



Direct dating confirms the presence of otter and badger in early Holocene Ireland

Robert C. Power, Ingelise Stuijts, Finbar McCormick & Sahra Talamo

To cite this article: Robert C. Power, Ingelise Stuijts, Finbar McCormick & Sahra Talamo (2023) Direct dating confirms the presence of otter and badger in early Holocene Ireland, *STAR: Science & Technology of Archaeological Research*, 9:1, 2253082, DOI: [10.1080/20548923.2023.2253082](https://doi.org/10.1080/20548923.2023.2253082)

To link to this article: <https://doi.org/10.1080/20548923.2023.2253082>



© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



[View supplementary material](#)



Published online: 25 Sep 2023.



[Submit your article to this journal](#)



[View related articles](#)



[View Crossmark data](#)

Direct dating confirms the presence of otter and badger in early Holocene Ireland

Robert C. Power ^{a,b}, Ingelise Stuijts^c, Finbar McCormick^d and Sahra Talamo ^{b,e}

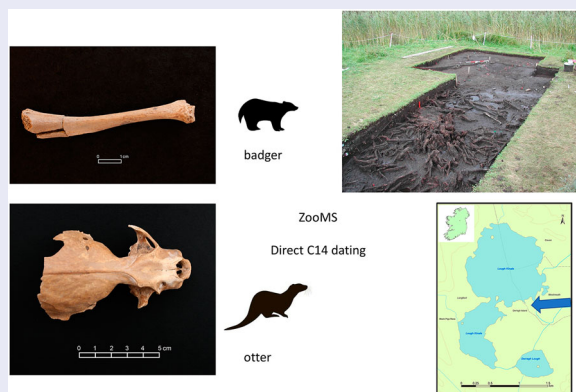
^aSchool of Archaeology, University College Dublin, Dublin, Ireland; ^bDepartment of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany; ^cThe Discovery Programme, Dublin, Ireland; ^dSchool of Geography, Archaeology and Palaeoecology, Queen's University Belfast, Belfast, UK; ^eDepartment of Chemistry G. Ciamician, Alma Mater Studiorum Bologna University, Bologna, Italy

ABSTRACT

The origin of Ireland's fauna is an unresolved issue in the history of the island. Although researchers once considered Ireland's mammals to have spread to Ireland during the early postglacial from 11,700 cal BP, research has increasingly suggested humans translocated many of these species to Ireland. However, due to sparse evidence, the origin of Ireland's purported native mustelid species remains unanswered. In this study, we shed light on the history of otter and badger in Ireland by directly dating suspected early examples of these species from Derragh, Co. Longford, a late Mesolithic campsite. The results demonstrate that both of these species have been present in Ireland for at least 7000–8000 years. It is not clear if they represent self-colonisers or Mesolithic anthropogenic translocations. Although these finds do not rule out local extinction and later reintroduction, they show that we can no longer assume they are solely late Holocene introductions.

KEYWORDS

Biogeography; anthropogenic translocations; archaeofaunal analysis; colonisation history; Mesolithic; human-environment interactions





Introduction


The limited number of animal taxa that occur in Ireland has been a source of comment for hundreds of years (Cróinín 2016; Wright 2000; Mitchell and Ryan 2001; Montgomery et al. 2014; van Wijngaarden-Bakker 1989). Differences between terrestrial mammal taxa in Ireland and mainland Europe have been believed to be a result of a peculiar postglacial recolonisation during the deglaciation of northwest Europe that cut off Ireland from mainland Europe far earlier than Britain was cut off from mainland Europe.

Past researchers have speculated that long disappeared late-surviving landbridges may have once

existed (Devoy 1995; Yalden 1981). These connections, possibly composed of gravel or ice connecting Ireland to Scotland or Wales, would have allowed fauna recolonisation during the postglacial period (Yalden 1981). Even taking into account the challenges of recolonisation via shifting low-lying landbridges that might restrict some species more than others, this landbridge model fails to explain the unusual composition of fauna found in early Holocene Ireland (Carden et al. 2012; Woodman, McCarthy, and Monaghan 1997).

Oceanographers now believe that post-Last Glacial Maximum sea-level rise cut off Ireland from the island of Britain and continental Europe before 19 kya, long before deglaciation (Corbet 1961;

CONTACT Robert C. Power  r.c.power@uamail.ucc.ie  School of Archaeology, University College Dublin, Dublin, UK; Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, Leipzig 04103, Germany

 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/20548923.2023.2253082>

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

Table 1. Earliest evidence of Irish mammal species, excluding bats as they may have used airborne dispersals. Three categories of fossil evidence are listed including the least strong e.g. culturally dating, which is subject to erroneous associations due to layer remixing, and strongest (directly dated), in addition genetic evidence is presented.

Taxa	Associated with culturally dated material	Fossil evidence		Genetic evidence	Citation
		Associated with C^{14} dated material	Directly C^{14} dated		
brown bear <i>Ursus arctos</i> Linnaeus, 1758	–	–	Early Mesolithic	Glacial survival	Woodman (2015)
mountain hare <i>Lepus timidus hibernicus</i>	–	Early Mesolithic (secure context)	–	Glacial survival	Woodman (1985)
Eurasian stoat <i>Mustela ermine</i> Bell 1837	–	–	Early Mesolithic	Glacial survival	Martínková, McDonald, and Searle (2007); Woodman, McCarthy, and Monaghan (1997) Woodman (1985)
wolf <i>Canis lupus</i> Linnaeus, 1758	–	Early Mesolithic (secure context)	–	–	–
wild pig <i>Sus scrofa</i> Linnaeus, 1758	–	Early Mesolithic	Early Mesolithic	–	Woodman (1985)
Lynx <i>Felis lynx</i> Linnaeus, 1758	–	–	Early Mesolithic	–	Woodman, McCarthy, and Monaghan (1997)
wild cat <i>Felis silvestris</i> Schreber, 1777	Mesolithic (unsecure context)	Early Mesolithic	–	–	Ryan (1980); Scharff 1906a)
Otter <i>Lutra lutra</i> Linnaeus, 1758	–	Mesolithic layer	–	Long established	Sleeman (2014); Spindler (2018)
badger <i>Ursus meles</i> Linnaeus, 1758	–	Mesolithic/ Neolithic/ Medieval	Early medieval	Neolithic-Medieval	Frantz et al. (2014); McCormick (1999); Sleeman (2014)
<i>Martes martes</i> Linnaeus, 1758	–	–	Late Bronze Age	–	Woodman, McCarthy, and Monaghan (1997)
red fox <i>Vulpes vulpes</i> Linnaeus, 1758	–	Early Bronze age	–	Early post glacial colonisation	McCormick (1999); Allan D. McDevitt et al. (2022)
red squirrel <i>Sciurus vulgaris</i> Linnaeus, 1758	–	–	–	–	McCormick (1999)
wood mouse <i>Apodemus sylvaticus</i> Linnaeus, 1758	–	Early Mesolithic	–	–	Preece, Coxon, and Robinson (1986)
pygmy shrew <i>Sorex minutus</i> Linnaeus, 1766	–	–	–	mid to late Holocene	Mascheretti et al. (2003)

Mitchell 1963; Montgomery et al. 2014). Advances in benthic imaging show that the last landbridge or ice-bridge connecting the island of Ireland to Scotland and the European mainland were flooded sometime before 15 kya when cold climatic conditions on the island still only supported subarctic mammal fauna (Clark et al. 2012; Edwards and Brooks 2008). This history of biogeographic isolation contrasts sharply with much of northwest Europe which remained accessible for mammalian recolonisation for much longer, for example, the island of Britain remained connected to Continental Europe until to 8 kya or later (Weninger et al. 2008). Ireland's early separation left its mark on the distinct history of human and fauna occupations. The documented human history of the island was shorter than elsewhere in Europe and entirely lacks a Lower and a Middle Palaeolithic. While an Upper Palaeolithic human presence predating the Mesolithic is confined to rare examples of worked faunal bone (Dowd and Carden 2016; Woodman 2015). Rising seas resulted in a notably lower number of mammalian recolonisation events than elsewhere in northwest Europe. Current scholarship implies a “prey gap”, an ecosystem that was disproportionately rich in carnivores (wolf (*Canis lupus*), bear (*Ursus arctos*), lynx (*Lynx*

lynx), wild cat (*Felis silvestris*), stoat (*Mustela ermine*)) with few herbivores (wild pig (*Sus scrofa*), hare (*Lepus timidus*), and wood mouse (*Apodemus sylvaticus*)) (Kitchener 2012; Sleeman 2008).

The lack of any landbridges or icebridges in a climate window suitable for recolonisation of temperate-type non-flying terrestrial mammals means that the origin of Ireland's fauna has been an unsolved question for biogeography and archaeology studies (Edwards and Brooks 2008). A number of these species such as the mountain hare, Eurasian stoat, otter (*Lutra lutra*), and badger (*Meles meles*), exhibit morphological and behavioural traits unique to Ireland, suggesting a longer split from European populations (Dadd 1970; Lynch 1996; Lynch and O'Sullivan 1993; O'Sullivan, Sleeman, and Murphy 1992; Sleeman and Davenport 2016).

There is evidence to conclude that several fauna is either cold-tolerant pre-Holocene survivals, i.e. stoat, mountain hare and the now extirpated brown bear (*Ursus arctos*), or were early Holocene recolonisers from cryptic refugia. However, there is insufficient archaeozoological evidence of many species including otter, badger, red fox (*Vulpes vulpes*), pine marten (*Martes martes*) and red squirrel (*Sciurus vulgaris*). This has resulted in research placing an increasing



Figure 1. Location of sites with extant evidence of mammals mentioned in the text.

emphasis that many of these species are a more recent part of the Irish landscape than once thought (Table 1) (Allen et al. 2020; Frantz et al. 2014; McDevitt et al. 2011; O'Meara et al. 2012; Woodman 2012; Yalden 1999). Archaeologists have found traces of these species such as otter from Mesolithic/Bronze Age levels at Moynagh Crannog, Co. Meath and Early Bronze Age levels (UB3682, 3587 ± 36 BP) at False Bay, Co. Galway and remains of badger from believed Early Bronze Age levels at Lough Gur Co. Limerick (McCormick 1999; McCormick et al. 1996; Murray 1996). A morphologically unclear tibia was found in secondary Mesolithic and Neolithic deposits at Derragh. This was identified with Zooarchaeology by Mass Spectrometry (ZooMS) as badger (Spindler

2018) (Figures 1 and 2; Supplementary figure 1). The earliest directly-dated badger remains so far are confined to the medieval period (Killuragh Cave, Co. Limerick; UB 18614, ^{14}C Age 1554 ± 27 BP) (Woodman et al. 2017), while no otter remains have been dated. Fossil taxa that are dated by their association with culturally and radiocarbon dated deposits often represent intrusive finds from more recent periods. This is particularly likely given that many of these taxa including otter and badger, either are burrowing mammals or reuse existing burrows, both of which frequently disturb and mix archaeological layers. Researchers have, using the fossil and the genetic record, speculated that many of the taxa once assumed to be native, may be early to mid-Holocene



Figure 2. Location of Derragh, Co. Longford. Inset map on the top left shows the location of Derragh on the island of Ireland.

introductions, brought to Ireland by boat for fur or other purposes (Lynch 1996; Lynch and O’Sullivan 1993; Mallory 2013; Montgomery et al. 2014; Woodman 2008). In some cases, such as the badger, researchers have suggested an introduction as recent as the medieval period (Monaghan 2017) and while genetic data has been interpreted as suggesting both natural colonisation (O’Meara et al. 2012) and colonisation through a series of waves with human aid via Britain (Allen et al. 2020; Guerrero et al. 2018). While the otter has been suggested to self-recolonise during the Bronze Age (Searle 2008). These interpretations challenge their status as native mammals and

may impact how ecologists design conservation policy around these species.

To elucidate the origin and phylogeographic history of Irish mustelids, we applied direct ^{14}C dating, and dietary stable isotope analysis on early mustelids remains that could be possibly intrusive to the Derragh archaeological site. These include an unmodified cranium identified as otter morphologically and an unmodified badger tibia identified morphological and with ZooMS from early Holocene deposits at the lakeside site of Derragh in Co. Longford (Fredengren 2007; McCarthy and McCormick 2018; Perri, Power, Stuijts, et al. 2018; Spindler 2018). We then

Table 2. Fauna remains analysed by the study.

Find id	Level	Context	Context overview	Layer cultural association	Taxa	Element
B563	D	93	A peat context including blades and flakes, one core and debitage	Mesolithic	<i>Otter (Lutra lutra)</i>	cranium
B493	H/I	38	A coarse sand and gravel layer with wood and bones. It is contemporary with the stone and gravel platform.	Mesolithic	<i>Badger (Meles meles)</i>	Immature tibia

performed species accumulation analysis, a common methodology in ecology to measure representativeness of sampling (Gotelli and Colwell 2001), on the number of taxa recovered from all mammal assemblages to document, if sufficient zooarchaeological remains have been found to estimate Mesolithic faunal diversity in Ireland.

Site and materials: site background, stratigraphy, and dating

The Derragh site (Irish: Doire Each; Co. Longford; 53.772, -7.403) is a former lake island, located at Derragh lough in the Irish Midlands, about 66 km from present-day sea shorelines. It is currently on a lake-shore, lying at the junction of Lough Kinale, Derragh Lough and the outlet of the River Inny, a tributary of the River Shannon. The archaeological potential at the site was detected after exposed Bann flakes were discovered in the 1970s (O'Sullivan 1998). The full extent of the site was exposed following lake drainage programmes. The Discovery Programme surveyed the site in 2002 and excavated over several weeks in the summers of 2003–2005 (Fredengren 2002; 2007; 2009; Fredengren, Kilfeather, and Stuijts 2010). Excavation of the site identified a stake structure, a hollow, three hearths and ash and hazelnut spreads dating to 7424–7020 cal BP. Worked oak planks overlaid this layer, which was sunk under more hazelnut shell spreads dating to 6890–6650 cal BP. Above these deposits lay a platform-like layer of stones with abundant archaeological evidence, including lithics, animal bones, including modified bones of wild pig and bear, dating to 6950–5970 cal BP (McCarthy and McCormick 2018; Perri, Power, Stuijts, et al. 2018). Lithic specialists argue that the weathering of the tools in this layer indicates secondary deposition (Sternke and Woodman 2006). The earliest date from primary deposits is a piece of oak charcoal underneath this layer dated 7620–7670 cal BP (McCarthy and McCormick 2018; Perri, Power, Stuijts, et al. 2018). Aside from some probable lithic evidence of Early Mesolithic occupation, the overwhelming amount of artefactual

evidence suggests a series of ephemeral Late Mesolithic to Early Neolithic occupations (Fredengren 2002; 2007; 2009; Perri, Power, Stuijts, et al. 2018; Perri, Power, and Heinrich 2018; Power 2018).

Methods

The bone samples (B493 and B563; Supplementary figure 2, 3) were pretreated at the Department of Human Evolution at the Max Planck Institute for Evolutionary Anthropology (MPI-EVA), Leipzig, Germany, using conventional methods (Talamo and Richards 2011). The outer surface of the bone samples was first cleaned by a shot blaster, and then 500 mg of the whole bone was taken. The samples were then decalcified in 0.5M HCl at room temperature until CO₂ effervescence ceased. Subsequently, 0.1M NaOH was added for 30 min to remove humics. The NaOH step was followed by a final 0.5M HCl step for 15 min. The resulting solid was gelatinised (Longin 1971) at pH3 in a heater block at 75°C for 20 h. The gelatine was then filtered in an Eeze-Filter™ (Elkay Laboratory Products (UK) Ltd.) to remove small (>80 µm) particles. The gelatine was then ultrafiltered (Brown et al. 1988) with Sartorius “VivaspinTurbo” 30 KDa ultrafilters. Prior to use, the filter was cleaned to remove carbon containing humectants (Brock, Ramsey, and Higham 2007). The samples are lyophilised for 48 h. All dates were corrected for a residual preparation background estimated from ¹⁴C free bone samples. These bones were kindly provided by the Mannheim laboratory and pretreated in the same way as the archaeological samples (Korlević, Talamo, and Meyer 2018).

The preservation of the collagen was ensured by only evaluating samples with a yield of collagen not less than 1%, C:N ratios (between 2.9 and 3.6), together with isotopic values were (van Klinken 1999). The isotopic values were obtained as a single run at MPI-EVA (Lab Code R-EVA) on a ThermoFinnigan Delta V Advantage isotope ratio mass spectrometer (IRMS) coupled to a Flash 2000 EA. Stable

Table 3. AMS radiocarbon dates $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values. Dates are calibrated at the 2-sigma confidence with the IntCal20 curve (Reimer et al. 2013), in the OxCal programme (Bronk Ramsey 2009).

AMS Nr.	Taxa	% Collagen	¹³ C	¹⁵ N	%C	%N	C:N	¹⁴ C Age	1s Err	cal BP (95.4%)
MAMS-34673	<i>Otter (Lutra lutra)</i>	18.5	-23.1	10.5	46.3	16.6	3.2	6815	28	7688–7588
MAMS-42400	<i>Badger (Meles meles)</i>	8.03	-19.9	11.36	40.5	15.62	3.4	6147	29	7158–6951

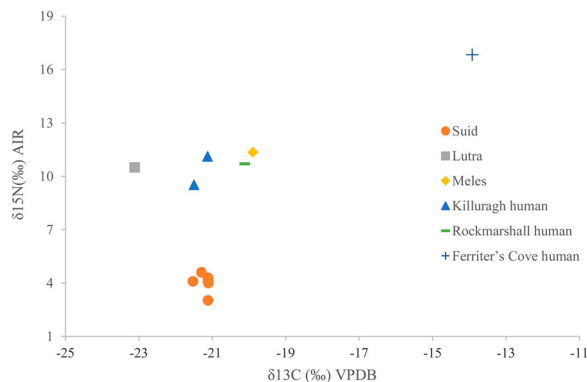


Figure 3. Carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope ratio values from otter and badger remains with other fauna and humans values from the Irish Mesolithic.

carbon isotope ratios are expressed relative to VPDB (Vienna PeeDee Belemnite) and stable nitrogen isotope ratios were measured relative to AIR [atmospheric N_2 with an analytical error of 0.2‰ (1σ) for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$]. After passing the quality criteria between approximately 5–6 mg of collagen was weighed into pre-cleaned tin cups and sent to the Klaus-Tschira-AMS centre, Mannheim, Germany (lab code: MAMS). Samples were then combusted in an Elemental Analyser and CO_2 converted catalytically to graphite and dated using the MICADAS-AMS (Kromer et al. 2013).

Lastly, we conducted sample-based species accumulation analysis (collectors curve) with a logarithmic function on the number of mammalian species detected in Mesolithic zooarchaeological assemblages, including land and marine mammals to ascertain if current diversity estimates are reliable. To do this we sourced the number of archaeological sites with in situ and reworked Mesolithic deposits from published sources including the database of Irish Excavation Reports (Excavations.ie.). Reports with deposits described as “possibly Mesolithic” were omitted but sites described as “Mesolithic” or “probably Mesolithic” were included (Supplementary table 1).

Results

Radiocarbon dating

The results place the two specimens at 95.4% probability (otter = 7688–7588 cal BP, badger = 7158–6951 cal BP) firmly in the Late Mesolithic period, corresponding to cultural and ^{14}C dates from this layer (Table 2). The otter is significantly older than reported dates from hazel brushwood from the same context 65 which overlays context 93 (Ua-32383 = 7470–7310 cal BP). It is also considerably older than the earliest date of the sequence, oak charcoal under the stone layer (GrN-26351 = 6480 \pm 40 BP)

(Fredengren n.d.). Although much older giant deer fragments occur at the site and are found in a layer above context 65, their human modification despite being extinct in the Mesolithic and direct dating show these represent secondary deposition (UBA-26786 10199 \pm 49 BP) (Fredengren n.d.). The incongruously early date of the otter is probably linked to the “Old Carbon Effect”. The freshwater Old Carbon Effect is poorly understood and its impact may be highly variable. Without more environmental information, it cannot be corrected for in this assemblage in the scope of this project; however, most research suggests its effect may only distort a date a few centuries and an age shift of 1200 uncal years as observed is improbable (Hart et al. 2019; Keaveney and Reimer 2012), while the badger yielded a date significantly older than dated bear bone (Ua 35464 = 5540 \pm 50 BP) and Neolithic cattle bone (Ua 35463 = 4860 \pm 45 and UBA 26784 = 5082 \pm 39 BP) from context 38, but this is expected given reworking that is evident in context 38 (McCarthy and McCormick 2018).

Carbon and nitrogen stable isotope ratio dietary reconstruction

The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results are presented in Table 3 and plotted in Figure 3. Their %C, %N and C:N elemental ratio values show sufficient collagen survival to infer dietary values (Ambrose and Norr 1993; van Klinken 1999). The otter’s $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, a carnivore, are -23.1‰ and 10.5‰ , are consistent with a diet that is contrasting with other studied taxa and shows it obtained its protein from a different source, likely from aquatic animals. The badger’s $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are -23.57‰ and 11.36‰ . Badgers are omnivorous and eat a high diversity of food items. The badger’s diet is trophically similar to the Rockmarshall Mesolithic forager. It is likely to have had an omnivorous diet comprised of terrestrial plant and animal foods.

Species accumulation analysis

Collation of published Mesolithic site data identified 115 sites on the island of Ireland with evidence of Mesolithic occupation. 30 sites with mammal assemblages were identified in which nine species were present. The resulting curve does not plateau (Figure 4). This indicates that current sample sizes of mammals on Mesolithic sites are not too limited to calculate Mesolithic species diversity. This indicates that mammal diversity is currently a function of sampling effort.

Discussion

The radiocarbon dates show that badger and otter were present in Ireland from at least the Later

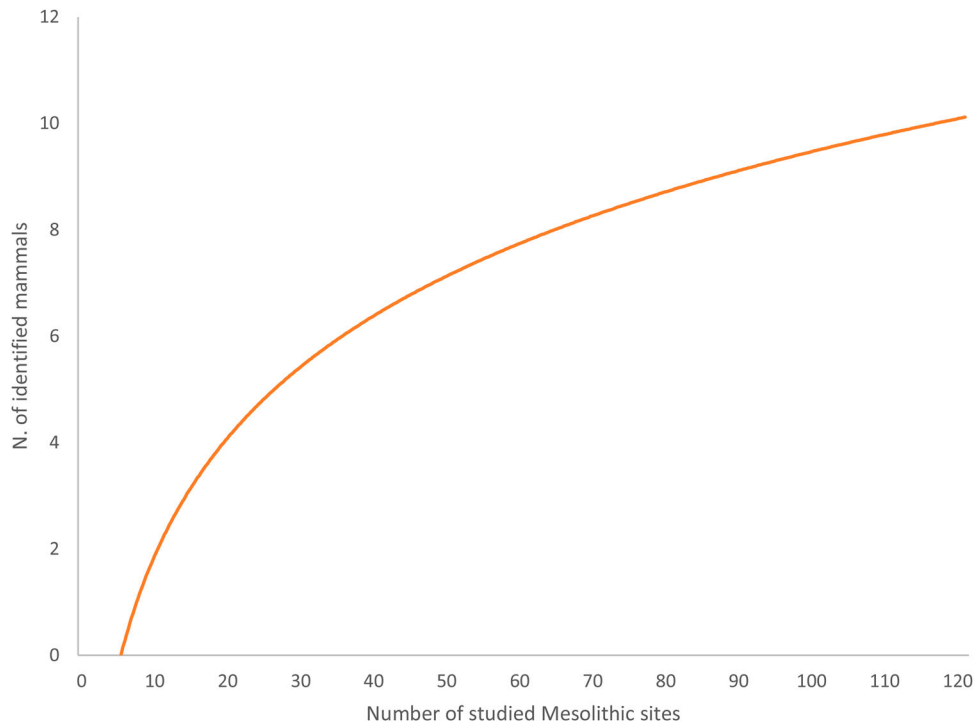


Figure 4. A species accumulation curve with a logarithmic function of the number of identified mammals detected on Mesolithic sites (12 species) indicates there is a likelihood of undetected early Holocene species. Includes seal and dolphin. This analysis does not take into account of multiple examples of a species on a site.

Mesolithic, and that otter may have been present from the end of the Early Mesolithic. The remains of otters, badgers and other mustelids are rare on Irish archaeological sites. Only the remains of stoat has been so far identified in Mesolithic deposits and directly dated, but it is not clear if they represent an anthropogenic or a natural deposit (Woodman, McCarthy, and Monaghan 1997). However, if Mesolithic foragers only valued this species for fur, they may have processed with out-of-camp butchery, resulting in less skeletal remains deposited on archaeological sites. However, elsewhere in the Mesolithic world, mustelid remains are less rare, for example, at Jutland where pine marten and otters were a large proportion of the faunal assemblage (Andersen 1973). Across Mesolithic Europe, pine marten with cut-mark evidence of skinning is frequent (Llorente-Rodríguez et al. 2016). Unlike other regions of Europe, Mesolithic faunal assemblages in Ireland have an extremely low number of identified specimens, and this contributes to the difficulty detecting these species in Ireland. The species accumulation curve shows that faunal assemblages have low species diversity and that although wild pigs will not be missed, our knowledge of rarer Mesolithic prey, non-staples is heavily influenced by chance finds (Figure 4). This hints that new fieldwork that identifies early Holocene zooarchaeological assemblages could yield so far unrecovered species.

The unmodified nature of the remains means that we cannot identify if Mesolithic people hunted otter

and badger at Derragh; while the early dates could mean that these remains were earlier deposits which were being used as a utilitarian source of materials or for ritualistic purposes. Even more parsimonious is the possibility that they simply are part of reworked deposits containing natural remains. It is already clear that at Derragh and other contemporary Irish Mesolithic sites, people retrieved and modified skeletal remains of the Pleistocene species giant deer (*Megaloceros giganteus*), which was already extinct for several thousand years (Warren 2017; Woodman 2012). Occupants of Mesolithic layers chopped the back of the skull for unknown reasons (McCarthy and McCormick 2018). Given that the otter skull may have been hundreds of years old when deposited, it is possible that the occupants of the site curated old otter and giant deer skulls for symbolic purposes, such as totems or it could simply represent an otter that died naturally. Although badgers are unlikely to occupy the immediate lakeshore environment due to their dislike of waterlogged environments, the otter would have been at home in the immediate surrounds which likely offered salmonids and eel (Perri, Power, and Heinrich 2018). Unlike otters, badgers avoid digging setts in waterlogged environments and the Derragh badger remain seems likely to have been brought to the site. Although Mesolithic transport and curation of a wide variety of skeletal elements from small fauna are well known, motives are often unclear (Overton 2014; 2016).

The dietary analysis provides lessons on the dietary ecology of badger and otter. The otters depleted $\delta^{13}\text{C}$ bone collagen stable isotope values show the otter probably consumed a freshwater diet, which is clearly distinct from that of extant human Mesolithic individuals. The values are similar to other studied Eurasian otters and indicate anadromous fish were not an important part of its diet (Drucker and Bocherens 2004). Its diet may have included non-anadromous salmonids, eel, stickleback, freshwater mussels and invertebrates, but it cannot be clarified (Ottino and Giller 2004). Badger $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values show an omnivorous diet similar to human values identified with inland Mesolithic people at Killuragh Cave, Co. Limerick and Loughan Island and the coastal site of Rockmarshall, Co. Louth, in contrast to the marine Mesolithic diets evident from enriched $\delta^{13}\text{C}$ at Ferriter's Cove, Co. Kerry. Past studies of stable isotopes of badgers have provided evidence of similar diets, as well as contrasting low trophic level diets too (Robertson et al. 2015; Villalba-Mouco et al. 2018). Badgers ecosystem engineers who influence nutrient cycling, and seed dispersal, particularly of large-seeded fruit and this may have implications for understanding other species on this island (Kurek et al. 2022).

The Derragh otter and badger bring the number of species present since the Mesolithic period to at least nine, even though genetic evidence based on DNA and morphology has been interpreted as suggesting that several of these were later arrivals. These lines of evidence may not be contradictory. Present-day populations of badger and otter may represent more recent colonisations that replaced, or admixed with initial founder populations or colonised empty landscapes following local extinction. Thus, extant populations of otters and badgers are not necessarily descended from the populations represented at Derragh. Cycles of colonisation and extinction have been suggested for Irish species such as the red squirrel (Fairley 1975). As a carnivore and omnivore species respectively, the addition of these two Mustelid species to lists of Mesolithic fauna do not help to explain the "prey gap", the seemingly disproportionately balance of predators (eight) to prey (four). In many cases, evidence of later arrivals is scant, and the apparent presence of a "prey gap" in the early Holocene may be due to insufficient archaeozoological assemblages (Kitchener 2012; Sleeman 2008). Ecologists have predicted that further prey species will be detected (Sleeman 2008).

The presence of otter and badger in Early Holocene Ireland has implications for biogeographical models that compare similarities of Irish fauna with other European faunas (Montgomery et al. 2014). It is possible that otters were translocated to Ireland, perhaps as cubs to provide fur for Mesolithic peoples but this is entirely conjectural. It has been observed that Irish

otters often show white pelage spots, which is a sign of domestication (Sleeman, pers. comm.) (Scharff 1906b). Researchers have already suggested that human manipulation of wild species in Ireland may have begun even prior to the adoption of farming and has been suggested in the case of wild pig, land snails and potentially all species aside from stoat and hare (Grindon and Davison 2013; Warren 2013; Woodman and McCarthy 2003). Human management may have extended beyond simple translocation, and it has been suggested that Mesolithic hunters conserved wild pigs through avoidance of hunting mature females (McCormick 2004). However, self-colonisation of mammals into Ireland must be considered as a serious possibility. Red fox, often thought to have been an ancient human-mediated species, has recently been suggested as an early post-glacial colonisation based on analysis of their genetic structure (McDevitt et al. 2022). Closely related species of otters have been observed to forage in marine waters up to 13 km offshore, while Scotland today only lies about twice this distance from parts of northeast Ireland, at the beginning of the Holocene it was several kilometres less (Blundell, Ben-David, and Bowyer 2002; Finnegan and Néill 2010; Woodman 2015). Recolonisation from cryptic refugia may have also occurred. Otters probably were readily able to self-colonise through dispersing into Ireland from the narrow sea channel between Scotland and north eastern Ireland. Badger dispersal over sea barriers is harder to understand. Red fox, often thought to have been an ancient human-mediated species, has recently been suggested as an early post-glacial coloniser about 16,000 years ago from Britain, based on analysis of their genetic structure (McDevitt et al. 2022). While red foxes may have self-colonised through routes open to badgers, they would have intensely cold open environments. Red foxes are more tolerant of cold environments than badgers, and would be a better candidate to disperse at this early date. Badger swimming ability is poorly documented but is believed to occur and North American badgers have been observed swimming 800 m from lakeshores (Duebber 1967; Kirkwood 2009; Sleeman, Cussen, and O'Leary 2002), while Irish badgers are known to swim and cross beaches (Sleeman, O'Leary, and Cussen 1999). It is unknown if Eurasian badgers could swim further distances, and if this possible in saltwater conditions. For badgers, human translocations may still be argued to represent a highly plausible origin. Nor can we rule out self-recolonisation from cryptic refugia. Released badgers would have represented a source of meat and fur to Mesolithic foragers who aside from wild pigs were largely bereft of terrestrial meat-bearing mammals. Although historical evidence would suggest that badger was not a major source of fur and meat in traditional Irish societies, there is evidence of their occasional use, i.e.

reference to *saill bruicc a Bérrre* “salted badger meat” in a twelfth-century poem (Kelly 1997). An early seventeenth century text states that “its flesh is not unpleasant to eat nor its pelt to be despised. It is reported that it is helpful against the spell of the evil eye. Because of this, tongs of hair made from the skin are added to the bridles of baggage animals” (O’Sullivan 2009). Another Irish source (Rutty 1772) notes that “the flesh, when roasted, is good food, like pig’s flesh, and makes a good ham; and the skin is tanned for breeches, waistcoats, etc.” Consumption of badger meat has been cited as motivation for translocation in the Mediterranean Neolithic world. In the Mediterranean it is believed badgers were introduced onto Crete by Neolithic peoples (Groves 1989; Vigne 1999) and cut marked remains testify to the regular use of this species.

Conclusions

The directly dated remains transform our knowledge of the presence of badger and otter in the Holocene. The results show that these species were present in Ireland since at least 7000 BP, and that Mesolithic faunal diversity was higher than thought. It is plausible that otters self-colonised Ireland, but it is less clear if badgers may have self-colonised. Due to the difficulties in self-colonisation, badgers may have been sufficiently valued to have been translocated to the island.

While the addition of this carnivore and omnivore, do not solve the “prey gap”, they indicate a more complex ecology that was more similar to other regions of Europe. While isotopically the otter displays a distinct and likely freshwater diet, the badger remains indicate a more mixed diet including plants and animal foods, tropically comparable to Irish Mesolithic foragers. Mesolithic people could have hunted these species, and brought their remains to the site. The wet nature of the environment suggests that at least badger remains was introduced to the Derragh site by people, but due to the lack of cutmarks this cannot be clarified.

Acknowledgements

We thank excavator Christina Fredengren and fieldworkers Dom Gallagher and Claire Anderson. We thank Heiko Temming for photography, and Domingo Carlos Salazar García, Luke Spindler, Paula Reimer, Marion Dowd, Angela Perri and Emily Murray for their support, Geoff Smith for reference collection support, Pat Mier Camarena for photo-shop, and we are grateful to David Stone, John O’Keefe, Denise O’Meara, Paddy Sleeman, Connor and Ted Walsh for the feedback on our article. We thank Marlen Sureck for graphical assistance. Thanks to National Museum of Ireland for assistance with sampling permissions. The samples were collected and analysed using a Licence to Alter 6230 and a Licence to Export 6230 under the terms of the National Monuments Acts 1930 to 2014.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by The Max Planck Society and the Discovery Programme.

Notes on contributors

Dr. Robert C. Power is a postdoctoral archaeologist at the School of Archaeology, University College Dublin. His research investigates human diet and adaptation in Eurasia and Africa.

Dr. Ingelise Stuijts is an independent environmental archaeologist who is affiliated with the Discovery Programme of Ireland. She specialises in reconstructing environments and human behaviours with pollen, wood and charcoal in prehistoric and historic Ireland as well as in other regions.

Dr. Finbar McCormick is a retired senior lecturer in the School of Natural & Built Environment in Queens University Belfast. His principle area of research is the settlement and economy in Early Medieval Ireland but he also has a long-standing interest in the mammalian history of Ireland.

Prof. Sahra Talamo is a professor in the Department of Chemistry CHIM in the University of Bologna where she runs a radiocarbon dating laboratory. She is interested in refining chronologies of human expansions in Eurasian as well as the population history of archaics.

ORCID

Robert C. Power  <http://orcid.org/0000-0001-7425-5709>
Sahra Talamo  <http://orcid.org/0000-0002-2406-3132>

References

- Allen, A., J. Guerrero, A. Byrne, J. Lavery, E. Presho, E. Courcier, J. O’Keeffe, et al. 2020. “Genetic Evidence Further Elucidates the History and Extent of Badger Introductions from Great Britain Into Ireland.” *Royal Society Open Science* 7 (4): 200288. <https://doi.org/10.1098/rsos.200288>.
- Ambrose, S. H., and L. Norr. 1993. “Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate.” In *Prehistoric Human Bone*, edited by J. B. Lambert, and G. Grupe, 1–37. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-662-02894-0_1.
- Andersen, S. H. 1973. “Ringkloster, en jysk inlandsboplads med Ertebøllekultur” [Ringkloster, an Inland settlement on Jutland with Ertebølle Culture Remains]. *Kuml* 23 (23): 11–108.
- Blundell, G. M., M. Ben-David, and R. T. Bowyer. 2002. “Sociality in River Otters: Cooperative Foraging or Reproductive Strategies?” *Behavioral Ecology* 13 (1): 134–141. <https://doi.org/10.1093/beheco/13.1.134>.
- Brock, F., C. B. Ramsey, and T. Higham. 2007. “Quality Assurance of Ultrafiltered Bone Dating.” *Radiocarbon* 49 (2): 187–192. <https://doi.org/10.1017/S0033822200042107>.

- Bronk Ramsey, C. 2009. "Bayesian Analysis of Radiocarbon Dates." *Radiocarbon* 51 (1): 337–360. <https://doi.org/10.1017/S0033822200033865>.
- Brown, T. A., D. E. Nelson, J. S. Vogel, and J. R. Southon. 1988. "Improved Collagen Extraction by Modified Longin Method." *Radiocarbon* 30 (2): 171–177. <https://doi.org/10.1017/S0033822200044118>.
- Carden, R. F., A. D. McDevitt, F. E. Zachos, P. C. Woodman, P. O'Toole, H. Rose, N. T. Monaghan, M. G. Campana, D. G. Bradley, and C. J. Edwards. 2012. "Phylogeographic, Ancient DNA, Fossil and Morphometric Analyses Reveal Ancient and Modern Introductions of a Large Mammal: The Complex Case of red Deer (*Cervus Elaphus*) in Ireland." *Quaternary Science Reviews* 42: 74–84. <https://doi.org/10.1016/j.quascirev.2012.02.012>.
- Clark, J., A. M. McCabe, D. Q. Bowen, and P. U. Clark. 2012. "Response of the Irish Ice Sheet to Abrupt Climate Change During the Last Deglaciation." *Quaternary Science Reviews* 35: 100–115. <https://doi.org/10.1016/j.quascirev.2012.01.001>.
- Corbet, G. B. 1961. "Origin of the British Insular Races of Small Mammals and of the 'Lusitanian' Fauna." *Nature* 191 (4793): 1037–1040. <https://doi.org/10.1038/1911037a0>.
- Cróinín, D. 2016. *Early Medieval Ireland, 400–1200*. Routledge. <https://doi.org/10.4324/9781315558783>.
- Dadd, M. N. 1970. "Overlap of Variation in British and European Mammal Populations." *Symposia of the Zoological Society of London* 24: 117–124.
- Devoy, R. J. N. 1995. "Deglaciation, Earth Crustal Behaviour and Sea-Level Changes in the Determination of Insularity: A Perspective from Ireland." *Geological Society, London, Special Publications* 96 (1): 181–208. <https://doi.org/10.1144/GSL.SP.1995.096.01.14>.
- Dowd, M., and R. F. Carden. 2016. "First Evidence of a Late Upper Palaeolithic Human Presence in Ireland." *Quaternary Science Reviews* 139: 158–163. <https://doi.org/10.1016/j.quascirev.2016.02.029>.
- Drucker, D., and H. Bocherens. 2004. "Carbon and Nitrogen Stable Isotopes as Tracers of Change in Diet Breadth During Middle and Upper Palaeolithic in Europe." *International Journal of Osteoarchaeology* 14 (3–4): 162–177. <https://doi.org/10.1002/oa.753>.
- Duebber, H. F. 1967. "Swimming by a Badger." *Journal of Mammalogy* 48 (2): 323. <https://doi.org/10.2307/1378046>.
- Edwards, R., and A. Brooks. 2008. "The Island of Ireland: Drowning the Myth of an Irish Land-Bridge?" *Mind the Gap: Postglacial Colonisation of Ireland; The Irish Naturalists' Journal* 29: 19–34. <http://www.jstor.org/stable/20764499>.
- Fairley, J. S. 1975. *Irish Beast Book*. Blackstaff Press. <http://agris.fao.org/agris-search/search.do?recordID=US201300531802>.
- Finnegan, L. A., and L. Ó. Néill. 2010. "Mitochondrial DNA Diversity of the Irish Otter, *Lutra Lutra*, Population." *Conservation Genetics* 11 (4): 1573–1577. <https://doi.org/10.1007/s10592-009-9955-4>.
- Frantz, A. C., A. D. McDevitt, L. C. Pope, J. Kochan, J. Davison, C. F. Clements, M. Elmeros, et al. 2014. "Revisiting the Phylogeography and Demography of European Badgers (*Meles Meles*) Based on Broad Sampling, Multiple Markers and Simulations." *Heredity* 113 (5): 443–453. <https://doi.org/10.1038/hdy.2014.45>.
- Fredengren, C. 2002. "Discovery Programme in Lough Kinale." *Archaeology Ireland* 16 (4): 20–23.
- Fredengren, C. 2007. "Lake Settlement Project – from the Deep Waters." *Antiquity* 81 (Project Gallery).
- Fredengren, C. 2009. "Lake Platforms at Lough Kinale – Memory Reach and Place: A Discovery Programme Project in the Irish Midlands." In *Transition in North-West Europe*, edited by S. McCartan, R. J. Schulting, W. G. and P. C. Woodman, 882–886. Oxford: Oxbow Books.
- Fredengren, C., A. Kilfeather, and I. Stuijts. 2010. *Lough Kinale: Studies of an Irish Lake*. Dublin: Wordwell Ltd.
- Fredengren, C. n.d. "Derragh Mesolithic Excavations." In *Lake Settlement Project. The Discovery Programme*.
- Gotelli, N. J., and R. K. Colwell. 2001. "Quantifying Biodiversity: Procedures and Pitfalls in the Measurement and Comparison of Species Richness." *Ecology Letters* 4 (4): 379–391. <https://doi.org/10.1046/j.1461-0248.2001.00230.x>.
- Grindon, A. J., and A. Davison. 2013. "Irish Cepaea Nemoralis Land Snails Have a Cryptic Franco-Iberian Origin That Is Most Easily Explained by the Movements of Mesolithic Humans." *PLoS ONE* 8 (6): e65792. <https://doi.org/10.1371/journal.pone.0065792>.
- Groves, C. L. 1989. "Feral Animals of the Mediterranean Islands: Documents of Early Domestication." In *The Walking Larder: Patterns of Domestication, Pastoralism, and Predation*, edited by J. Clutton-Brock, 46–58. London: Unwin Hyman.
- Guerrero, J., A. W. Byrne, J. Lavery, E. Presho, G. Kelly, E. A. Courcier, J. O'Keeffe, et al. 2018. "The Population and Landscape Genetics of the European Badger (*Meles meles*) in Ireland." *Ecology and Evolution* 8 (20): 10233–10246. <https://doi.org/10.1002/ece3.4498>.
- Hart, J. P., R. S. Feranec, T. J. Abel, and J. L. Vavrsek. 2019. "Freshwater Reservoir Offsets on Radiocarbon-Dated dog Bone from the Headwaters of the St. Lawrence River, USA." *PeerJ* 7: e7174. <https://doi.org/10.7717/peerj.7174>.
- Keaveney, E. M., and P. J. Reimer. 2012. "Understanding the Variability in Freshwater Radiocarbon Reservoir Offsets: A Cautionary Tale." *Journal of Archaeological Science*. <https://doi.org/10.1016/j.jas.2011.12.025>.
- Kelly, F. 1997. *Early Irish Farming: A Study Based Mainly on the Law-Texts of the 7th and 8th Centuries AD*. Dundalk: Dundalgan Press Ltd.
- Kirkwood, R. 2009. "Badger Braves the Brine." *Veterinary Record* 165 (4): 122. <https://doi.org/10.1136/vetrec.165.4.122-b>.
- Kitchener, A. C. 2012. "Re-wilding Ireland: Restoring Mammalian Diversity or Developing New Mammalian Communities?" *The Irish Naturalists' Journal, All-Ireland*, 4–13. <https://doi.org/10.1016/j.biocon.2009.05.007>.
- Korlević, P., S. Talamo, and M. Meyer. 2018. "A Combined Method for DNA Analysis and Radiocarbon Dating from a Single Sample." *Scientific Reports* 8 (1): 4127. <https://doi.org/10.1038/s41598-018-22472-w>.
- Kromer, B., S. Lindauer, H.-A. Synal, and L. Wacker. 2013. "MAMS – A New AMS Facility at the Curt-Engelhorn-Centre for Archaeometry, Mannheim, Germany." *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 294: 11–13. <https://doi.org/10.1016/j.nimb.2012.01.015>.
- Kurek, P., Ł. Piechnik, B. Wiatrowska, A. Ważna, K. Nowakowski, X. Pardavila, J. Cichocki, and B. Seget. 2022. "Badger *Meles Meles* as Ecosystem Engineer and Its Legal Status in Europe." *Animals* 12 (7): 898. <https://doi.org/10.3390/ani12070898>.

- Llorente-Rodríguez, L., C. Nores-Quesada, J. A. López-Sáez, and A. Morales-Muñiz. 2016. "Hidden Signatures of the Mesolithic-Neolithic Transition in Iberia: The Pine Marten (*Martes martes* Linnaeus, 1758) and Beech Marten (*Martes foina* Erxleben, 1777) from Cova Fosca (Spain)." *Quaternary International* 403: 174–186. <https://doi.org/10.1016/j.quaint.2015.05.046>.
- Longin, R. 1971. "New Method of Collagen Extraction for Radiocarbon Dating." *Nature* 230: 241–242. <https://doi.org/10.1038/230241a0>.
- Lynch, J. M. 1996. "Postglacial Colonization of Ireland by Mustelids, with Particular Reference to the Badger (*Meles meles* L.)." *Journal of Biogeography* 23: 179–185. <https://doi.org/10.1046/j.1365-2699.1996.00961.x>.
- Lynch, J. M., and W. M. O'Sullivan. 1993. "Cranial Form and Sexual Dimorphism in the Irish Otter *Lutra lutra* L." *Biology and Environment: Proceedings of the Royal Irish Academy* 93: 97–105. <https://doi.org/10.2307/20499883>.
- Mallory, J. P. 2013. *The Origins of the Irish*. London: Thames and Hudson Ltd.
- Martínková, N., R. A. McDonald, and J. B. Searle. 2007. "Stoats (*Mustela erminea*) Provide Evidence of Natural Overland Colonization of Ireland." *Proceedings of the Royal Society B: Biological Sciences* 274 (1616): 1387–1393. <https://doi.org/10.1098/rspb.2007.0334>.
- Mascheretti, S., M. B. Rogatcheva, I. Gündüz, K. Fredga, and J. B. Searle. 2003. "How Did Pygmy Shrews Colonize Ireland? Clues from a Phylogenetic Analysis of Mitochondrial Cytochrome *b* Sequences." *Proceedings of the Royal Society of London. Series B: Biological Sciences* 270 (1524): 1593–1599. <https://doi.org/10.1098/rspb.2003.2406>.
- McCarthy, M., and F. McCormick. 2018. "The Faunal Remains from Derragh." In *The Quaternary Irish Midlands*, edited by G. McGlynn, I. Stuijts, and B. Stefanini, 215–227. Dublin: Digital Printing.
- McCormick, F. 1999. "Early Evidence for Wild Animals in Ireland." In *The Holocene History of the European Vertebrate Fauna: Modern Aspects of Research*, edited by N. Benecke, 355–371. Rahden: Verlag Marie Leidorf GmbH.
- McCormick, F. 2004. "Hunting Wild Pig in the Late Mesolithic." In *From Megaliths to Metals; Essays in Honour of George Eogan*, edited by H. Roche, and G. Eogan, 1–5. Oxford: Oxbow Books.
- McCormick, F., M. Gibbons, F. G. McCormac, J. Moore, D. Weir, and A. Sheridan. 1996. "Bronze Age to Medieval Coastal Shell Middens Near Ballyconneely, Co. Galway." *The Journal of Irish Archaeology* 7: 77–84.
- McDevitt, Allan D., I. Coscia, S. S. Browett, A. Ruiz-González, M. J. Statham, I. Ruczyńska, L. Roberts, et al. 2022. "Next-generation phylogeography resolves post-glacial colonization patterns in a widespread carnivore, the red fox (*Vulpes vulpes*), in Europe." *Molecular Ecology* 31 (3): 993–1006. <https://doi.org/10.1111/mec.16276>.
- McDevitt, A. D., R. Vega, R. V. Rambau, G. Yannic, J. S. Herman, T. J. Hayden, and J. B. Searle. 2011. "Colonization of Ireland: Revisiting 'The Pygmy Shrew Syndrome' Using Mitochondrial, Y Chromosomal and Microsatellite Markers." *Heredity* 107 (6): 548–557. <https://doi.org/10.1038/hdy.2011.41>.
- Mitchell, G. F. 1963. "Morainic Ridges on the Floor of the Irish Sea." *Irish Geography* 4 (5): 335–344. <https://doi.org/10.1080/00750776309555562>.
- Mitchell, G. F., and M. Ryan. 2001. *Reading the Irish Landscape*. Dublin: Town House.
- Monaghan, N. T. 2017. "Irish Quaternary Vertebrates." In *Advances in Irish Quaternary Studies*, edited by Peter Coxon, Stephen McCarron, and Fraser Mitchell, 255–291. Paris: Atlantis Press. https://doi.org/10.2991/978-94-6239-219-9_9.
- Montgomery, W. I., J. Provan, A. M. McCabe, and D. W. Yalden. 2014. "Origin of British and Irish Mammals: Disparate Post-Glacial Colonisation and Species Introductions." *Quaternary Science Reviews* 98: 144–165. <https://doi.org/10.1016/j.quascirev.2014.05.026>.
- Murray, E. 1996. "An Early Bronze Age Settlement Site at False Bay, Connemara." Unpublished BSc archaeology thesis, Queens University Belfast.
- O'Meara, D. B., C. J. Edwards, D. P. Sleeman, T. F. Cross, M. J. Statham, J. R. McDowell, E. Dillane, et al. 2012. "Genetic Structure of Eurasian Badgers *Meles meles* (Carnivora: Mustelidae) and the Colonization History of Ireland." *Biological Journal of the Linnean Society* 106 (4): 893–909. <https://doi.org/10.1111/j.1095-8312.2012.01927.x>.
- O'Sullivan, A. 1998. "The Archaeology of Lake Settlement in Ireland." In *Discovery Programme Monographs*, Vol. 4, 1–236. Dublin: Royal Irish Academy.
- O'Sullivan, D. C. 2009. *The Natural History of Ireland by Philip O'Sullivan Beare*. Cork: Cork University Press.
- O'Sullivan, W. M., D. P. Sleeman, and D. M. Murphy. 1992. "Otters *Lutra lutra* Feeding on Carrion." *The Irish Naturalists' Journal* 24 (4): 140–143.
- Ottino, P., and P. Giller. 2004. "Distribution, Density, Diet and Habitat Use of the Otter in Relation to Land Use in the Araglin Valley, Southern Ireland." *Biology & Environment: Proceedings of the Royal Irish Academy* 104 (1): 1–17. <https://doi.org/10.3318/BIOE.2004.104.1.1>.
- Overton, N. J. 2014. *Memorable Meetings in the Mesolithic: Tracing the Biography of Human-Nonhuman Relationships in the Kennet and Colne Valleys with Social Zooarchaeology*. Manchester: The University of Manchester. <https://www.escholar.manchester.ac.uk/jrul/item/?pid=uk-ac-man-scw:229627>.
- Overton, N. J. 2016. "More than Skin Deep: Reconsidering Isolated Remains of 'Fur-Bearing Species' in the British and European Mesolithic." *Cambridge Archaeological Journal* 26 (4): 561–578. <https://doi.org/10.1017/S0959774316000391>.
- Perri, A. R., R. C. Power, and S. Heinrich. 2018. "27. Evidence of Mesolithic Zoonotic Parasites at Derragh, Co. Longford." In *The Quaternary the Irish Midlands*, edited by G. McGlynn, I. Stuijts, and B. Stefanini, 232–236. Dublin: Irish Quaternary Association.
- Perri, A. R., R. C. Power, I. Stuijts, S. Heinrich, S. Talamo, S. Hamilton-Dyer, and C. Roberts. 2018. "Detecting Hidden Diets and Disease: Zoonotic Parasites and Fish Consumption in Mesolithic Ireland." *Journal of Archaeological Science* 97c: 137–146. <https://doi.org/10.1016/j.jas.2018.07.010>.
- Power, R. C. 2018. "23. Mesolithic Site Organisation and Fuel use at Derragh: Insights from Phytoliths." In *The Quaternary the Irish Midlands*, edited by G. McGlynn, I. Stuijts, and B. Stefanini, 208–214. Dublin: Irish Quaternary Association.
- Preece, R. C., P. Coxon, and J. E. Robinson. 1986. "New Biostratigraphic Evidence of the Post-Glacial Colonization of Ireland and for Mesolithic Forest Disturbance." *Journal of Biogeography* 13 (6): 487. <https://doi.org/10.2307/2844814>.

- Reimer, P. J., E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C. B. Ramsey, C. E. Buck, et al. 2013. "IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP." *Radiocarbon* 55 (4): 1869–1887. https://doi.org/10.2458/azu_js_rc.55.16947.
- Robertson, A., R. A. McDonald, R. J. Delahay, S. D. Kelly, and S. Bearhop. 2015. "Resource Availability Affects Individual Niche Variation and its Consequences in Group-Living European Badgers *Meles Meles*." *Oecologia* 178 (1): 31–43. <https://doi.org/10.1007/s00442-014-3202-5>.
- Rutty, J. 1772. *An Essay Towards the Natural History of County Dublin*. Dublin: W. Sleator.
- Ryan, M. 1980. "An Early Mesolithic Site in the Irish Midlands." *Antiquity* 54 (210): 46–47. <https://doi.org/10.1017/S0003598X00112086>.
- Scharff, R. F. 1906a. "On the Former Occurrence of the African Wild Cat (*Felis Ocreata*, Gmel.) in Ireland." *Proceedings of the Royal Irish Academy. Section B* 26: 1–12..
- Scharff, R. F. 1906b. "On the Occurrence of a Speckled Otter in Ireland." *The Irish Naturalists' Journal* 18: 141–142.
- Searle, J. B. 2008. "The Colonization of Ireland by Mammals." *The Irish Naturalists' Journal* 29: 109–115.
- Sleeman, D. P. 2008. "Quantifying the Prey Gap for Ireland." *The Irish Naturalists' Journal* 29: 77–82. <https://www.jstor.org/stable/20764504>.
- Sleeman, D. P. 2014. "Ireland, an Unexpected Focus for Genetic Biodiversity and the Ecological Implications." *Irish Naturalists' Journal* 33 (Mind the Gap II: New Insights into the Irish postglacial): 3–7..
- Sleeman, D. P., R. E. Cussen, and D. O'Leary. 2002. "The Badgers *Meles Meles* (L.) of Coney Island, Co Sligo." *The Irish Naturalists' Journal* 27 (1): 10–18.
- Sleeman, D. P., and J. Davenport. 2016. "Evidence of Poor Diet Quality in the Small-Bodied Eurasian Badgers (*Meles Meles*) on Rutland Island, Co." *Donegal. The Irish Naturalists' Journal* 35 (1): 22–26.
- Sleeman, D. P., D. O'Leary, and R. Cussen. 1999. "The Colonisation by Badgers of Coney Island, Co Sligo, Ireland." *Small Carnivore Conservation* 20: 28–29.
- Spindler, L. 2018. "ZooMS Analysis of Bone Fragments from Derragh Lough." In *Irish Quaternary Association Field Guide*, edited by G. McGlynn, I. Stuijts, and B. Stefanini, Vol. 35, 208–214. Dublin: Irish Quaternary Association.
- Sternke, F., and P. C. Woodman. 2006. *Lithic Finds Report for 03E0942 – Derragh, Co. Longford*.
- Talamo, S., and M. Richards. 2011. "A Comparison of Bone Pretreatment Methods for AMS Dating of Samples >30,000 BP." *Radiocarbon* 53: 443–449. <https://doi.org/10.1017/S0033822200034573>.
- van Klinken, G. J. 1999. "Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements." *Journal of Archaeological Science* 26 (6): 687–695. <https://doi.org/10.1006/jasc.1998.0385>.
- van Wijngaarden-Bakker, L. H. 1989. "Faunal Remains and the Irish Mesolithic." In *The Mesolithic in Europe International Symposium*, edited by C. Bonsall, Vol. 3, 125–133. John Donald Publishers Ltd. <http://cat.inist.fr/?aModele=afficheN&cpsidt=6510915>.
- Vigne, V. D. 1999. "The Large "True" Mediterranean Islands as a Model for the Holocene Human Impact on the European Vertebrate Fauna? Recent Data and New Reflections." In *The Holocene History of the European Vertebrate Fauna Modern Aspects of Research*, edited by Norbert Benecke, 295–322. Rahden: Verlag Marie Leidorf GmbH.
- Villalba-Mouco, V., V. Sauqué, I. Sarasketa-Gartzia, M. V. Pastor, P. J. le Roux, D. Vicente, P. Utrilla, and D. C. Salazar-García. 2018. "Territorial Mobility and Subsistence Strategies During the Ebro Basin Late Neolithic-Chalcolithic: A Multi-Isotope Approach from San Juan Cave (Loarre, Spain)." *Quaternary International* 481: 28–41. <https://doi.org/10.1016/j.quaint.2017.05.051>.
- Warren, G. M. 2013. "Transformations? The Mesolithic of North-West Europe." In *The Oxford Handbook of the Archaeology and Anthropology of Hunter-Gatherers*, edited by V. Cummings, P. Jordan, and M. Zvelebil, 537–555. Paris: Oxford University Press.
- Warren, G. M. 2017. "The Human Colonisation of Ireland in Northwest European Context." In *Advances in Irish Quaternary Studies*, 293–316. Atlantis Press. https://doi.org/10.2991/978-94-6239-219-9_10.
- Weninger, B., R. Schulting, M. Bradtmöller, L. Clare, M. Collard, K. Edinborough, J. Hilpert, et al. 2008. "The Catastrophic Final Flooding of Doggerland by the Storegga Slide Tsunami." *Documenta Praehistorica* 35: 633. <https://doi.org/10.4312/dp.35.1>.
- Woodman, P. C. 1985. *Excavations at Mount Sandel, 1973–77, County Londonderry*. Belfast: HM Stationery Office.
- Woodman, P. C. 2008. "Mind the Gap or Gaps?" *The Irish Naturalists' Journal* 29: 5–18. <https://doi.org/10.2307/20764498>.
- Woodman, P. C. 2012. "Making Yourself at Home on an Island: The First 1000 Years (+?) of the Irish Mesolithic." *Proceedings of the Prehistoric Society* 78: 1–34. <https://doi.org/10.1017/S0079497X00027080>.
- Woodman, P. C. 2015. *Ireland's First Settlers*. Oxford: Oxbow Books.
- Woodman, P. C., M. Dowd, L. Fibiger, R. F. Carden, and J. O'Shaughnessy. 2017. "Archaeological Excavations at Killuragh Cave, Co. Limerick: A Persistent Place in the Landscape from the Early Mesolithic to the Late Bronze Age." *The Journal of Irish Archaeology* 26: 1–32. <https://doi.org/10.2307/26564119>.
- Woodman, P. C., and M. McCarthy. 2003. "Contemplating Some Awful (ly Interesting) Vistas: Importing Cattle and Red Deer Into Prehistoric Ireland." In *Neolithic Settlement in Ireland and Western Britain*, edited by Ian Armit, Eileen M. Murphy, Eimear Nelis, and Derek Simpson, 31–39. Oxford: Oxbow.
- Woodman, P. C., M. McCarthy, and N. Monaghan. 1997. "The Irish Quaternary Fauna Project." *Quaternary Science Reviews* 16 (2): 129–159. [https://doi.org/10.1016/S0277-3791\(96\)00037-6](https://doi.org/10.1016/S0277-3791(96)00037-6).
- Wright, T. 2000. *Giraldus Cambrensis: The Topography of Ireland*. Translated by T. Forester. Cambridge: Parentheses Publications. https://www.yorku.ca/inpar/topography_ireland.pdf.
- Yalden, D. W. 1981. "The Occurrence of the Pigmy Shrew *Sorex Minutuson* Moorland, and the Implications for its Presence in Ireland." *Journal of Zoology* 195 (2): 147–156. <https://doi.org/10.1111/j.1469-7998.1981.tb03455.x>.
- Yalden, D. W. 1999. *The History of British Mammals*. London: Poyser Natural History.