest likelihood that an individual was a religious person, and a score of five represents the highest likelihood. For this study, a score of three or more was considered a religious individual. There is little variation in medieval Irish Christian burials, and therefore the difference between two and three factors fulfilled was considered sufficient to distinguish between religious and lay individuals (O'Brien, 2009; O'Brien, 1992; Scott, 2011).

*Factor 1- Location of burial in the cemetery* (66 of 88 individuals, 75%)- Burial outside of the eastern end of the church was the most likely area for burial of important ecclesiastical people in the early medieval period (Horn et al., 1990; Marshall and Rourke, 2000; Marshall and Walsh, 2005), and burial inside the church became favored for ecclesiastical and high-ranking people in the late medieval period (Fry, 1999:170). Within the

church the areas nearest the altar, such as the chancel, are considered holy and were likely reserved for ecclesiastical burials (O'Donnabhain, 2010). Certain areas of the burial ground outside of the church could be segregated for use by the ecclesiastical community, as recorded in the *Annals of the Four Masters* (Fry, 1999; Mays, 2006; O'Donovan, 1851). A high percentage of individuals in this study qualified for this factor because sites that had a possibility of yielding monastic individuals were favored during site selection.

*Factor 2- Burial group has mostly male or juvenile burials (55 of 88 individuals=62.5)*- This causes the cemetery to not have the 1:1 sex ratio expected of a typical population, can indicate the presence of ecclesiastical burials (Halpin and Buckley, 1995; Marshall and Walsh, 2005). This is only true in the case of monastic sites that were not nunneries, which held communities of religious women (Bitel, 1986; Collins, 2015).

*Factor 3- Grave style or grave goods (7 of 88 individuals, 8.0%)*- Indicative grave goods or grave style that may indicate a religious person include high-status burial preparations such as stone-lined graves and inscribed stones. Stick pins are one such type of indicative grave good because religious personnel were often buried in a habit rather than the traditional cloth burial shroud (Fry, 1999).

*Factor 4- Geographical setting of site (3 of 88 individuals, 3.5%)*- The setting of the monastery can be taken into account. For instance, some early medieval monasteries lack the facilities to minister to a lay population or are set in isolated areas with a natural physical boundary, such as a body of water. Archaeologists have suggested that males buried at early medieval monasteries that are not near a lay population are religious individuals (Delaney, 1975; Fanning, 1981; Henry, 1945; Marshall and Rourke, 2000; Marshall and Walsh, 2005; O'Donnabhain, 2014). Illaunloughan was the only site at which this factor applied.

*Factor 5- Historical information about site (30 of 88 individuals, 34.1%)* - All sites in this study except Illaunloughan have written evidence that the sites were monastic in nature.

These written sources include annals that mention abbots at the sites (Toureen Peakaun, Lorrha) and histories of the Cistercian and Dominican orders (Tintern Abbey and Dominican Priory Drogheda) (Bolger and Moloney, 2012; Halpin and Buckley, 1995; Lynch, 2010; O'Hagan, 2012). This factor was only considered fulfilled if the individual was buried at the site during the time period covered by the historical information.

Table 3. Criteria Used to Estimate if an Individual was Ecclesiastical.

<b>Criteria</b>	<b>Factors indicating ecclesiastical individual</b>
1. Location of burial in the cemetery	Burial near east end of the church or inside the church
2. Burial group has mostly male or juvenile burials, or female if a nunnery site	Sex distribution is not indicative of a typical population
3. Grave style or grave goods	Grave goods indicating ecclesiastical burials may include a habit pin indicating burial in habit or grave markers like inscribed stones
4. Geographical setting of site	Monastic site lacks a known adjacent lay settlement nearby, such as a small island, especially for early medieval sites
5. Historical information about site	Historical texts exist indicating the presence of an abbot or monastic population

## 7. Estimating mobility through biogeochemistry

### 7.1. Radiogenic strontium isotope ratios

Individual's mobility during their lifetimes can be estimated by comparing radiogenic strontium isotope ratios from human bone and teeth to the ratios found in the bedrock, soil, and ecosystem in the area of the burial site (Bentley, 2006; Ericson, 1985; Knudson et al., 2012). These ratios increase with the age of the underlying bedrock because the amount of

$^{87}\text{Sr}$  increases through radioactive decay of  $^{87}\text{Rb}$  while the amount of  $^{86}\text{Sr}$  is stable (Dasch, 1969; O'Connor, 1988; Wallace et al., 1994). In the environment, the isotopes of  $^{87}\text{Sr}$  and  $^{86}\text{Sr}$  do not experience substantial biopurification or fractionation as they travel through ecosystems' trophic levels (Blum et al., 2000), so human  $^{87}\text{Sr}/^{86}\text{Sr}$  values can be directly compared to those in the ecosystem to deduce mobility. Strontium is substituted for calcium in bone hydroxyapatite (Turekian and Kulp, 1956), and certain sources of strontium are more likely to be incorporated into the human body based on weathering of rock and soil formation (Bentley and Knipper, 2005; Knudson et al., 2014). Oceans have a worldwide consistent radiogenic strontium ratio ( $^{87}\text{Sr}/^{86}\text{Sr}=0.7092$ ), and sea spray contributes this ratio to terrestrial ecosystems in coastal environments (Veizer, 1989; Whipkey et al., 2000). Sea spray does not necessarily overwhelm the ratios of bioavailable available strontium isotopes in coastal contexts, but it can contribute a high percentage of strontium to soils growing near the ocean (Alonzi et al., 2015). Mobility should only be inferred when the radiogenic strontium ratios for the humans and local area differ in the third or fourth decimal place, due to variations that occur in bones and teeth throughout the body (Knudson et al., 2016).

## *7.2 Sources of strontium in medieval Irish diets*

Strontium acts like calcium in chemical reactions and replaces calcium in the mineral fraction of bone and tooth enamel because they have very similar ionic radiuses (Sr-1.32 Å; Ca- 1.18 Å), and strontium found in the human body is introduced by calcium-rich food sources (Bentley, 2006; Ezzo, 1994; Turekian and Kulp, 1956). Geological formations can have heterogeneous mineral compositions, thus causing the soil to have different isotopic ratios of strontium available to organisms than the underlying bedrock based on weathering and soil formation processes (Bentley, 2006; Burton and Hahn, 2016; Knudson et al., 2014;

Price et al., 2002). Because of these factors, it is necessary to assess the sources of strontium in the diets of the individuals being studied.

In medieval Ireland, calcium-rich sources of food were derived from terrestrial, aquatic, and marine sources. Such dietary sources that are known from historical and archaeological evidence include dairy products and the bones of fish and terrestrial animals (Kelly, 1997; McCormick et al., 2011; Montgomery et al., 2007; Montgomery et al., 2003; O'Sullivan et al., 2013). Salmon and trout, which are anadromous fish that inhabit both aquatic and marine waters, are specifically mentioned in medieval Irish Law Texts (Kelly, 1997). These types of fish could carry the typical marine radiogenic strontium isotope ratio ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.07092$ ) into inland environments. Evidence for fishing includes bones found on archaeological sites as well as medieval fishing weirs found in the Shannon and Fergus Estuaries (O'Sullivan et al., 2013; Stout and Stout, 2016). Also, seaweed was likely an important source of marine-derived strontium in medieval diets. First, seaweed may have been mixed with soils to improve the quality of the fields for agricultural purposes in medieval Ireland and Scotland (Kelly, 1997; Montgomery et al., 2007). Finally, sea salt was likely used to preserve foods, as pickling vegetables was very common in medieval Ireland (Kelly, 1997). Because of the multitude of food sources connected to the ocean in medieval Ireland, it is likely that most individuals had some exposure to marine-derived strontium in their lifetimes.

Dairying and consumption of animal bone were likely the most common calcium-rich terrestrial source of strontium in the medieval Irish diet (Kelly, 1997; McCormick et al., 2011). However, crops seem to have increased in importance as a component in diets between the Iron Age and early medieval period, as pollen evidence suggests that forests were cleared and agriculture increased by the fourth century (McCormick et al., 2011:5). In the late medieval period, cereal-drying kilns are evidence for the drying and storage of cereal

crops (McCormick et al., 2011; Stout and Stout, 2016). Also, the increased presence of enclosures and fences indicate a need to keep animals out of lands used for cereal crops (McCormick et al., 2011:6).

The management of dairy herds is discussed in written evidence such as law texts and Saints' Lives, and cows were an important prestige item in medieval Irish society (Kelly, 1997; McCormick, 1995). The age at death profile for cows found at medieval Irish archaeological sites suggests that these herds were maintained for the purpose of dairying (McCormick et al., 2011:42). Also, historical records and law texts record the practice of booleying, which refers to moving cows to sometimes faraway pastures during different times of year (Boyle, 2004; Kelly, 1997). The movement of the cows associated with booleying might be a source of non-local strontium to medieval Irish people, although the records about booleying do not indicate that the dairy products were transported back to the home territory along with the cows. Most food, including dairy, consumed during the early and late medieval periods in Ireland was likely of local or relatively local origin, as little evidence for long-distance trade of food exists. Archaeological evidence suggests that there was trade of salt, wine, ceramics, and metal goods between Ireland and the Continent in the early medieval period, but evidence for non-Irish pottery declines in the seventh century (Loveluck and O'Sullivan, 2016).

### *7.3 Stable oxygen isotope values*

Oxygen isotopes ( $\delta^{18}\text{O}$ ) vary based on regional hydrology and are correlated with climate (Domínguez-Villar et al., 2008; Gat, 1996; Grootes et al., 1993; Négrel et al., 2003), and they can also be used to estimate whether an individual was local or non-local to the site by comparing the human-derived values to those found in precipitation and local waterways

(Longinelli, 1984; Luz et al., 1984; Schwarcz and Schoeninger, 1991). Oxygen isotope values are impacted by practices such as breastfeeding, weaning, and consuming boiled liquids through the process of isotopic fractionation (Knudson, 2009; Wright and Schwarcz, 1998). They also vary seasonally and with climate change (Balasse, 2002; Domínguez-Villar et al., 2008; Gat, 1996; Grootes et al., 1993). The radiogenic strontium and oxygen isotopic systems pattern differently over Ireland, and using a combination of these data allows for a more accurate assessment of non-local individuals (Cahill Wilson and Standish, 2016; Darling et al., 2003; Knudson et al., 2012) (see Figure 1). Stable oxygen isotopic data are shown in terms of  $\delta^{18}\text{O}$  and measured in parts per thousand, known as per mil (‰). The relationship between the concentrations of oxygen isotopes and this value is defined as follows:  $\delta^{18}\text{O} = ((\delta^{18}\text{O} / \delta^{16}\text{O}_{\text{sample}}) / (\delta^{18}\text{O} / \delta^{16}\text{O}_{\text{standard}})) - 1) 1000$  (Coplen, 1994).

## 8. Materials and methods

### 8.1. Archaeological site selection and sampling strategy

Sites were selected based on the availability of accessible cleaned and analyzed skeletal collections of individuals buried at medieval Irish monastic sites. Bone preservation is poor at many of the early medieval monastic sites that have been excavated in Ireland, so the available sites were severely limited. Each skeleton was inspected before inclusion in this study to ensure sufficient preservation, and badly preserved individuals were excluded from the experimental design. A first and third molar and piece of bone from a rib or long bone was collected from each individual in this study, if the dental or skeletal element was present. The collections analyzed in this study are housed at the University College Cork or the

National Museum of Ireland (NMI), and they were sampled and exported under the Permits to Alter and Export #6166, issued by the NMI.

### *8.2. Plant baseline site selection and sampling strategy*

Plants were sampled to establish the strontium isotope signatures found in the four counties containing the archaeological sites (Co. Kerry, Co. Louth, Co. Tipperary, and Co. Wexford). Plant sampling sites were selected based on practices that have been agreed upon by members of the Irish Isotopes Research Group (Daly et al., 2016; Snoeck et al., 2016). Non-woody plants were sampled from wooded or undisturbed areas in order to avoid the effects of non-local strontium introduced by fertilizer used on modern agricultural fields. These plants were dried and imported for analysis at Arizona State University (ASU) under USDA APHIS Permit no. PCIP-14-00573.

### *8.3. Sex and age estimations*

Sex and age estimations had been carried out prior to this study, and the original terminology used by the osteologists are used here (Bolger and Moloney, 2012; Buckley, 2005; Halpin and Buckley, 1995; Ó Donnabháin and Ní Mhurchadha, 2010; O'Donnabhain, 2010). As age at death is not central to the research question of this paper, no further refinement of the age categories was undertaken. Sex is used as part of the criteria for estimating that an individual is ecclesiastical, and the original sex estimations were sufficient for this purpose.

### *8.4. Sample preparation for elemental concentration and radiogenic strontium analyses*

All samples in this study were prepared at Arizona State University (ASU) in the Archaeological Chemistry Laboratory (ACL) based on established methods (Knudson et al., 2016). The samples were first photographed and then cast in plaster to document the morphology of the teeth. The teeth and bone samples were then cleaned using a Dremel drill with a diamond-tipped bit. During this process, only cortical bone is retained for analysis, as the porous cancellous bone is more likely to be impacted by post-depositional contamination. The bone samples then undergo chemical cleaning, which consists of a thirty-minute bath in Millipore water within an ultrasonic cleaner followed by a thirty-minute bath in 0.8 mL of acetic acid ( $\text{CH}_3\text{COOH}$ ) within an ultrasonic cleaner. The samples are then placed in another five-minute Millipore water bath before being dried in an oven set at  $50^\circ\text{C}$  for one hour. The bone samples are ashed in a furnace set to  $800^\circ\text{C}$  for 10 hours. The enamel powder is taken directly from the mechanically cleaned tooth using a clean diamond-tipped Dremel drill bit. Both the tooth enamel powder and the ashed bone are dissolved in 500  $\mu\text{L}$  trace metal grade (15.5-16M) nitric acid ( $\text{HNO}_3$ ) before undergoing strontium separation.

#### *8.5. Analysis of elemental concentrations*

In the W.M. Keck Foundation Laboratory for Environmental Biogeochemistry (KFLEB) at ASU, concentrations of elements including uranium, phosphorus, neodymium, and calcium were analyzed to estimate the level of contamination of the samples. Samples with inadequate concentrations or unexpected ratios of the elements listed above were excluded from further study. First, a stock solution was created by dissolving 0.0030 g of clean powdered bone ash or tooth enamel in 3.50 mL of Millipore water (18.2 M $\Omega$ ) and 0.5mL VWR 16M  $\text{HNO}_3$  (Trace Metal Grade). Then, 0.53 mL of this stock solution was

diluted with 14.47 mL twice-distilled 0.32 M HNO<sub>3</sub>. A Thermo-Finnigan X-series quadrupole inductively coupled plasma mass spectrometer (Q-ICP-MS) was used to analyze the samples and a calibration curve comprising internal standards and NIST 1400. The CUE-0001 samples had a mean Ba/Sr =  $0.48 \pm 0.01$  ( $1\sigma$ , n = 19) and a mean Ca/P =  $1.94 \pm 0.05$  ( $1\sigma$ , n = 19). The NIST-1400 samples had a mean Ba/Sr =  $1.05 \pm 0.03$  ( $1\sigma$ , n = 19) and a mean Ca/P =  $1.88 \pm 0.04$  ( $1\sigma$ , n = 19).

#### *8.6. Separation of strontium isotopes and analysis of strontium isotopic ratios*

In the KFLEB, SrSpec EiChrom resin was used to separate the strontium (Knudson et al., 2012). The resin was washed several times to mitigate contamination and loaded into a glass column. Enough stock solution to provide 100  $\mu\text{g}$  of calcium was dried down and dissolved in 1 mL of 5 M HNO<sub>3</sub>, and this was diluted with 1.4 mL of 18.2 M $\Omega$  Millipore water for plant samples. For human samples, the required amount of stock solution was dried down, dissolved in 0.23 mL of 5 M HNO<sub>3</sub> and then diluted in 3.37 mL of 18.2 M $\Omega$  Millipore water. A Neptune multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS) in the KFLEB was used to analyze the radiogenic strontium ratios (Knudson et al., 2012). SRM-987, a standard, was run at 25 ppb and the average was  $^{87}\text{Sr}/^{86}\text{Sr} = 0.710255 \pm 0.000030$  ( $2\sigma$ , n = 118). The expected average of this standard is  $^{87}\text{Sr}/^{86}\text{Sr} = 0.710235 \pm 0.000020$  ( $2\sigma$ , n = 76), which coincides with the values presented here (Hodell et al., 1989).

#### *8.7. Sample preparation and analysis for oxygen isotope analysis*

Samples were prepared in the Archaeological Chemistry Laboratory at Arizona State University and analyzed in the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University (NAU), following methods in Koch et al. (1997) and Knudson et al. (2015). Fifteen milligrams of tooth enamel powder or 20 mg of bone powder is treated with 0.04 ml 2% bleach (NaOCl) per milligram of enamel or bone powder. The solution is agitated, left to sit for 24 hours, and decanted and rinsed with Millipore water to remove the NaOCl. The sample is then washed three times, which involves adding Millipore water, agitating, centrifuging, and decanting. The sample is then treated with 0.04 ml acetic acid ( $\text{CH}_3\text{COOH}$ ) for each milligram of powder, agitated, centrifuged, left to sit for 24 hours, and dried.

The samples are then analyzed on a Gasbench connected to a Delta V Advantage isotope ratio mass spectrometer (IRMS) at NAU. The standard NBS-19 had an average of  $\delta^{18}\text{O}_{\text{VPDB}} = -2.21 \pm 0.15 \text{ ‰}$  ( $1\sigma$ ,  $n = 15$ ). Oxygen isotope values were calibrated using the international standards NBS-18 ( $\delta^{18}\text{O}_{\text{VPDB}} = -23.00 \pm 0.36 \text{ ‰}$  ( $1\sigma$ ,  $n = 17$ )), NBS-19 ( $\delta^{18}\text{O}_{\text{VPDB}} = -2.21 \pm 0.15 \text{ ‰}$  ( $1\sigma$ ,  $n = 15$ )), and LSVEC ( $\delta^{18}\text{O}_{\text{VPDB}} = -26.13 \pm 0.73 \text{ ‰}$  ( $1\sigma$ ,  $n = 10$ )) to the VPDB scale. Uncertainty was measured by analyzing an in-house standard of calcium carbonate ( $\text{CaCO}_3$ ,  $\delta^{18}\text{O}_{\text{VPDB}} = -13.01 \pm 0.14 \text{ ‰}$ ). No replicates of archaeological samples were undertaken, so it is not possible to estimate precision and total analytical uncertainty as suggested by Szpak et al. (2017). Using equations 4, 5, 6, and 7 in Szpak et al. (2017), systematic error or accuracy as measured by ( $u(\text{bias})$ ) is  $\pm 0.54 \text{ ‰}$  based on the known value and standard deviation of the in-house check standard of calcium carbonate.

The oxygen isotopic values ( $\delta^{18}\text{O}_{\text{c[VPDB]}}$ ) in this study are derived from carbonate in the bone and teeth. They were converted to  $\delta^{18}\text{O}_{\text{dw[VSMOW]}}$  values, which can be used to compare the human data with the groundwater values recorded for Ireland and the United Kingdom (Darling et al., 2003; Pellegrini et al., 2016). The range of  $\delta^{18}\text{O}_{\text{[VSMOW]}}$  values found in the groundwater and surface waters of modern-day Ireland is about -7.5 to -4.5 ‰ (Darling et al., 2003). However, oxygen isotopic values exhibit a minimum meaningful difference of  $\delta^{18}\text{O}_{\text{[VSMOW]}} = 2.9 \text{ ‰}$  for  $\delta^{18}\text{O}_{\text{apatite}}$ , resulting in a range of about  $\delta^{18}\text{O}_{\text{[VSMOW]}} = -10.5$  to  $-1.5 \text{ ‰}$  for the expected values of drinking water found in humans living in Ireland (Darling et al., 2003; Pestle et al., 2014). The original ( $\delta^{18}\text{O}_{\text{c[VPDB]}}$ ) values were used in statistical analyses because the conversion equations introduce a small amount of error.

Three equations were used to convert the oxygen isotope values that derive from carbonate and phosphate. Equation 1 is used to convert oxygen isotope ratios derived from carbonate between the Vienna Standard Mean Ocean Water (VSMOW) and Vienna Pee Dee Belemnite (VPDB) standards (Coplen et al., 1983; Knudson, 2009). Equation 2 relates oxygen isotope ratios derived from carbonate to those derived from phosphate, two different minerals found in bone and teeth (Iacumin et al., 1996). Equation 3 is used to convert the oxygen isotope data derived from human phosphate to the drinking water (dw) values that would be expected for water in the environment (Luz et al., 1984):

$$(1) \delta^{18}\text{O}_{\text{c[VSMOW]}} = (1.03091 \times (\delta^{18}\text{O}_{\text{VPDB}})) + 30.91 \text{ (Coplen et al., 1983; Knudson, 2009)}$$

$$(2) \delta^{18}\text{O}_{\text{c[VSMOW]}} = (8.5 + (\delta^{18}\text{O}_{\text{p[VSMOW]}})) / 0.98 \text{ (Iacumin et al., 1996)}$$

$$(3) \delta^{18}\text{O}_{\text{p[VSMOW]}} = (0.78 \times \delta^{18}\text{O}_{\text{dw[VSMOW]}}) + 22.70 \text{ (Luz et al., 1984)}$$

## 9. Results

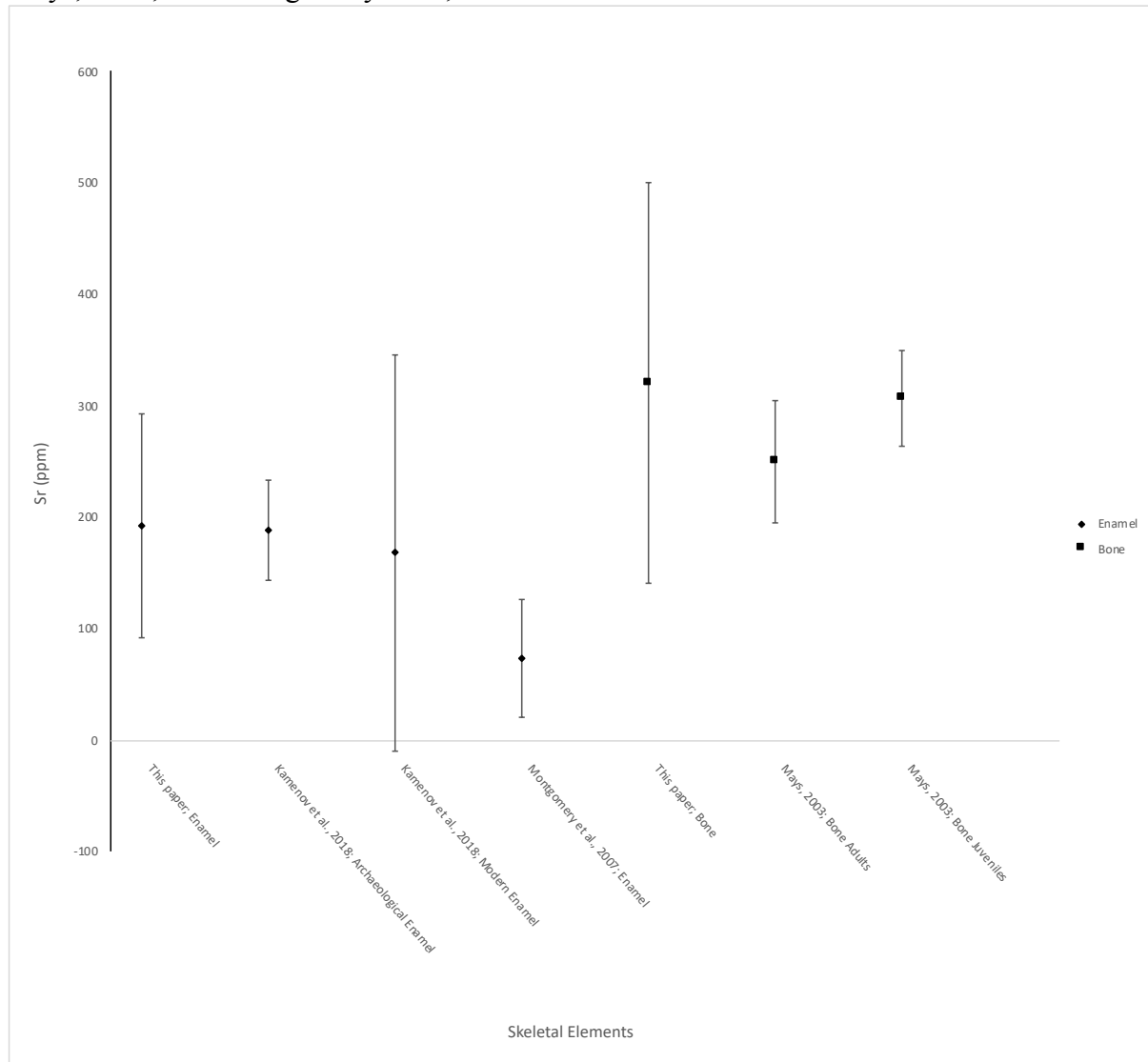
### 9.1. Diagenesis and elemental concentrations

The concentrations of the elements uranium, calcium, and phosphorus were obtained to test that the strontium and oxygen data originate from well-preserved material.

Hydroxyapatite is the mineral component of teeth and bone, and the ratio of calcium to phosphorus in this molecule is 2.1:1 (Posner, 1985). In modern humans, Ca/P is estimated to be  $2.17 \pm 0.31$  ( $n=78$ ,  $1\sigma$ ), and all samples analyzed in this study fall within this range (Zaichick and Tzaphlidou, 2002). Low levels of uranium are another indicator of good preservation, and the mean  $U/Ca = 1.44 \times 10^{-5} \pm 2.72 \times 10^{-5}$  ( $n=179$ ,  $1\sigma$ ) supports the conclusion that the samples are sufficiently preserved for analysis (Price et al., 2002).

Strontium concentrations were assessed to examine if the bone and teeth samples had taken up unusually high levels of strontium from the burial environment. For all samples from all sites, the average strontium concentrations were not significantly different between the enamel samples ( $n=95$ , range=47-567 ppm, mean= $192 \pm 100$  ppm,  $1\sigma$ ) and bone samples ( $n=83$ , range=78-732 ppm, mean= $321 \pm 179$  ppm,  $1\sigma$ ) (see Figure 2). Four outliers were identified: three teeth (ACL-8734 IRE-DPD-F1B1, ACL-8670 IRE-IL-172, and ACL-8667 IRE-IL-106) and one long bone (ACL-8656 IRE-TA-40). Strontium concentrations were compared to other similar studies to assess if the values were within expected ranges for modern and archaeological human populations (Kamenov et al., 2018; Mays, 2003; Montgomery et al. 2007). The mean values in this study are not significantly different from the average values for the previous studies, although a wide range of values in both modern and archaeological populations are observed.

Figure 2. Strontium concentrations (ppm) for all tooth and bone samples in the study. Error bars represent one standard deviation. Comparative data derived from Kamenov et al., 2018, Mays, 2003, and Montgomery et al., 2007.



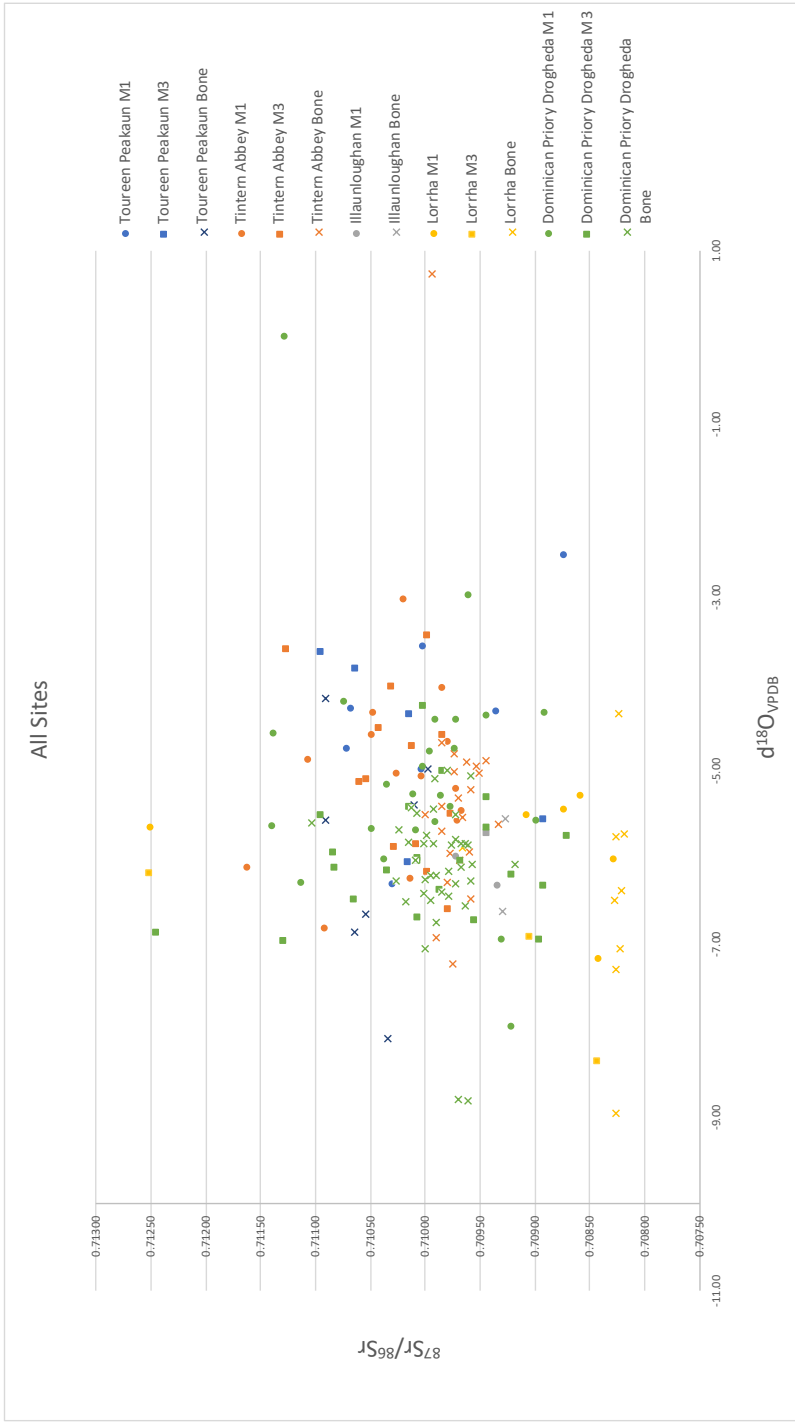
## 9.2. Results for human samples

The human samples comprise M1, M3, and bone samples. The radiogenic strontium isotope ratios and oxygen isotope data for each sample are presented in (see Table 1 and Figure 3), and the summary statistics for each site and overall are presented in Table 4. The value for ACL-8647 IRE-TA-12 ( $\delta^{18}\text{O}_{\text{VPDB}} = 0.7$ ) is reported in Table 1 but was discarded from the analyses. It is outside of the realm of naturally-occurring values in Ireland and the United Kingdom, and this value is not reported in other European areas (Darling et al., 2003).

Table 4. Summary statistics of the radiogenic strontium isotope ratios, oxygen isotope data, and strontium concentration for each site and overall.

Site	$^{87}\text{Sr}/^{86}\text{Sr}$			$\delta^{18}\text{O}_{\text{VPDB}}$			Enamel Sr (ppm)			Bone Sr (ppm)		
	Number	Mean	$2\sigma$	Number	Mean	$2\sigma$	Number	Mean	$2\sigma$	Number	Mean	$2\sigma$
<i>Summary</i> All sites and samples	179	0.70988	0.00153	177	-5.6	2.4	95	192	200	83	321	358
Toureen Peakaun	19	0.71021	0.00127	19	-5.0	2.7	12	86	69	7	100	46
Illaunloughan	6	0.70940	0.00033	5	-6.0	0.9	4	385	299	2	355	NA
Lorrha	19	0.70892	0.00265	18	-6.4	2.3	9	151	198	10	361	198
Tintern Abbey	49	0.71001	0.00094	49	-5.2	2.5	25	223	182	24	410	310
Dominican Priory Drogheda	86	0.70998	0.00122	86	-5.8	2.2	48	195	158	40	294	103

Figure 3. Scatterplot of All Human  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}_{\text{VPDB}}$  Data.



### 9.3. Bioavailable strontium baseline results

The bioavailable strontium baseline data are derived from modern plant samples (see Appendix 1). Summary statistics for each County are presented in Table 5.

Table 5. Summary statistics of the radiogenic strontium isotope ratios for the bioavailable strontium baseline data.

County	$^{87}\text{Sr}/^{86}\text{Sr}$		
	Number	Mean	$2\sigma$
Kerry	15	0.071027	0.00154
Wexford	20	0.71122	0.00274
Louth	11	0.71079	0.00256
Tipperary	21	0.71127	0.00418

### 9.4. Estimating non-local individuals: Bioavailable strontium baseline and statistical methods

Non-local individuals can be estimated in several ways. Individuals are considered non-local if removing their values considerably lowers the standard deviation, variance, and standard error for a site's population (Tung and Knudson, 2011; Wright, 2005). This aligns with Burton and Hahn's (2016) conclusion that there are many scenarios in which human radiogenic strontium ratios differ from those of the local bioavailable strontium, due to contributions from sources such as non-local foods, sea spray, or other aerosol components. They also suggest that principle modes, which present as plateaus in charted data, are likely the best estimation of local values for humans buried at a given site, except in unusual archaeological contexts (Burton and Hahn, 2016:119). In this study, individuals who fell

more than two standard deviations away from the mean values for each site's population were considered outliers and trimmed from the dataset. Removing these outlier individuals did lower the above metrics, confirming that they derive from a separate population. Of the measures discussed here, this is the most conservative method of estimating non-local individuals from all of the sites.

Non-local individuals were also compared to the bioavailable radiogenic strontium isotope ratio derived from plant samples of the local area. Based on the 1:500,000 Bedrock Map from the Geological Survey of Ireland, the local area is defined as bedrock packages that are within 3 km of the site (Geological Survey of Ireland, 2017). However, baseline samples were only used as a comparative tool due to the possibility for a wide range of values to be present in any given catchment (Burton and Price 2013; Burton and Hahn 2016; Sillen et al. 1998). These baseline values corresponded roughly with the local population at each site. Inputs from sea spray, aeolian dust, marine based foods, glaciation, and other pedogenic factors account for variation of the local population from the baseline samples (Burton and Price 2013; Burton and Hahn 2016; Sillen et al. 1998). The range of values is  $^{87}\text{Sr}/^{86}\text{Sr}=0.70874$  to  $^{87}\text{Sr}/^{86}\text{Sr}=0.71705$  (n=14, packages 54, 58, 61) for Toureen Peakaun, Co. Tipperary,  $^{87}\text{Sr}/^{86}\text{Sr}= 0.70937$  to  $^{87}\text{Sr}/^{86}\text{Sr}= 0.70973$  (n=2, package 53) for Illaunloughan, Co. Kerry,  $^{87}\text{Sr}/^{86}\text{Sr}=0.70874$  to  $^{87}\text{Sr}/^{86}\text{Sr}=0.71146$  (n=14, packages 62,64, and 65) for Lorrha, Co. Tipperary,  $^{87}\text{Sr}/^{86}\text{Sr}=0.71152$  to  $^{87}\text{Sr}/^{86}\text{Sr}=0.7143$  (n=3, packages 31 and 39) for Tintern Abbey, Co. Wexford, and  $^{87}\text{Sr}/^{86}\text{Sr}= 0.70921$  to  $^{87}\text{Sr}/^{86}\text{Sr}=0.71291$  (n=19, packages 49 and 64) for Dominican Priory Drogheda, Co. Louth (See Table 6 for ages and descriptions of bedrock packages). Due to land-access issues, it was not possible to sample the geological package underlying the Lorrha site. A substitute value is suggested to be in the range of  $^{87}\text{Sr}/^{86}\text{Sr}= 0.70874$  to  $^{87}\text{Sr}/^{86}\text{Sr}= 0.71146$  (n=20), which is the range of values of all samples from the same Mississippian time period (~325-355 mya) (Walker et al., 2012).

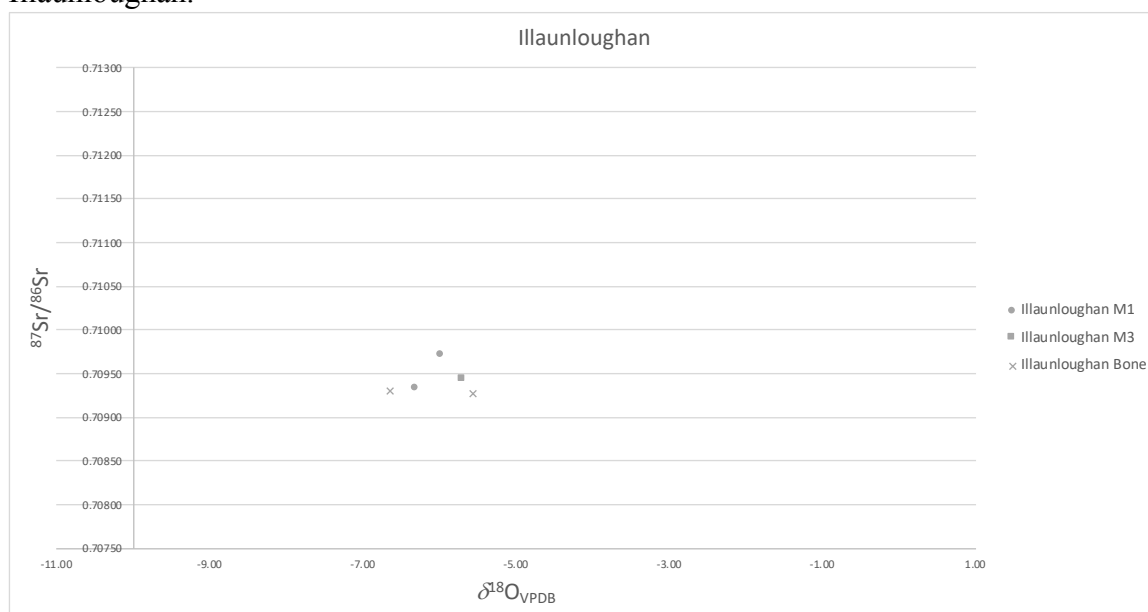
Table 6. Descriptions and Geological Ages for the Bedrock Packages Sampled During the Construction of the Bioavailable Radiogenic Strontium Isotope Baseline.

Bedrock Package	Description	Geological Age (all from the Paleozoic Era)
31	Slate, marine	Cambrian (~540-485 mya)
39	Slate, sandstone, shale, siltstone, marine	Middle to Late Ordovician (~460-445 mya)
49	Mudstone, conglomerate, greywacke, marine	Silurian (~445-420 mya)
53	Sandstone, mudstone, siltstone	Middle Devonian (~395-385 mya)
54	Sandstone, siltstone, conglomerate	Upper Devonian to Carboniferous (~385-300 mya)
58	Limestone, shale, sandstone, marine	Mississippian (~355-325 mya)
61	Limestone, shale, marine	Mississippian (~355-325 mya)
62	Limestone	Mississippian (~355-325 mya)
64	Shale, limestone, marine	Mississippian (~355-325 mya)
65	Limestone, shale, chert, marine	Mississippian (~355-325 mya)

#### *9.5. Mobility and ecclesiastical individuals at Illaunloughan, Co. Kerry*

All four individuals buried at Illaunloughan were estimated to be local to the area surrounding the site based on the statistical and baseline methods (see Figure 4). The burial population at this site consists of three early medieval ecclesiastical individuals and one late medieval lay individual.

Figure 4. Scatterplot  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}_{\text{VPDB}}$  Data from Individuals Buried at the Site of Illaunloughan.

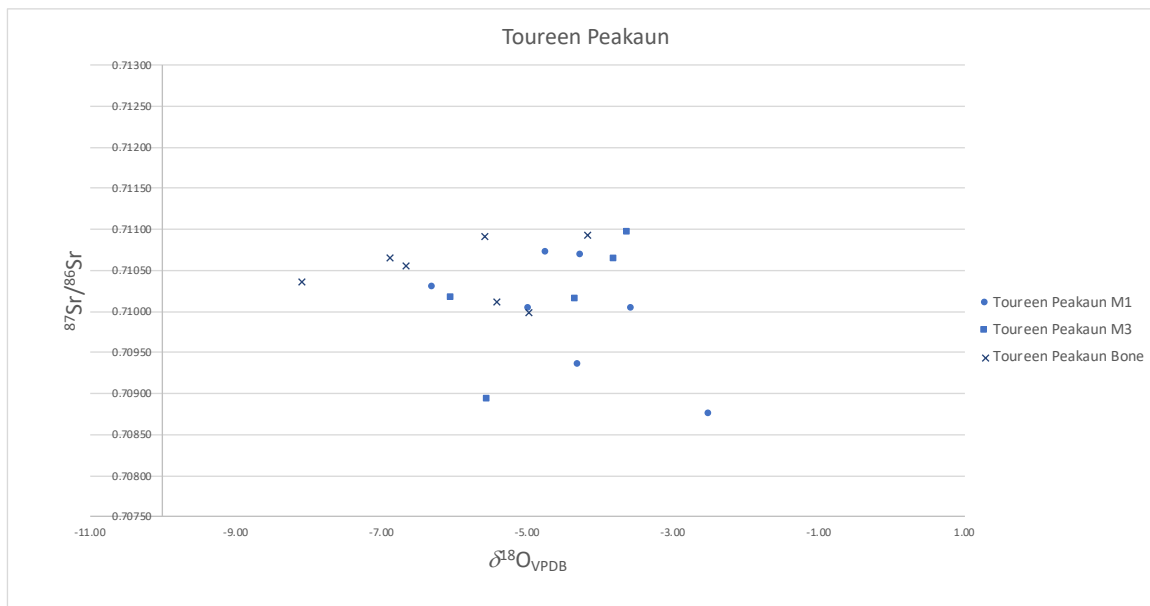


#### 9.6. Mobility and ecclesiastical individuals at Toureen Peakaun, Co. Tipperary

Out of eight individuals analyzed from the site, two are classed as non-local to the site at some point in their lives (see Figure 5). ACL-8605 IRE-TP-0494 (M1) and ACL-8606 IRE-TP-0494 (M3) represent the same individual, and the value for ACL-8606 IRE-TP-0494 ( $^{87}\text{Sr}/^{86}\text{Sr}=0.70892$ ) is an outlier for both the statistical and baseline methods. ACL-8605 IRE-TP-0494 ( $^{87}\text{Sr}/^{86}\text{Sr}=0.70874$ ) is only an outlier based on the statistical methods, as its value coincides with the lowest baseline value for the Toureen Peakaun site. The second individual (ACL-8609 IRE-TP-0421) is an outlier based on its oxygen value  $\delta^{18}\text{O}_{\text{VPDB}}=-8.1$ . The oxygen isotope value for this sample of  $\delta^{18}\text{O}_{\text{dw[VSMOW]}} = -11.6$  is outside of the range of  $\delta^{18}\text{O}_{\text{[VSMOW]}} = -10.5$  to  $-1.5$  ‰ that are estimated to be the drinking water values in Ireland.

One individual of the eight at the site is classed as an ecclesiastical individual, ACL-8599 IRE-TP-0596, but this individual is not estimated to be non-local.

Figure 5. Scatterplot  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}_{\text{VPDB}}$  Data from Individuals Buried at the Site of Toureen Peakaun.

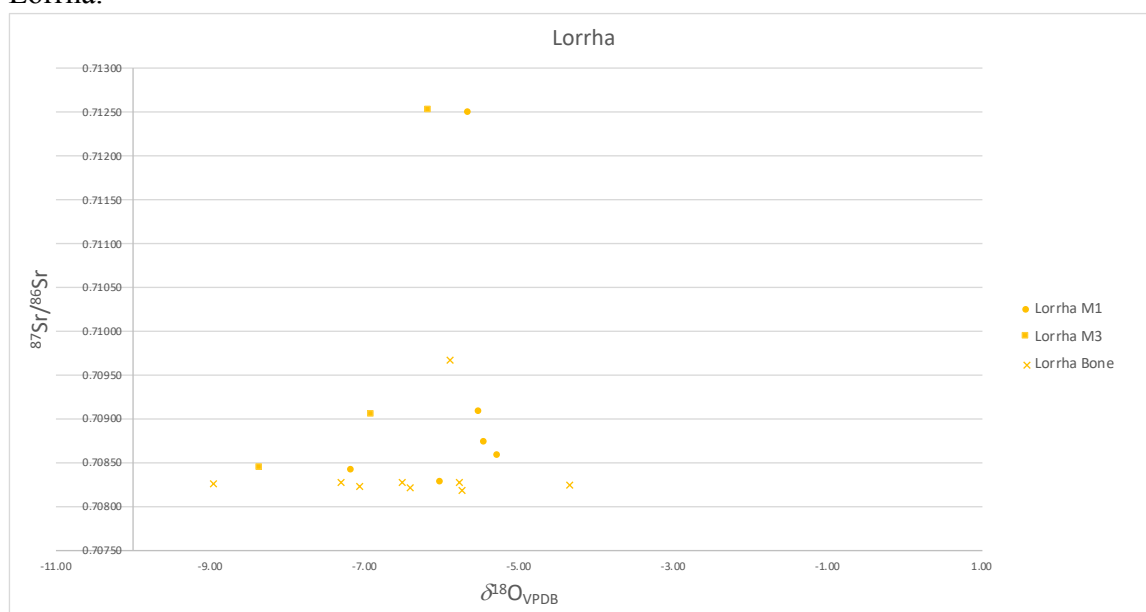


### 9.7. Mobility and ecclesiastical individuals at Lorrha, Co. Tipperary

Two individuals were considered non-local based on statistical methods (see Figure 6). ACL-8686 IRE-LR-29 (M1;  $^{87}\text{Sr}/^{86}\text{Sr} = 0.71249$ ) and ACL-8687 IRE-LR-29 (M3;  $^{87}\text{Sr}/^{86}\text{Sr} = 0.71251$ ) represent an individual who is estimated to be non-local based on their radiogenic strontium isotope values. ACL-8673 IRE-LR-48 is estimated to be non-local due to the oxygen isotope value of  $\delta^{18}\text{O}_{\text{VPDB}} = -9.0$  and  $\delta^{18}\text{O}_{\text{dw[VSMOW]}} = -12.8$ . This value is both a statistical outlier and falls outside of the expected  $\delta^{18}\text{O}_{\text{[VSMOW]}} = -10.5$  to  $-1.5$  ‰ for drinking water values in Ireland. The oxygen values for ACL-8679 IRE-LR-3

( $\delta^{18}\text{O}_{\text{dw[VSMOW]}} = -12.0$ ) also falls outside of this expected drinking water range, although it is not a statistical outlier. Based solely on the geological values presented above, nine out of ten individuals would be considered non-local to the site. These are ACL-8671 IRE-LR-7, ACL-8672 IRE-LR-7, ACL-8673 IRE-LR-48, ACL-8674 IRE-LR-37, ACL-8675 IRE-LR-37, ACL-8676 IRE-LR-26, ACL-8677 IRE-LR-26, ACL-8678 IRE-LR-3, ACL-8679 IRE-LR-3, ACL-8680 IRE-LR-3, ACL-8681 IRE-LR-34, ACL-8682 IRE-LR-25, ACL-8685 IRE-LR-22, and ACL-8688 IRE-LR-29 (see Table 1 for values). However, it is possible that the baseline sampling did not adequately capture the radiogenic strontium ratio at the site of Lorrha. No individuals at Lorrha were estimated to be ecclesiastical.

Figure 6. Scatterplot  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}_{\text{VPDB}}$  Data from Individuals Buried at the Site of Lorrha.

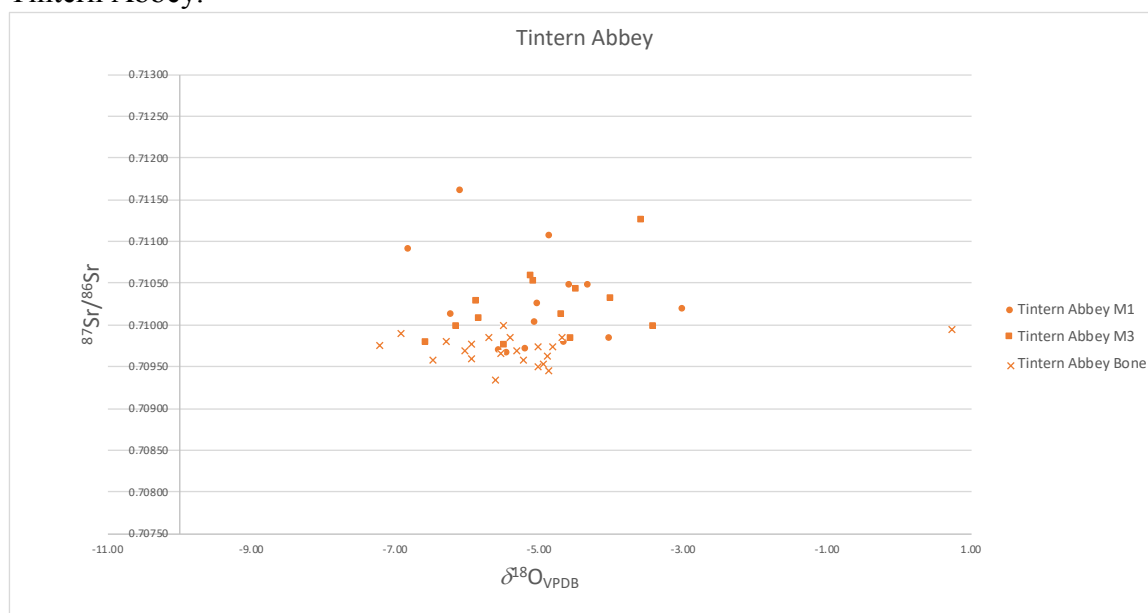


### 9.8. Mobility and ecclesiastical individuals at Tintern Abbey, Co. Wexford

Of the twenty-four individuals analyzed at this site, two are outliers based on the statistical analysis of the radiogenic strontium isotope ratios (see Figure 7). ACL- 8619 IRE-

TA-54 (M1;  $^{87}\text{Sr}/^{86}\text{Sr} = 0.71107$ ) and ACL-IRE-TA-54 (M3;  $^{87}\text{Sr}/^{86}\text{Sr} = 0.71126$ ) represent one non-local individual, and ACL-8626 IRE-TA-60 ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.71161$ ) represents another non-local. Based on the geological values in the vicinity of Tintern Abbey, all but one individual (ACL-8626 IRE-TA-60) would be considered an outlier. However, Tintern Abbey is less than 3 km from the ocean, and no individuals are outliers if the marine value of  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7092$  is considered to be the lower limit of the local range (Veizer, 1989). These individuals appear to have consumed a marine source of strontium, deriving either from diet or sea spray. Nine individuals were estimated to be ecclesiastical (see Table 1 for values). Of these, one was considered non-local by the statistical analysis (ACL-8619 IRE-TA-54), and one was considered non-local by both statistical analysis and baseline bioavailable strontium values (ACL-8626 IRE-TA-60).

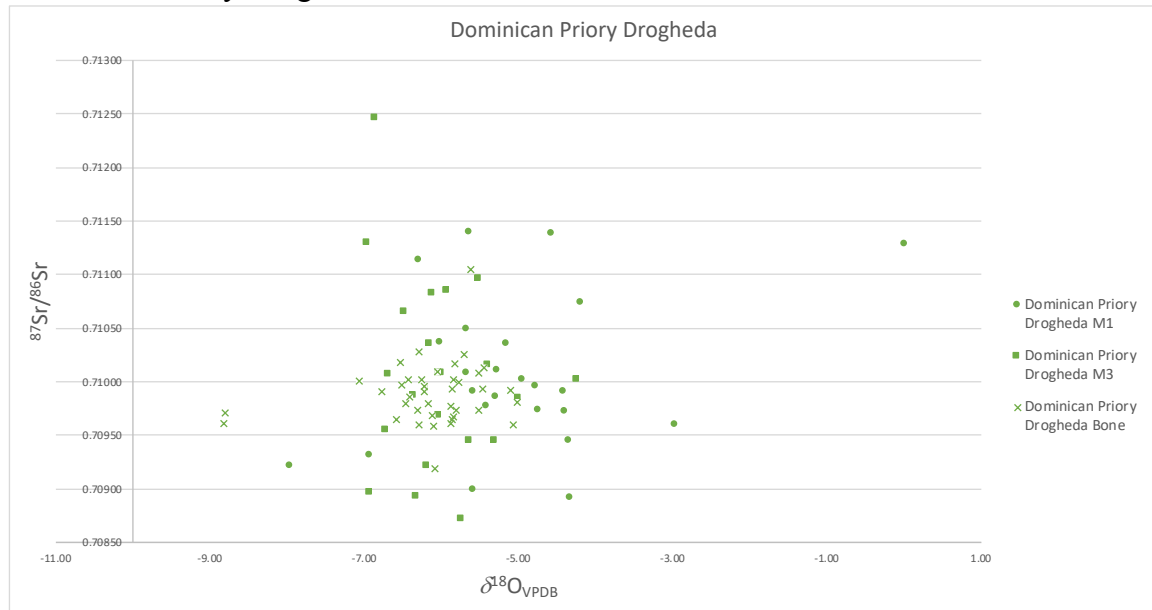
Figure 7. Scatterplot  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}_{\text{VPDB}}$  Data from Individuals Buried at the Site of Tintern Abbey.



### 9.9. Mobility and ecclesiastical individuals at Dominican Priory Drogheda, Co. Louth

Six individuals are considered non-local by statistical methods (see Figure 8). Based on the radiogenic strontium ratios, ACL-8722 IRE-DPD-23, ACL-8739 IRE-DPD-28, ACL-8740 IRE-DPD-28, ACL-8762 IRE-DPD-59, ACL-8768 IRE-DPD-21, ACL-8769 IRE-DPD-21 are non-local (see Table 1 for values). The oxygen isotope values indicate that ACL-8762 IRE-DPD-59 (also an oxygen outlier), ACL-8767 IRE-DPD-7, ACL-8771 IRE-DPD-5, and ACL-8773 IRE-DPD-5 are non-local (see Table 1 for values). Based on the expected drinking water oxygen isotope values in Ireland of  $\delta^{18}\text{O}_{[\text{VSMOW}]} = -10.5$  to  $-1.5$  ‰, ACL-8754 IRE-DPD-45, ACL-8767 IRE-DPD-7, and ACL-8773 IRE-DPD-5 are estimated to be outliers (see Table 1 for values). Comparison to the radiogenic strontium baseline ratios suggests that another three individuals are outliers: ACL-8699 IRE-DPD-18 ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70918$ ), ACL-8714 IRE-DPD-40A ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70899$ ), ACL-8715 IRE-DPD-40A ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70896$ ), ACL-8721 IRE-DPD-23 ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70891$ ), ACL-8722 IRE-DPD-23 ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70871$ ) (also a statistical outlier), ACL-8754 IRE-DPD-45 ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70920$ ), ACL-8755 IRE-DPD-45 ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70892$ ). Five individuals were estimated to be ecclesiastical (see Table 1). None of these ecclesiastical individuals are estimated to be non-local to the site.

Figure 8. Scatterplot  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}_{\text{VPDB}}$  Data from Individuals Buried at the Site of Dominican Priory Drogheda.



### 9.10. Comparison of percentages of local and non-local individuals

A non-parametric Chi-square test is used to determine if percentages of mobile ecclesiastical and lay people are significantly different between all of the sites (see Table 7) (Shennan, 2001). The proportions are based on the individuals estimated to be non-local by the statistical method discussed above in order to eliminate the impact of uneven sampling of geological samples on these calculations. However, the geological data support the conclusions of the statistical methods in most cases. These data indicate that ten of seventy (14.3%) of lay people in this study are non-local, and two of eighteen (11.1%) of ecclesiastical people in this study are non-local. A Chi-square test indicates that these percentages are not significantly different at a p-value of 0.05 (Chi-square=0.1225, test p-value=0.7263).

Zero of four (0%) early medieval ecclesiastical individuals are non-local, and two of fourteen (14.3%) late medieval ecclesiastical individuals are non-local. A Chi-square test cannot be used to determine if the percentages of non-local ecclesiastical people are significantly different between the early and late medieval time periods because there are no non-local ecclesiastical individuals from the early medieval period. In comparison, one of two (50%) early medieval lay people is non-local, and eight of sixty-eight late medieval lay people are non-local (11.8%). Based on these data, it is not possible to conclude that there was or was not a difference in mobility between ecclesiastical and lay people in the early medieval period due to the small sample size. However, a chi-square test indicates that there is no significant difference between the percentage of non-local ecclesiastical and lay people during the late medieval period at a p-value of 0.05 (Chi-square=0.0689, test p-value=0.7929). Finally, there is no significant difference between overall proportion of non-local people buried at the sites in the early medieval period ( $1/6=16.7\%$ ) and late medieval period ( $11/82=13.4\%$ ), based on a Chi square test at a p-value of 0.05 (Chi-square=0.0502, test p-value=0.8227).

Given that bone carbonate oxygen values are particularly susceptible to diagenesis (Chenery et al. 2012:309; Katzenberg 2008:419; Yoder and Bartelink 2010:116), the overall conclusions of this study were compared to those that would have been drawn if bone oxygen data had been excluded from the dataset. Four individuals, all designated to be lay, had been estimated to be non-local based solely on bone carbonate oxygen data of five samples (ACL-8609 IRE-TP-0421, ACL-8673 IRE-LR-48, ACL-8767 IRE-DPD-7, ACL-8771 IRE-DPD-5, ACL-8773 IRE-DPD-5). Excluding these individuals from the non-local group results in 6/70 (8.57%) of lay individuals being non-local, in comparison to 10/70 (14.3%) lay individuals being non-local if the oxygen data are utilized. Even if the bone carbonate oxygen data are discounted, there is still no significant difference between overall proportion of local and

non-local lay and ecclesiastical individuals, with a Chi square test at a p-value of 0.05 (Chi-square=0.1117, test p-value=0.7382).

Table 7. Proportions and Percentages of Ecclesiastical and Mobile Individuals. Ecclesiastical individuals fulfill at least 3 of the criteria listed in Table 3. Non-local individuals are estimated by the statistical method outlined above, rather than by comparing to geological samples.

	Ecclesiastical Individuals	Non-local Ecclesiastical Individuals	Percentage of Non-local Lay Individuals	Percentage of Non-local People (Total per Site)
Overall	18/88=20.5%	2/18=11.1%	10/70=14.3%	12/88=13.6%
Toureen Peakaun	1/8=12.5%	0/1=0%	2/7=28.6%	2/8= 25%
Illaunloughan	3/4=75%	0/3=0%	0/1=0%	0/4= 0%
Lorrha	0/10= 0%	0/0=0%	2/10=20%	2/10= 20%
Tintern Abbey	9/24=37.5%	2/9=22.2%	0/15=0%	2/24= 12.5%
Dominican Priory Drogheda	5/42=11.9%	0/5=0%	6/37=16.2%	6/42= 14.3%

#### 9.11. $^{87}\text{Sr}/^{86}\text{Sr}$ over the life course

Plots of the three tissues analyzed (M1, M3, and bone) demonstrate changes in one individual's radiogenic strontium isotope ratios over time, which can be used to represent life histories of individuals (Marsteller et al., 2017) (see Figures 9, 10, 11, and 12). The first molar crown (M1) represents the age of ~0-40 months, the third molar crown (M3) represents from 8-14 years of age, and bone represents the last 20 years of life (Christensen and Kraus, 1965; Garn et al., 1962; Gleiser and Hunt, 1955; Hedges et al., 2007). These plots show that all sites in this study except for Illaunloughan drew in people from the local area who were not raised directly adjacent to the monastery.

All sites show a convergence of values in the bone samples. This convergence can be interpreted as individuals moving to the site or as the influence of diagenesis. However, given that the metrics used to assess contamination suggest that much of the bone data can be

contributed to biogenic sources (see section 9.1), it is likely that these data represent a trend in mobility. At the site of Toureen Peakaun, individuals show changes in M1, M3, and bone values that are inconsistent with one source of contamination. Both the individuals represented by ACL-8615 IRE-TP-0490 and ACL-8601 IRE-TP-0596 have M1 and M3 ratios that fall in the center of the range, with bone data rising to 0.71091, the highest values at the site. The individual represented by ACL-8604 IRE-TP-0417 has an M3 value that is more radiogenic than the highest bone value at the site (0.71095). This suggests that while diagenetic contamination exists, it likely did not overpower all biogenic strontium ratios, perhaps due to mechanical and chemical cleaning protocols that mitigated this contamination. However, it is not possible to absolutely distinguish if the cause of convergence of Sr ratios is due to human behavior during life or diagenetic contamination after burial due to equifinality of the values.

Figure 9.  $^{87}\text{Sr}/^{86}\text{Sr}$  Over the Life Course for the Site of Toureen Peakaun.

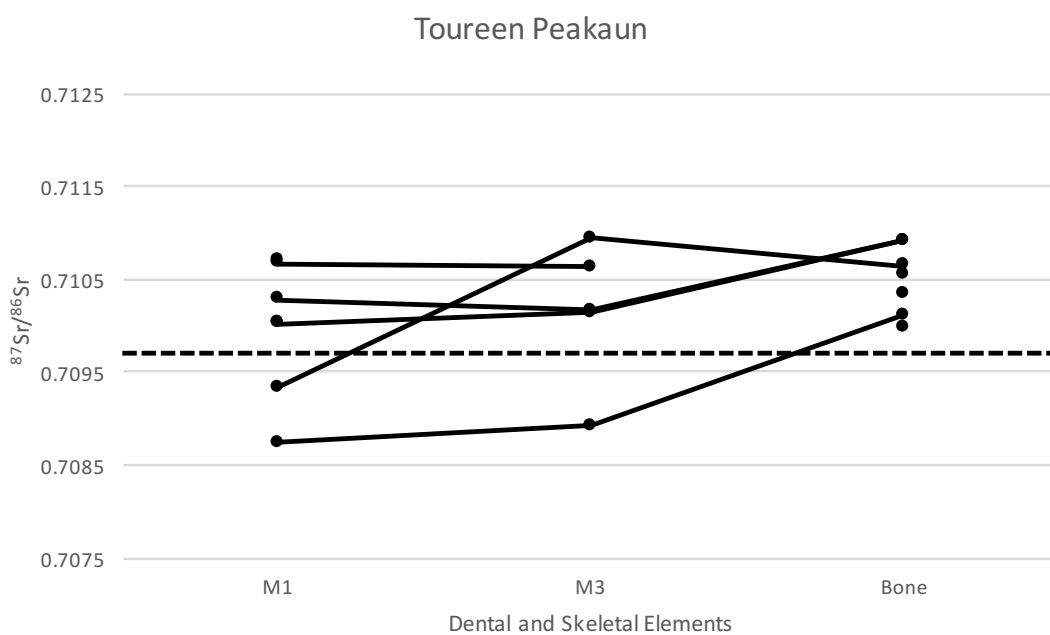


Figure 10.  $^{87}\text{Sr}/^{86}\text{Sr}$  Over the Life Course for the Site of Lorrha.

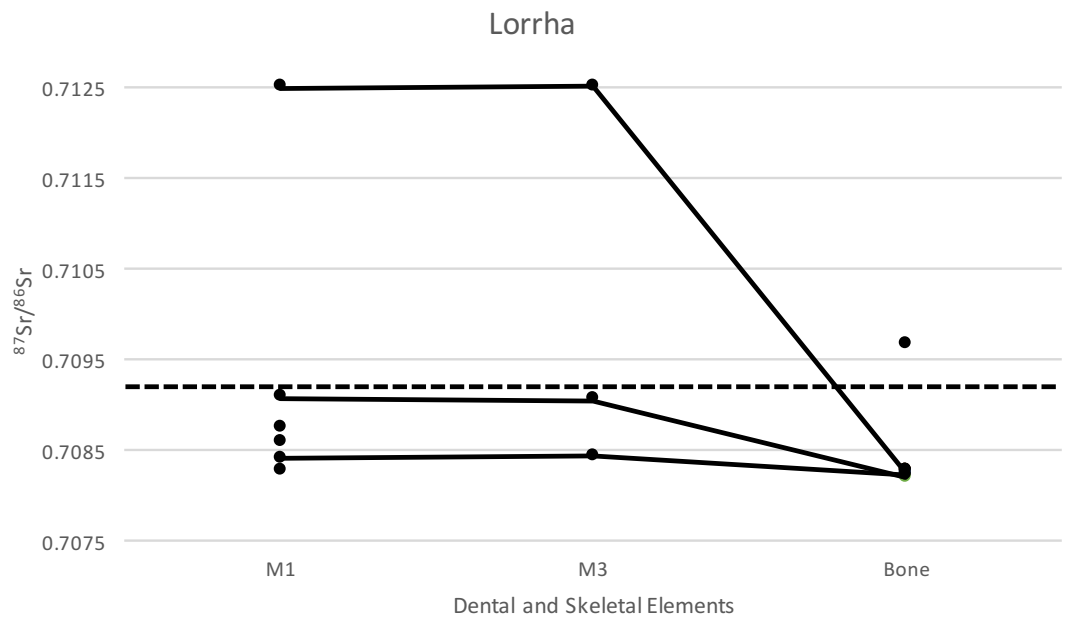


Figure 11.  $^{87}\text{Sr}/^{86}\text{Sr}$  Over the Life Course for the Site of Tintern Abbey.

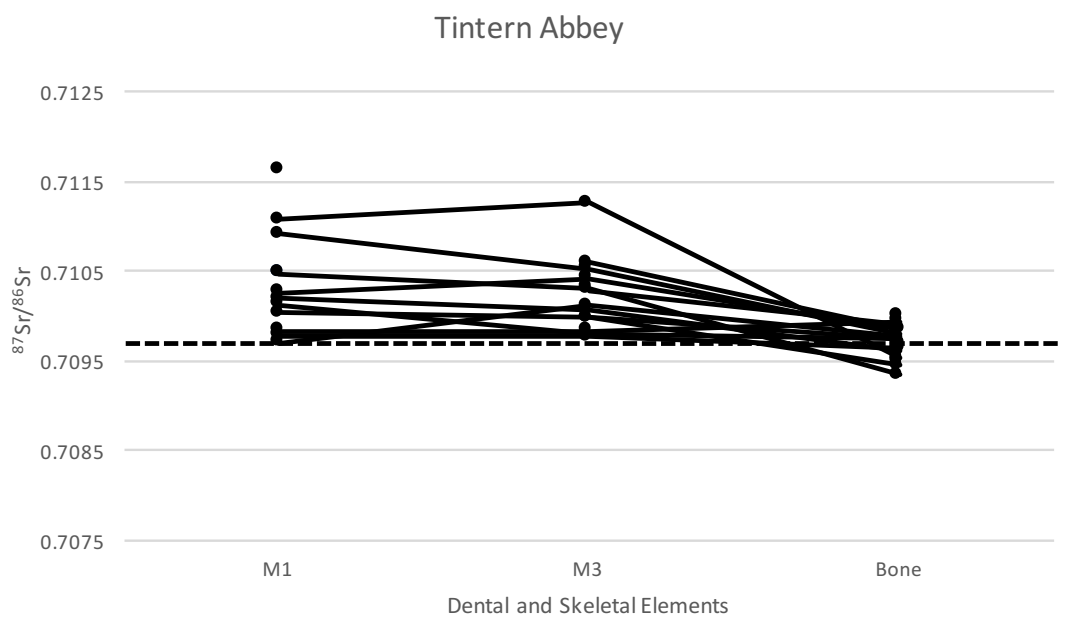
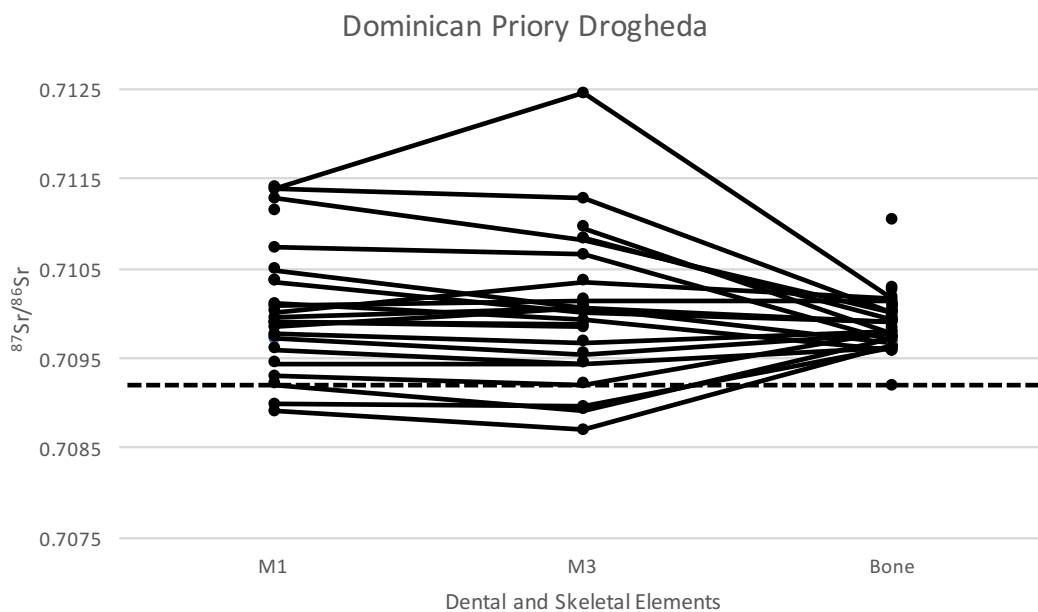


Figure 12.  $^{87}\text{Sr}/^{86}\text{Sr}$  Over the Life Course for the Site of Dominican Priory Drogheda.

## 10. Discussion

### 10.1. Evidence for mobility at early and late medieval monastic sites

The early and late medieval ecclesiastical people in this study did not exhibit significantly different levels of mobility from the lay people. The evidence from the historical texts appears to be biased towards notable individuals, and a low level of mobility seems to be common for both ecclesiastical and lay populations during the early and late medieval periods. Low rates of mobility in both lay and ecclesiastical groups are likely tied to the early medieval laws that restrict individuals' rights to within their own kingdom or *túath* (Kelly, 1988:4; Stout, 2017:54). Kelly (1988:4) suggests that only educated members of the upper classes were able to travel freely between *túatha*. Regardless, it appears that texts

overemphasize the prevalence of mobility in the monastic experience, perhaps purposefully utilizing the early prominence of pilgrim saints to raise the status of these famous ecclesiastics, similar to the practice of veneration of pilgrim saints' relics (Johnston, 2016; Ó Carragáin, 2003a). However, the texts could be accurately portraying high levels of mobility for the most elite ecclesiastical people, who occur in such small numbers that it none were available to test for this study. These most elite people would be found in graves marked by cross-inscribed recumbent stones and elaborate burial settings near the eastern side of the church or the altar or they could be found in tomb shrines (Scott, 2011:69). None of the individuals in this study were buried in such elaborate settings as to label them elite religious personnel.

Also, overall percentages of mobile individuals are not significantly different between the early and late medieval periods, even though the late medieval period involved notable interactions with other cultures via the introduction of the Continental monastic orders and the influx of Anglo-Normans (Otway-Ruthven, 1968; Stalley, 1987). The sites in this study span urban sites, such as the Dominican Priory in Drogheda, to relatively isolated sites such as Illaunloughan and Toureen Peakaun. It is interesting to see that the different contexts of these sites do not appear to correlate to measurably higher levels of mobility. However, future studies and larger sample sizes for the early medieval populations are needed to truly assess whether rates of mobility changed between the two periods.

The plots of individuals' radiogenic strontium isotope values over their life course indicate that people buried at these monastic sites converged over their lives (see Figures 9, 10, 11, and 12). Monasteries likely acted as a catchment for medieval Irish people in life and death. For instance, monasteries on the continent were recorded as having fairs and markets on their grounds that would draw crowds (Fry, 1999). The Cistercian order focused on agriculture, and lay brothers gathered to the monastery to farm and complete crafts (Stalley,

1987). Also, as in the case of Illaunloughan, education and fosterage were possible reasons for children to gather at monasteries, and this movement would have been captured in the differences of the isotopic data derived from M1 and bone if the individual died at an age of around 20 years or less (Hedges et al., 2007; Marshall and Walsh, 2005; Parkes, 2004, 2006). Monasteries offered economic and social opportunities that seem to have encouraged people to move closer to them. Dominican Priory Drogheda and Lorrha were founded in medieval population centers, and it is likely that further individuals were attracted by the founding of the monasteries. Contrastingly, Illaunloughan, Toureen Peakaun, and Tintern Abbey were not founded by existing towns. It is telling that this pattern applies to all monasteries in this study, regardless of their placement nearby or far from a town.

Monasteries also drew people after their death. In the early medieval period, Saint's cults and relics were very popular, and these saints were often venerated at a specific site (Ó Carragáin, 2003a). Families were likely associated with a certain church or monastic site over time, and some families probably supported the running of a specific monastery, known as a proprietary monastery (Ó Carragáin et al., 2011; O'Brien, 2009). Also, the Church's burial policy emphasized the necessity of being buried on consecrated ground after the eighth century (O'Brien, 2009), which is the period covered in this study, perhaps in an effort to consolidate the community or receive remuneration for burials. The sites in this study may have acted as gathering places for the local population in both life and death.

## *10.2. Possible origins outside of Ireland*

Although no individuals in this study exhibit radiogenic strontium isotope ratios or oxygen isotope values that clearly do not occur on the island of Ireland, several individuals exhibit combinations of both data that occur more commonly in Britain. Individuals with

values of less than  $\delta^{18}\text{O}_{\text{VSMOW}} = -10.5\text{‰}$  fall outside of the reported range for drinking water in Ireland (Darling et al., 2003). However, these values are within the known range for Britain, after accounting for the  $\delta^{18}\text{O}_{\text{[VSMOW]}} = 2.9\text{‰}$  minimum meaningful difference, which accounts for the difference between values obtained by different laboratories (see Table 1) (Darling et al., 2003; Pestle et al., 2014). The individuals with possible British origins are from the sites of Lorrha (ACL-8673 IRE-LR-48, ACL-8679 IRE-LR-3), Toureen Peakaun (ACL-8609 IRE-TP-0421), and Dominican Priory Drogheda (ACL-8754 IRE-DPD-45, ACL-8767 IRE-DPD-7, ACL-8773 IRE-DPD-5), and they display a range of radiogenic strontium isotope values from  $^{87}\text{Sr}/^{86}\text{Sr} = 0.70826$  to  $^{87}\text{Sr}/^{86}\text{Sr} = 0.71035$  (see Table 1). These combinations of oxygen isotope values and radiogenic strontium isotope ratios can be found in Britain, where bioavailable radiogenic strontium isotope ratios range from  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7070$  to  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7222$  and  $\delta^{18}\text{O}_{\text{[VSMOW]}} = -4.5$  to  $\delta^{18}\text{O}_{\text{[VSMOW]}} = -9.0$  (Darling et al., 2003; Evans et al., 2010). However, these data are not differentiated enough to conclude definitively that these individuals lived outside of Ireland during their lifetimes. The other six non-local individuals not mentioned here exhibit isotopic data that are present in Ireland but not in Britain.

## 11. Conclusion

The data suggest that people who participated in monasticism as monks or religious personnel were not demonstrably more mobile during their lifetimes than members of the lay community buried at the monasteries. Furthermore, it appears that the percentage of people who undertook mobility during their lifetimes is not demonstrably different between the early and late medieval periods, despite the different historical contexts of the periods and sites in

this study. However, this study has shown that monastic sites were a focal point for local communities in early and late medieval Ireland, as people moved closer to the monasteries in the last twenty years of their lives based on the data derived from bone (see Figures 9, 10, 11, and 12) (Hedges et al., 2007). Monastic sites drew people to live near them during life, and they drew people to them for burial after death. The monastic communities seem to have been composed of mostly local people, and it is unlikely that the average monk traveled long distances to join a monastery. The written evidence suggesting that monasticism is closely tied to mobility appears to be biased towards exceptional or fictional individuals. Perhaps this participation of local people in the organization of the Church served to strengthen the bond between monastic and lay communities, supporting the Church's political and social dominance in Ireland during the medieval period.

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Appendix 1. Contextual Information and Isotope Data for Plant Samples, Representing the Bioavailable Radiogenic Strontium Isotope Ratio Baseline

<b>Laboratory Number</b>	<b>Specimen Number</b>	<b>County and Sampling Location</b>	<b>GPS Coordinates</b>	<b><math>^{87}\text{Sr}/^{86}\text{Sr}</math></b>
ACL-8526	IRE-54-22-K	Kerry (Dromatouk), Ireland	51.88647, -9.53454	0.70991
ACL-8527	IRE-54-23-K	Kerry (Bonane)	51.83066, -9.51906	0.71105
ACL-8528	IRE-53-17-K	Kerry (Skellig View)	51.85637, -10.36701	0.70937
ACL-8529	IRE-53-18-K	Kerry (Capparoe Cottages)	51.87149, -9.72215	0.70973
ACL-8530	IRE-43-5-K	Kerry (Near Blaskets)	52.15001, -10.46955	0.70948

ACL-8531	IRE-52-6-K	Kerry (Connor's Pass)	52.18187, -10.20727	0.71029
ACL-8532	IRE-64-7-K	Kerry (Magherabeg Lower)	52.27559, -10.02639	0.70922
ACL-8533	IRE-35-9-K	Kerry (Annascaul)	52.16417, -9.97561	0.70994
ACL-8534	IRE-71-28-K	Kerry (Tarbert Walk)	52.57568, -9.37279	0.71021
ACL-8535	IRE-64-26-K	Kerry (Ballyseedy Wood)	52.25273, -9.65668	0.71135
ACL-8536	IRE-64-24-K	Kerry (Headfort)	52.03941, -9.3792	0.70965
ACL-8537	IRE-71-27-K	Kerry (Glanageety Wood)	52.26909, -9.54447	0.71093
ACL-8538	IRE-64-25-K	Kerry (Listowel Park)	52.44612, -9.47538	0.71099
ACL-8539	IRE-61-29-K	Kerry (The Line Road)	52.40062, -9.75124	0.71022
ACL-8540	IRE-71-15-K	Kerry (Kilcummin Bog)	52.12866, -9.46043	0.71173
ACL-8541	IRE-35-1-W	Wexford (Oaklands)	52.37844, -6.95646	0.71126
ACL-8542	IRE-38-2-W	Wexford (Carrickbyrne Hill)	52.36394, -6.79225	0.71248
ACL-8543	IRE-31-3-W	Wexford (Tintern Wood)	52.23742, -6.83977	0.71167
ACL-8544	IRE-31-4-W	Wexford (Tintern Wood)	52.2359, -6.83584	0.71152
ACL-8546	IRE-35-6-W	Wexford (Lacken Hill)	52.40385, -6.8800	0.71108
ACL-8548	IRE-5-8-W	Wexford (Monaseed Walk)	52.74776, -6.40514	0.71160
ACL-8549	IRE-4-9-W	Wexford (Ballythomashill)	52.76102, -6.35306	0.71022
ACL-8550	IRE-35-10-W	Wexford (Coolmelagh)	52.68361, -6.57938	0.71131
ACL-8551	IRE-35-11-W	Wexford (Killinieran)	52.72624, -6.27701	0.71140
ACL-8552	IRE-39-12-W	Wexford (Killinieran)	52.72499, -6.27968	0.71430
ACL-8553	IRE-8-13-W	Wexford (Mount Leinster) (actually in Waterford)	52.63729, -6.79399	0.70997
ACL-8555	IRE-38-15-W	Wexford (Templeshannon)	52.50282, -6.55561	0.71240
ACL-8556	IRE-32-16-W	Wexford (Templeshannon)	52.50282, -6.55561	0.71248
ACL-8558	IRE-30-18-W	Wexford (Shelmaliere)	52.29614, -6.58141	0.71324

ACL-8559	IRE-61-19-W	Wexford (The Raven)	52.38034, -6.36801	0.70947
ACL-8560	IRE-64-20-W	Wexford (The Raven)	52.3776, -6.3689	0.70990
ACL-8561	IRE-74-21-W	Wexford (Kilmore Quay)	52.18765, -6.60748	0.70950
ACL-8562	IRE-16-22-W	Wexford (Kilmore Quay)	52.1787, -6.59274	0.70949
ACL-8563	IRE-17-23-W	Wexford (Kilmore Quay)	52.18129, -6.59837	0.70939
ACL-8564	IRE-32-24-W	Wexford (Castlebridge)	52.38649, -6.46678	0.71177
ACL-8565	IRE-60-1-L	Louth (Ardee River Walk)	53.85347, -6.53915	0.70985
ACL-8566	IRE-61-2-L	Louth (Ardee River Walk)	53.85346, -6.54217	0.70998
ACL-8567	IRE-49-3-L	Louth (Clogher Head)	53.79659, -6.2210	0.71042
ACL-8568	IRE-49-4-L	Louth (Stephenstown Pond)	53.96453, -6.45919	0.71168
ACL-8569	IRE-49-5-L	Louth (Carlingford Commons)	54.03841, -6.1934	0.71099
ACL-8570	IRE-64-6-L	Louth (Townleyhall)	53.72413, -6.42974	0.71130
ACL-8571	IRE-49-7-L	Louth (Townleyhall)	53.72481, -6.43256	0.71291
ACL-8572	IRE-42-8-L	Louth (Whiteriver)	53.79779, -6.48262	0.71289
ACL-8573	IRE-9-9-L	Louth (Ravensdale)	54.0795, -6.34852	0.70965
ACL-8574	IRE-64-10-L	Louth (Drogheda)	53.71389, -6.3591	0.70984
ACL-8575	IRE-64-11-L	Louth (Magdalene Tower Drogheda)	53.71852, -6.35147	0.70921
ACL-8576	IRE-61-1-T	Tipperary (Near Toureen Peakaun)	52.40997, -7.99141	0.70874
ACL-8577	IRE-54-2-T	Tipperary (Near Toureen Peakaun)	52.40577, -7.99255	0.71100
ACL-8578	IRE-58-3-T	Tipperary (Near Toureen Peakaun)	52.40878, -7.99376	0.71141
ACL-8579	IRE-49-4-T	Tipperary (Doonane Forest)	52.73724, -8.32494	0.71209
ACL-8580	IRE-54-5-T	Tipperary (Doonane Forest)	52.7504, -8.32001	0.71027
ACL-8581	IRE-54-6-T	Tipperary (Glengarra Wood)	52.33921, -8.10571	0.71062
ACL-8582	IRE-49-7-T	Tipperary (Devil's Bit)	52.80076, -7.96628	0.71184

ACL-8583	IRE-71-8-T	Tipperary (Grange Crag Loop)	52.65779, -7.5426	0.71321
ACL-8584	IRE-64-9-T	Tipperary (Grange Crag Loop)	52.65924, -7.54216	0.71146
ACL-8585	IRE-49-10-T	Tipperary (Tountinna)	52.8468, -8.39413	0.71150
ACL-8586	IRE-62-11-T	Tipperary (Marlfield Glenbawn)	52.34435, -7.7777	0.71057
ACL-8587	IRE-62-12-T	Tipperary (Knockanaroe)	52.95529, -8.03751	0.70902
ACL-8588	IRE-58-13-T	Tipperary (Bishop's Wood)	52.57021, -8.03042	0.71038
ACL-8589	IRE-54-14-T	Tipperary (Bishop's Wood)	52.57053, -8.03594	0.71705
ACL-8590	IRE-64-15-T	Tipperary (Cahir Park)	52.3585, -7.92196	0.70933
ACL-8591	IRE-72-16-T	Tipperary (Knockabritta)	52.56581, -7.61428	0.71229
ACL-8592	IRE-54-17-T	Tipperary (Liam Lynch)	52.26052, -7.87728	0.70973
ACL-8593	IRE-54-18-T	Tipperary (Slievenamuck)	52.43267, -8.17861	0.71080
ACL-8594	IRE-49-19-T	Tipperary (Upperchurch)	52.7076, -8.03551	0.71600
ACL-8595	IRE-62-20-T	Tipperary (Lough Doire Bhile)	52.61784, -7.68041	0.70973
ACL-8596	IRE-64-21-T	Tipperary (Lough Doire Bhile)	52.61596, -7.67574	0.70968

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