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| **Institution:** University of Glasgow (UofG) | | |
| **Unit of Assessment:** UoA7 Earth Systems and Environmental Sciences | | |
| **Title of case study:** Age determinations of human remains and animal parts aid police decisions on criminal investigations and prosecutions | | |
| **Period when the underpinning research was undertaken:** 2003−present | | |
| **Details of staff conducting the underpinning research from the submitting unit:** | | |
| **Name(s):** | **Role(s) (e.g. job title):** | **Period(s) employed by submitting HEI:** |
| Prof. Gordon Cook | Professor | 1978–present |
| Dr Elaine Dunbar | Research Scientist | 2001–present |
| **Period when the claimed impact occurred:** 2012–present | | |
| **Is this case study continued from a case study submitted in 2014? N** | | |

## 1. Summary of the impact

The UofG Radiocarbon Laboratory has developed world-leading analytical capability to provide year of birth and/or death using radiocarbon analysis of bone and teeth, together with isotopic analyses to aid identification of geographic origins and unusual diets. Since 2014, they have delivered critical data on >280 cases of unidentified human remains for forensic investigations throughout the UK and internationally. This includes demonstrating that child remains found at a number of former Mother & Baby Home sites in the Republic of Ireland dated from the 1920s–1960s. Critical age data has also been provided on animal remains in wildlife criminal cases. The impact of this work has been to facilitate police investigative decision-making and criminal convictions, reduce police time and financial expenditure, and alleviate emotional trauma for victims' families by providing vital information needed for closure.

## 2. Underpinning research

For over 35 years, accurate dating of human and animal remains in both modern and archaeological environments, using radiocarbon ($^{14}C$) dating, has been a focus of The UofG Radiocarbon Laboratory (the Laboratory) at the Scottish Universities Environmental Research Centre. The Laboratory has carried out pioneering research to improve the accuracy of measurements across a variety of applications. A GBP4 million grant from the Natural Environment Research Council (NERC) Joint Infrastructure Fund facilitated acquisition of an accelerator mass spectrometer (AMS) in 2003. This has enabled UofG researchers to advance the precision and accuracy of radiocarbon dating of small skeletal components.

Since the 1980's, the Laboratory has focused on refinements in sample preparation of a variety of materials (wood, shell, bone, peat, etc) to develop radiocarbon standards for international inter-comparisons. UofG (with colleagues in Mathematical Sciences) have organised all the global inter-calibration exercises over the past 30 years and now holds an archive of reference materials (including bone) for the international radiocarbon community.

The collagen component of bone and the collagen/enamel components in teeth are often well preserved after death. Since 2014, UofG research has focused on refinements in the preparation of bone and teeth, examining background bone $^{14}C$ values and exploring why these differ from other sample types [summarised in 3.1–3.3]. While $^{14}C$ analysis of single bones can determine whether a person was alive during the nuclear era, it cannot provide an accurate estimate of year of death, information that is crucial for law enforcement. Where applicable, the laboratory has measured $^{14}C$ in different skeletal components with different collagen turnover rates to improve

the estimation of year of death. It was also the first to develop a methodology for determining year of birth from AMS $^{14}C$ analysis on different components of a single tooth, enabling estimates of year of birth to within 1–2 years in modern human remains [3.4].

Therefore, UofG research has combined forensic anthropological techniques and $^{14}C$ measurements from multiple bone fragments (with differing collagen turnover rates) and teeth, to refine the years of birth and death in human remains [3.5]. The laboratory has also used dietary stable carbon, nitrogen and sulphur isotopic ratios in bone collagen to determine whether an individual had a distinctive diet (diets can point to certain sectors of the population or people from certain geographic regions while $^{14}C$ levels are influenced by consumption of non-terrestrial (marine) resources). Finally, their analyses of strontium and oxygen isotopic ratios in tooth enamel aid in the determination of geographic origin. This provides a unique suite of analyses to aid police investigations. No other facility within the UK has the capability for this spectrum of analyses with the requisite interpretative expertise.

In 2007, Prof Cook was invited by the National Crime Agency (NCA) to join their Expert Advisers Database "***to support law enforcement***" [5.2]. He has subsequently outlined what information can be provided by measurements of both natural and anthropogenic radionuclide activities in human skeletal remains in reviews for police and legal professionals [3.6, 3.7]. The techniques described above have also been used at the request of a number of police forces to date keratin and collagen in animal parts such as ivory, fur and rhino horn to determine whether their trade is compliant with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

## 3. References to the research


3.1 Dunbar, E., Cook, G.T., Naysmith, P., Tripney, B.G., Xu, S. (2016) AMS $^{14}C$ Dating at the Scottish Universities Environmental Research Centre (SUERC) Radiocarbon Dating Laboratory. Radiocarbon 58(1), 9–23 (doi.org/10.1017/RDC.2015.2)

3.2 Dunbar, E., Naysmith, P., Cook, G.T., Scott, E.M., Xu, S. and Tripney, B.G. (2017) Investigation of the analytical F$^{14}C$ bone background value at SUERC. Radiocarbon, 59(5), pp. 1463–1473. (doi:10.1017/RDC.2017.67)

3.3 Naysmith, P., Dunbar, E., Scott, E.M., Cook, G.T. and Tripney, B.G. (2017) Preliminary results for estimating the bone background uncertainties at SUERC using statistical analysis. Radiocarbon, 59(5), pp. 1579–1587. (doi:10.1017/RDC.2017.70)

3.4 Cook, G.T., Dunbar, E., Black, S.M. and Xu, S. (2006) A Preliminary assessment of age at death determination using the nuclear weapons testing 14C activity of dentine and enamel. Radiocarbon 48, 305–313. (doi:10.1017/S0033822200038765)

3.5 Cook, G.T., Ainscough, L.A.N. and Dunbar, E. (2015). Radiocarbon analysis of modern skeletal remains to determine year of birth and death—a case study. Radiocarbon 57, 327–336. (doi:10.2458/azu_rc.57.18394)

3.6 Cook, G.T. and MacKenzie, A.B. (2014). Radioactive Isotope Analyses of Skeletal Materials in Forensic Science: A Review of Uses and Potential Uses. International Journal of Legal Medicine 128, 685–698. doi:10.1007/s00414-014-0970-8

3.7 Brock, F., Cook, G.T. (2017). Forensic Radiocarbon Dating of Human Remains: The past, the present, and the future. Archaeological and Environmental Forensic Science 1, 3–16. doi:10.1558/aefs.30715



**Grants:**
NERC JIF award (GR3/J0001)

## 4. Details of the impact

**Aiding police decisions on criminal investigations and prosecutions**

The accurate, precise and rapid determination of the year of birth and/or death, based on analysis of human skeletal remains, is critical to deciding whether they are historic or if criminal investigation is required, particularly for surface-found human remains where there is no archaeological context. In acknowledgement of his research expertise in forensic radiocarbon dating, in 2007, on behalf of the Association of Chief Police Officers, Prof Cook was invited to join the police database of expert scientists/witnesses by the Specialist Operations Centre's Crime Advice Team at the National Policing Improvement Agency. Analysis volume at the Laboratory has increased 15-fold since 2013 as national and international police forces became increasingly aware of the Laboratory's expertise in radiocarbon and stable isotope analyses and data interpretation.

Since 2014, the Laboratory's analysis of human remains has contributed more than 280 reports [5.1] to: (i) approximately 50% of all UK Police Forces, the State of Jersey Police and Ireland's An Garda Síochána; (ii) coroners' reports (including in the Republic of Ireland and Falkland Islands) and resulted in several criminal convictions [5.2]. This work has been carried out on behalf of all the major UK forensic science companies (e.g. Forensic Access, Eurofins Scientific, Alecto Forensic Services and Cellmark Forensic Services) [5.3]. A leading independent Forensic Pathologist states that "***SUERC is an invaluable resource available to investigating authorities in this country… Pinpointing or excluding a particular time period will focus investigations and cut down on unnecessary enquiries elsewhere."***

Of the >280 cases analysed since 2014, 17 cases were identified as human remains from the modern era, thus requiring full forensic investigation. The Home Office has calculated that each murder enquiry costs around GBP3.2 million, with GBP2.3 million relating to social and economic costs and GBP874,000 to the investigating force. More than 90% of human remains submitted to the Laboratory were too old to require a forensic investigation or inquest, thus providing rapid and cost-effective analysis of human remains that has directly influenced the decisions made by both forensic science companies, police detectives and lawyers, with direct cost savings for the UK police and criminal justice system of up to GBP12.2 million since 2014.

In addition to $^{14}C$ isotope measurement, Prof Cook provided additional detailed analysis of dietary isotopes in the remains of 5 of these individuals, (namely stable carbon, nitrogen and sulphur), and strontium and oxygen isotope profiles, which facilitated identification of the geographical regions to which the bones were related. These cases are still outstanding in the criminal court system [5.1].

The work by the Laboratory has helped ease the emotional trauma suffered by families, either in the identification of their relative or when it was demonstrated that the remains were not of the correct time period [5.4, 5.5].

One of the most significant examples of this alleviation of emotional distress is related to the Mother and Baby Homes investigation in the Republic of Ireland. From 2011, the journalist and historian Catherine Corless has focused national and international attention on the fate of 796 children who died in at the Mother and Baby Home in Tuam, Co. Roscommon. On the recommendation of the then State Pathologist of Ireland, the Mother and Baby Homes Commission of Investigation in Ireland (MBHCOI) [5.5] asked The Laboratory to date some of the remains found at the Tuam home. The Laboratory's analysis determined that the remains dated between 1925 and 1961, during the period that the Mother and Baby Home was in operation in Tuam. On 3 March 2017, the Commission announced completion of their test excavation of the

Tuam site, stating that "***Radiocarbon dating was essential in linking the remains found in Tuam to the Bon Secours Mother & Baby Home.***" [5.6]. In the words of Catherine Corless [5.7] ***"… it was the final proof that those remains were not from famine times, as I had been trying to prove for so long".***

This dating evidence provided by through The Laboratory's research has had far-reaching effects on Irish Society. As one of Ireland's foremost gender historians has noted ***"this public acknowledgement had a profound effect on some survivors as they have documented in press reports and interviews in other media. It particularly vindicated the work of Catherine Corless and her understanding of the burial practices in the Tuam institution. It also led to questions of accountability more broadly, and calls for an excavation of the area became more vocal from some quarters... The Minister for Children, Roderic O'Gorman,*** *[on 06/09/2020 advocated]* ***in favour of the excavation in Tuam and also a State apology for survivors of the mother and baby homes. While the coming months will tell, these would be two important steps for survivors, their families and Irish society and will have been greatly influenced by the work of Prof Cook"*** [5.8].

**Changing the landscape of prosecutions for wildlife crime**

In addition to human forensic analysis, The Laboratory has performed forensic radiocarbon analyses of 31 animal parts including rhino horn, ivory and animal pelts for Wildlife Crime Police Units across the UK and forensic science companies acting on behalf of the police, to establish whether trade in these animal parts was subject to CITES regulations [5.9b]: ***"The SUERC Radiocarbon Laboratory was chosen for the analysis due to its reputation and the unique nature of the task and expertise required" –*** Joint Nature Conservation Committee.

In 7 cases, the ivory was deemed to be legal (pre-1947), while the other cases rhino horn, ivory and animal pelts were illegally traded. The evidence provided by UofG was critical to a successful prosecution in one such case where "***[h]ad we not been able to charge him with the CITES offences all we would have been left with would have been the Customs and Excise offences (for which he would have been unlikely to receive a custodial sentence***)" (Lincolnshire Constabulary, 2019 [5.9a]).

In addition, radiocarbon dating ***"data has been used to create educational material, documenting the history of the tusks, outlining what available scientific testing can tell us about the tusks and linking to the conservation status of African elephant and its history through CITES… Determining the source and age of ivory using forensic scientific techniques can help to determine if it was legally acquired… assist with law enforcement in source countries and helps build a better picture of the scale and extent of illegal killing of elephants and key trade routes, informing legislation and management actions."****[5.9b].*

Following the Ivory Act 2018, UofG continues to support the National Wildlife Crime Unit in the analysis of those items exempt from the Act, as the NWCU prepare for the new regulations leading to *"****a surge in people trying to sell these items or trying to disguise the items when selling them****"* [5.9c].

The international reputation of the Laboratory's bone-related radiocarbon research, its unique breadth of analytical capability and the speed of turnaround of analyses have thus made it the go-to laboratory for police forces, forensic pathologists and forensic science companies for both human and animal remains.

**Sources to corroborate the impact**

5.1. Database of police reports available on request from HEI

5.2. Police Force testimonies and statements received from a) Northumbria Police; b) North Wales Police; c) West Midlands Police; d) Devon and Cornwall Police; e) J.C., Independent Forensic Pathologist; f) British Transport Police; g) Garda Siochana
5.3. Testimonials citing impacts on professional practice from forensic service companies:
   a. Alecto Forensic Services Ltd –Forensics Ecology Services Manager.
   b. Reporting Scientist – Anthropology and Archaeology
   c. Independent Senior Forensic Anthropologist, Ireland
5.4. Testimonial obtained from National Crime Agency
5.5. Fifth Interim Report from Mother and Baby Homes Commission of Investigation for Irish Government.
5.6. Transcript from interview with Director and Chair, Mother and Baby Homes Commission of Investigation.
5.7. Statement from Historian and Journalist, whose work compiling information regarding the deaths of 796 children at the Nom Secours Mother and Baby Home in Tuam, Galway, led directly to the Mother and Baby Homes Commission of Investigation
5.8. Statement from Historian, NUI Galway outlining the cultural and social impacts of radiocarbon dating evidence within the MBHCOI report. Statement seconded by Lecturer in Human Rights, Irish Centre for Human Rights, NUI Galway.
5.9. Testimonies received on animal work from:
   a. Lincolnshire Constabulary.
   b. JNCC – UK CITES Scientific Authority.
   c. National Wildlife Crime Unit