Lessons Learned and Lessons Taught in Open Zooarchaeology

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Open and FAIR are not just words funding organizations want us to put in applications, and they are not just concepts designed to make taxpayers happy. They are great ways to design, conduct, reproduce, and disseminate science and scientific thinking. At least they should be. Over the past decade I have had the opportunity to be part of open science projects in a variety of research and teaching environments involving different stages of science from research design to dissemination and feedback. In this presentation I will compare and contrast the different regional approaches I have come to get to know better than others, and discuss what tools we might have to overcome the challenges of contesting approaches to Open Science in zooarchaeology in particular and in environmental archaeology in general.

Open Access, Open Data, and Open Standards: Sharing Environmental Archaeological Data Generated through Developer Funded Excavation

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The last decade in British archaeology has seen an increasing overlap between developer funded and academic archaeology with the development of the so called ‘big data’ projects, which have used huge amounts of developer funded data to develop ground-breaking new syntheses, particularly for the Roman period. It now seems to be almost universally accepted that ‘big data’ has been a good thing and that the future of developer funded data must be open access. However, the ways in which these developments have impacted different archaeological specialisms is diverse and has generated a good deal of disagreement over how this open access future is to be achieved among communities of specialists. Should data standards be enforced? And if so how? Through the peer review of supporting data sets? Or should we all just learn to live with ‘characterful data’ – relying on future, yet to be realized machine learning algorithms to make our data sets talk to each other? This paper will explore some of these issues using a ‘big data’ case study developed as part of the English Landscapes and Identities Project and comparing this to the speaker’s experience of generating data within a large developer funded commercial practice.

Pros and Cons of Open Access Archaeobotanical Data: the uses of ArboDat

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There are a growing number of archaeobotanical databases. Whilst the majority have been developed as part of research projects and include specific types of data from selected sites, a few were created to compile and disseminate data from sites of all periods and across various regions. Although projects are often required to share collated data, there seems to be no consensus on what data should be shared and how. This presentation will address some of the challenges and benefits of open access archaeobotanical data, using the ArboDat database as an example. ArboDat is an active database for archaeobotanical remains with a growing number of users in the UK and beyond. We are using it for the Biodiversity and Land-use Project to compile records of plant-macro remains from across the British

Isles over the past millennia. Such large-scale data compilation has highlighted the difficulties of data standardisation and the benefits of shared accrued knowledge. The advantages and potential problems of using a common database between researchers will be discussed, as well as the responsibility to accurately represent and disseminate original reports.

Archaeobotany Networks and Data Sharing

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In the archaeobotany community, in particular when dealing with botanical macro-remains, raw and complex data are managed in a decentralised way up to now. They are mainly handled individually or by working groups. Thus, data availability depends largely on individual networks. A public domain for long-term storage and exchange of raw data does not yet exist. By contrast in the palynology community centralized databases for raw pollen counts are established (European Pollen Database (EPD), Pangaea, Neotoma).

The compilation of the enormous wealth of archaeobotanical data from decentralised storage facilities would improve our knowledge on plant-human interaction in the past, and increase the impact of archaeobotanical research on recent discourses. Here we suggest two different approaches for bringing together the diverse data. One is the net-of-the-networks approach that, as a first step, provides a flexible platform connecting already existing data repositories and informs – first of all on a metadata-level – about their content and accessibility. A second is the aim to establish a centralized data portal for archaeobotanical on-site raw data that could be linked with the portal PANGAEA® - Data Publisher for Earth & Environmental Science (https://www.pangaea.de) - and maintained in the long run with Alfred Wegener Institut, Helmholtz Zentrum für Polar und Meeresforschung (AWI) and the Centre for Marine Environmental Science (MARUM) at Bremen University.

The Role of 'Open Data' in Investigating Long-term Human Land-Use Impacts on Land-Cover and Biodiversity

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Recent accelerations in the intensity of human land-use have been implicated for changes in biodiversity, but the relationships between land-use change and diversity are complex and include important historical legacies and major transformations which are likely to have occurred across much longer timescales than those covered by direct observation records. This presentation will primarily focus on a collaborative research project between Historic England and the Universities of Plymouth and Birmingham, which is synthesising palaeoecological datasets (insects, pollen and archaeobotanical data) from across the British Isles from both the natural and archaeological sciences to reconstruct biodiversity patterns and evaluate relationships between these patterns and land-use over multi-millennial timescales[1]. This research draws upon open databases, such as the European Pollen Database, and subsequently will make methods, results and syntheses openly available for use by the wider scientific community following the approach taken in previous related projects[2,3]. The challenges, opportunities and benefits of using and producing open data are illustrated, thus demonstrating how

open science practices can improve the reliability and application of research through standardization of data archiving and publication of reproducible methods.

1. *'Biodiversity and Land-use in the British Isles'* project: https://tinyurl.com/long-term-biodiversity
2. PANGAEA data archive '*Changing the face of the Mediterranean*' project: https://doi.pangaea.de/10.1594/PANGAEA.900983
3. PANGAEA data archive '*Deforesting Europe*' project: https://doi.pangaea.de/10.1594/PANGAEA.853947

The Strategic Environmental Archaeology Database (SEAD)

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The Strategic Environmental Archaeology Database (www.sead.se) is an Open Access resource for proxy data on past environments, climates and human activities. The system includes all data from the BugsCEP fossil insect database, as well as (mainly) Swedish data on plant macrofossils, pollen, dendrochronology, geochemistry and ceramic thin sections. But SEAD can store more or less anything that can be counted or measured, along with a complex web of dating evidence, metadata and modern reference or calibration data to aid searching and interpretation.

SEAD's online interface provides intuitive browsing of datasets (https://browser.sead.se/), as well as a faceted browser for item (e.g. species or value) level filtering of results across datasets. Ecological classifications also allows datasets to be searched on the basis of the environmental implications of their fauna or flora. This system is also being expanded to include the cultural use of plants and animals, and allows for concept/semantic linking of interpreted data to other systems through SEAD's API's. The system is part of a network of archaeological and palaeoecological databases and portals including DataARC, SBDI, ARIADNE+, IPERION-HS, Neotoma and the EarthLife consortium.

More than 10 years from its inception, the project has expanded far beyond its initial scope. The system is now being adapted to handle results from osteological and isotope analyses, as well as a large amount of dendrochronology data. It also acts as a vehicle for experiments in data visualisation and semantic networking. This presentation will demonstrate some of this functionality, and hopefully inspire others to contribute data and start using SEAD.

Using the Arches platform for Heritage and Environmental Archaeology Data

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Few open source software packages are intended specifically for use with heritage data. While open source databases such as PostgreSQL or MySQL can be used, users themselves must do the 'heavy lifting' of deciding on the structure of tables, linkage between entries and displaying the data on the web to make it easily accessible.

The Arches platform (www.archesproject.org) provides a convenient way of entering, storing and presenting heritage data suitable for consumption by the public or by researchers. Under active development funded by the Getty Foundation and the World Monument Fund, it currently provides the HER for the cities of Lincoln and Los Angeles, supports research applications such as Endangered Archaeology of the Middle East and North Africa and is under evaluation by Historic England and several local authorities. Free to obtain and use, it runs on Linux or Windows and is based on standard open source technologies including Python, PostgreSQL, JavaScript, HTML, XML and CIDOC CRM.

Although Arches is intended to provide a platform for the recording and presentation of heritage assets, its flexible yet standards-based design allows it to be extended to hold almost any kind of scientific or environmental data. This paper will discuss lessons learned from a current project which is using Arches to provide a Historic Environment Record database for the island of Jersey, and plans to use the package to hold and present environmental archaeology data from zooarchaeology and isotope analysis for my PhD research.

Comparative Perspectives and Current Trends in Multi-Isotopic Analyses: Towards an Integrated Bioarchaeological Isotope Database Website for the Greater Near East

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Isotopic analyses of bioarchaeological remains provide quantitative and high-resolution, empirical evidence for crop management, food choices, land-use, and mobility in the ancient past. Although mixed subsistence strategies, settled-nomad interactions, and migrations have traditionally been key research questions in the archaeology of the Greater Near East, the utilisation of isotopic analyses is relatively new in this landscape. However, the field has rapidly developed over the last decade and large, diverse datasets have become available in various sub-regions. On a much broader scale, nevertheless, these site-based projects remain disconnected and isotopic landscapes (*isoscapes*) of the region at large remain poorly studied and understood. As such, it has now become pertinent to discuss research trends, methodologies, and results within inter-site, inter-regional, and pan-regional perspectives. We demonstrate the utility of pan-regional and inter-regional comparative perspectives, not only for better understanding human-landscape interactions based on emerging patterns, but also for moving the field forward from a methodological standpoint.

As members of the *Archaeological Isotopes Research Group*, which has been developing since 2016, based at ASOR Annual Meetings, we call attention to the utility of collating isotope datasets in our research region in order to facilitate comparative interpretations, collaboration in setting research agendas, and developing compatible methodological standards. A broader discussion has already been broached about the need for integration and centralised data resources like IsoArch (https://www.isoarch.eu) and the Neotoma Paleoecology Database (https://www.neotomadb.org). Along similar lines, we will advocate for the development of an online platform for open source isotope data sharing in our research region.

Pandora and IsoMemo: Partnership-based Models for Big Historical Data

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Pandora and IsoMemo are Big historical Data initiatives bringing together several repositories of isotopic and non-isotopic data from diverse fields within archaeological and historical research. Both initiatives follow a partnership-based model in which autonomous repositories are responsible for defining metadata and collecting data according to specific research needs.

The Pandora and IsoMemo initiatives promote open access to archaeological and historical data and the development of new databases, having developed the concept of source recognition for both data producers and compilers. They also coordinate data collection among partners and develop open access tools for data search and data mirroring to ensure its long-term accessibility.

Another major feature of both initiatives is the development of new modelling tools for the analysis of Big historical Data and data integration of isotopic and non-isotopic datasets leading to the development of large-scale interdisciplinary projects. In this paper, the organizational model behind both initiatives will be described and several examples of ongoing archaeological projects will be presented to illustrate the research potential of the initiatives.

Open and FAIR Data in Stable Isotope Analysis – Some Reflections

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Stable isotope analysis in archaeology has become more routine in recent years, and with this has come an increased amount of legacy data. Trends in research, "big data" approaches and machine learning have also had an impact on archaeological research and re-use of such data. However academic publishing, university structures such as REF and undergraduate syllabi are yet to fully embrace or catch up with these trends and the Open and FAIR principles that should accompany them. There is inconsistency and a lack of clarity in reporting key data and metadata, and this carries over onto data analysis and statistical reporting. However, there are now a fantastic range of open source software and repositories that are available to researchers, and perhaps more importantly enable free and open sharing with the public. This also raises questions around how we deal with our data, analytically speaking, as well as long term curatorship, which will also be touched upon. This paper will use stable isotope data meta-analysis from Britain as an example of the variability of data and code publishing practices within archaeological science and environmental archaeology more broadly, and the challenges this poses for our field moving forward. It will also demonstrate the analytical and interpretative potential of metanalytical approaches and propose a methodology for best practice in publishing stable isotope datasets and computational workflows in line with Open Science and FAIR principles.

Out with the New, in with the Old: Recent Advances in Palaeoecological Modelling with Open Data

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Computational models of past environments and ecological dynamics on a regional scale can be a useful complement to conventional site-based environmental archaeology. Modelling past ecosystems has become significantly easier in recent years with the development of several open datasets, including high resolution global climate and environmental data (e.g. WorldClim2, MERRAClim, CHELSA, SoilGrids), downscaled palaeoclimate reconstructions from global circulation models (e.g. PaleoView, PaleoClim), and biodiversity data (e.g. GBIF). At the same time, better computational tools have made complex modelling methods more accessible and reproducible. The statistical programming language R has become the core of both computational archaeologists' and ecologists' toolkits, bringing with it an extensive collection of packages for working with open environmental data (e.g. the rOpenSci project), archaeological data (e.g. rcarbon), and geostatistical models (e.g. raster, dismo).

In this paper, I review these advances and their potential for palaeocological modelling in an archaeological context, using as a case study environmental niche modelling applied to reconstructing the palaeodistribution of human-exploited flora and fauna in Epipalaeolithic Southwest Asia. The results highlight the value of open environmental data in understanding the regional ecosystems in which past humans were embedded, but there remain considerable methodological challenges in integrating such 'top-down' models with 'bottom-up' insights from environmental archaeology. Archaeological data is now the weak link: fragmentation, lack of standardisation, and the need for time-consuming digitisation of 'legacy' datasets hampers the direct integration of archaeological and ecological understanding. I

therefore argue that continuing to improve the accessibility of environmental archaeology data is key to building better models of past ecosystems.

We Need to Talk about Time

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To quote the 10th incarnation of Doctor Who "people assume that time is a strict progression of cause to effect, but *actually* from a non-linear, non-subjective viewpoint – it's more like a big ball of wibbly, wobbly time-y wimey stuff". Environmental archaeologists, whilst lacking a sonic screwdriver, are constantly dealing with time-y wimey stuff, especially when it comes to big data syntheses. Having worked on a diverse range of synthesis projects including animal burials (Morris 2012), metrics (Thomas *et al*. 2013), fish (Orton *et al.* 2014) and urban assemblages (Morris forthcoming), I have come to appreciate that time is a major variable we need to engage with.

Often environmental archaeologists are used to working on individual sites, with periods/phases established by stratigraphy, pottery and other dating. The boundaries between the periods are given to us as a framework to work within. The challenge with synthesis comes when combining the environmental data from hundreds of separate sites, each with its own phasing framework and date range. A host of grouping approaches are open to us, such as: focusing on natural breaks, using beginning, mid or end points in date ranges, or uniform chronological bins with aoristic analysis. Each method has its advantages and disadvantages, often suitability depends on how the environmental remains were deposited. For example, are we looking at material that was deposited in a single activity, or does our date range represent the duration of multiple events? If the former, then the date range is actually probabilistic – the single deposition event occurred at some point between the start and end dates, and monte carlo simulations may help us explore this issue. This paper aims to explore these possibilities, and start a conversation about time.

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Biometric Mixture Modeling to Estimate Age and Sex Composition of Faunal Assemblages

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An animal's sex plays a central role in determining its body size and behavior patterns, which in turn affect the animal's susceptibility to different hunting and herding strategies. The sex composition of animal bone assemblages thus reflects anthropologically relevant factors about past ecologies and exploitation strategies. Traditional methods of estimating an animal's sex from skeletal remains are complicated by fragmentation and variability across different populations, making it difficult to create

absolute estimates of animal sex. By adopting a more probabilistic approach to estimating sex, mixture modeling provides the opportunity to summarize entire assemblages of faunal measurements as well as estimate the sex of specific elements. I describe a Bayesian multilevel mixture model for estimating the sex composition of faunal assemblages based on standard breadth measurements of postcranial limb bones. These methods use regularly reported data to produce probabilistic estimates of the sex composition of an assemblage, incorporating measurement error and other common estimates of sex composition when available. The multilevel structure of the model uses log-size index (LSI) values to address variability across different anatomical parts to provide an overall estimate of sex composition in the measured assemblage. Probabilistic estimates produced by this open source algorithm can then be used to directly test hypotheses about sex differences in exploitation, composition, or behavior. Beyond composition, these models also produce sex-specific biometric estimates that can also establish investigations into regional and chronological trends in exploitation and paleoecology.

Climate Models and Summed Probability Distributions: Using open data and reproducible methods for understanding environmental and demographic contexts of the technological transition during the Late Pleistocene in Korea

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Open science developments can give insights into the environmental and demographic contexts of past foragers' behaviors. This research demonstrates reproducibility of open science practices by showing how to use open data and methods to produce environmental and demographic contexts that help interpret the archaeological records in places and time periods where such contexts are sparse. Beyer et al. (2020) present a simulated high-resolution climate data set for the last 120,000 years including global monthly temperature, precipitation, and cloud cover, which is useful as an environmental proxy in archaeological research. My study shows how to derive mean annual temperature from Beyer et al.'s open data by applying site information such as latitude and longitude and use it as an environmental context. In addition to environmental contexts, archaeologists consider demographic context, like population trends, to better understand past human behaviors. Summed probability distributions (SPD) of radiocarbon dates are often used as proxies, regardless of their limitations including the lack of excavated sites in certain periods, sample size and calibration effects, because they provide overall approximation of past population trends. Recent open science developments have produced R packages that allow archaeologists to infer past demographic patterns. This study shows how to use the 'rcarbon' package (Crema and Bevan, n.d.) to generate and evaluate SPD models with radiocarbon dates, and use them as demographic contexts. In short, this case study from the Korean Late Pleistocene will demonstrate the value of open data, shared repositories, and reproducible analysis.

Striving for Reproducibility in Environmental Archaeology

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The recent 2016 *Nature* survey (Baker 2016) concerning reproducibility found 90% of respondents think there is a 'crisis of reproducibility' in the scientific community and 70% of scientists surveyed had tried and failed to reproduce another scientist's experiments. This is an issue that must be addressed in Environmental Archaeology so that we can build robust methods and therefore greater validity in our conclusions. But how can we be reproducible in Archaeology when our practises are often destructive? We are an applied science discipline and therefore must prove reproducibility in our scientific methods as well as in the application of these methods to archaeological assemblages. Proving reproducibility, replicability and robustness of our scientific methods means using stringent scientific design and greater transparency. This can only be achieved through establishing large datasets in open collaborative projects. We can achieve this by changing how we are currently working to introduce collaborative

version-control tools, such as Github, to fully capture reproducible workflows and create research compendia for publication along with research articles.

For the archaeological application of methods, working in multi-disciplinary teams using different scientific methods to address a single archaeological question is a form of triangulation and it is used in other science disciplines to yield more robust conclusions (Munafo & Davey Smith 2018). The biases of each approach need to be made explicit so that they can be addressed in the analysis phase and researchers need to work together on overall interpretation using data from all the approaches. Only truly open science practices in Environmental Archaeology can address this 'crisis of reproducibility' and build more robust methods to aid more accurate interpretations of our past.

The 'Openness' of Archaeological Palaeoenvironmental Archives

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As this season's *Association for Environmental Archaeology* conference theme asserts, there is a collective desire amongst environmental archaeologists to achieve an openness of quantitative data through mutual collaborative participation and active processes of curation. Yet this desire for an openness of information is not a new phenomenon. Over the last two centuries, the physical remains from archaeological excavations stored in collections were - up until the mid-20th century – considered intrinsic apparatus in scientific process, especially in the facilitation of typologists and taxonomists. Whilst the importance of access to the physical organic remains themselves has waned, there has been a recent resurgence with the escalation of synthetic projects which require archived remains.

Fortunately, the collection and curation of archaeological palaeoenvironmental remains intended for future research has become formalised. Regrettably, factors such as shifting political priorities and budget cuts have led to poorly resourced services and unpredictable collections. This has resulted in a national collection of biological remains from archaeological contexts which are not always as manageable and navigable as we would like, causing challenges for those who require access to the physical remains.

In this paper I would like to demonstrate how the desire for openness of information in archaeology is a theme which has always affected our working practices and illustrates that whilst current methods of the curation of palaeoenvironmental remains face certain challenges, small changes in our collective working practice can potentially bring about big changes.

Reflections on Five Years of Open Quaternary

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Open Quaternary was launched in March 2015 as a 100% gold open access journal covering Quaternary science, environmental archaeology and Palaeolithic archaeology. To date, it has published over 40 articles, and hosts four special collections of themed papers. From the outset, it was intended to keep publication affordable for researchers, and to encourage open sharing of data underlying published research.

This paper reflects on the development of the journal from its foundation as a grassroots initiative by Quaternary scientists to the present day, and outlines current developments in open access publication and ethical research practice.

Open access in Environmental Archaeology – act locally and think globally

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Bioarchaeological evidence from archaeological sites comprising botanical, zoological and other organic finds (so-called on-site evidence) represents one of the major components of (pre)historic environmental data and are by definition of a local character. However, when made visible and accessible to an interdisciplinary community they can be integrated in regional and supra-regional contexts, therefore gaining more scientific impact outside the proper research area. Combined (bio-)archaeological data can reveal changes of environment and anthropogenic land use systems relevant not only for archaeological research. Having implications for palaeoecological research or climate modeling, these data can even serve as a relevant source of information for environmental protection and conservation projects.

Archaeological complexes and their corresponding chronologies usually range from local to supra-regional extent. Thus, dynamics in past economy and environment can be reasonably approached from comparative perspectives, including such ranges of datasets.

Therefore, a major question is how to make the on-site bioarchaeological data from single sites accessible to the scientific community to arrive at larger scale data management platforms of supra-regional relevance? There are ethical issues related with the use of data created by other researchers or institutions and embargoes on data use, which might limit many of those attempts. Practices from quaternary sciences (palynology, geosciences etc.) can provide useful examples and highlight pros and cons for such actions. Another question touches upon the efficiency of encouraging appropriate authorities, funding bodies, smaller or bigger projects to deliver their data based on both proper and safe quotation and a clearly defined research integrity system.

To be of any scientific use, such comparative datasets need to follow a standardized system of data collection and archiving, incorporating the latest know-how in data management policies. This comprises not only issues of classification, terminology, and quantification of the materials, but also context-related information on archaeological features, functionalities and chronologies.

Open Access implies the idea of substantial data being accessible for free to the public or at least to a certain scientific community for use. Can open access lead to “Big Data” in bioarchaeology and help to promote and strengthen the value of this research field in a broader scientific context? Do we need a centralized platform to achieve the aim of a supra-regional data exchange and evaluation? Do issues of governance, such as commons, come into play? Based on the examples of the presentation we will provide some practical considerations.