Stable isotopes in zooarchaeology: an introduction

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Zooarchaeology has a long history as a specialisation that uses qualitative osteological methods, including the collection of taxonomic data, the recording of bone modification, and the ageing and sexing of animal bones to address broader archaeological questions. Metrical analyses, including geometric morphometrics, the use of scanning electron microscopy, thin sectioning, and biomolecular analyses have all added to the types of quantitative data with which we can explore (zoo)archaeological questions. These zooarchaeological data cannot only be transformed into knowledge of the cultural and socioeconomic roles of animals in the past, but can also inform on larger ecological and socioeconomic structures; they can tell us about palaeoethology and palaeobiogeography, site formation processes and use of space within sites, consumption patterns, and religious and ritual practices. The study of animals in archaeology should not be viewed as an obscure specialisation with little outside relevance; indeed, it is a critical component to understanding broader patterns in both the environmental and social realms.

The applications of stable isotope geochemistry are numerous, and its use as an analytical technique in archaeology has progressed substantially over the past few decades. For example, some early stable isotope studies in archaeology focused on analysis of oxygen isotope ratios ($\delta^{18}\text{O}$) from biogenic carbonate of marine molluscs (e.g. Deith 1983, 1985, 1986; Shackleton 1973) to reconstruct season of collection, and by extension, season of site use. Sampling shells for palaeoenvironmental information has become a well-established practice (e.g. Burchell et al. 2012, 2013; Mannino et al. 2003, 2007; Milner 2002). Early analyses of

carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) from archaeological human bone collagen (e.g. Chisholm et al. 1982; Shoeninger and DeNiro 1984; van der Merwe 1982) used analyses of modern animal tissues and bone collagen as a baseline for establishing dietary differences between marine/terrestrial and C_3/C_4 plant-based diets in ancient human populations. While subsequent research has continued to pursue and elaborate on these types of questions, the papers in this volume are testament to the fact that the applications of stable isotope analyses in archaeology are broad in scope. They include projects that use $\delta^{18}\text{O}$, $\delta^{13}\text{C}$, and $\delta^{15}\text{N}$, as well as strontium ($^{87}\text{Sr}/^{86}\text{Sr}$) and sulphur ($\delta^{34}\text{S}$) to investigate questions about human and animal diet, seasonal transhumance and herding strategies, economic exchange networks, species biogeography and climate. One of the continuing challenges for stable isotope analysis as a methodological technique is its successful integration with existing archaeological knowledge. When stable isotope analysis is used to discuss topics in zooarchaeology, it is increasingly important to understand the ecology, physiology, and osteological development of sampled taxa in order to interpret stable isotope data.

This volume grew out of a 1-day conference, “Integrating Zooarchaeology and Stable Isotope Analyses”, which I organised at the McDonald Institute for Archaeological Research, University of Cambridge, on 21 June 2012. A selection of papers on research in the Old World presented at the conference (Çakırlar and Şeşen, Stevens et al., Madgwick et al., Hammond and O’Connor, and Arnold et al.) is joined in this volume by two contributions from North America (Fisher and Valentine and Szpak et al.). The papers are geographically and temporally diverse, ranging from the Third Millennium BC in Syria; Iron Age, Roman, and Mediaeval Britain; and the Early Iron Age (First Millennium AD) in South Africa, to the Fremont Period (AD 400–1350) in the American Southwest and the late

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pre-contact through to historic period (1500 BC–AD 1880) on the Northwest Coast of Canada. In addition to the diversity of research questions interrogated in these studies, what is most striking about this collection of papers is the creative and multi-faceted applications of zooarchaeological methods and stable isotope techniques—and their integration—to resolve those questions.

Çakırlar and Şeşen's paper, "Reading between the lines: $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ isotopes of *Unio elongatulus* shell increments as proxies for local palaeoenvironments in Mid Holocene northern Syria", contributes data to a timely issue: to what extent did local environmental change influence human settlement and site abandonment? The study highlights the importance of taxonomic differentiation of *Unio* shells in order to eliminate the effects of inter-specific physiological variation in the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ signals recorded in shell carbonate, utilising type-specimen collections in order to validate the attribution of species to archaeological specimens. In addition, by noting the overall relative taxonomic abundances of terrestrial mammals and molluscs, the authors establish the role of the shellfish in the diet and reinforce their usefulness as an archaeologically-linked proxy for environmental change. Accurate species identification and the description of the faunal sample in its archaeological context are standard practice in zooarchaeological literature and must also be given equal consideration as the foundation for the interpretation of any stable isotope data. Finally, the study also includes data from modern samples to establish the suitability of the taxon as a palaeoclimate proxy, and combines stable isotope analysis with high-resolution sclerochronological information as a secondary line of evidence in order to support the validity of the stable isotope results.

In "One for the Master and one for the Dame: Stable isotope investigations of Iron Age animal husbandry in the Danebury Environs", Stevens et al. use stable isotope analysis ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) to test several models of herd management, which they construct using existing archaeological and isotopic data. The authors point out that specific micro-environmental factors, whether natural or man-made, influence the isotopic signature of plant communities, creating isotopically distinct "isozones" within landscapes. This inherent landscape variability may contribute to highly variable isotopic values within populations. Importantly, the study considers the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ data with reference to its zooarchaeological context, but also acknowledges that the additional layer of complexity revealed by the stable isotope analysis would not be evident through the macro-analysis of faunal and botanical remains alone.

Variability is also an important theme in the paper by Madgwick et al., "Fallow deer (*Dama dama*) management in Roman South-East Britain", where the authors employ the innovative use of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values as

landscape "signatures" to distinguish potentially native versus imported specimens of fallow deer, in conjunction with the analysis of sulphur isotopes to discuss proximity to the coast and salt-marsh feeding in this quasi-domestic taxon. The taxonomic identification of osteological elements is integral to supporting the authors' ability to differentiate between imported animal parts (i.e. antlers and legs) as opposed to those skeletal elements more indicative of a breeding population, leading to a well-integrated preliminary discussion of the history of fallow deer in Britain.

Hammond and O'Connor's paper, "Pig diet in Medieval York: Carbon and nitrogen stable isotopes", uses $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ to question the assumption that pigs were yard-kept and fed human refuse during this period. Previous osteological analyses of pig remains and stable isotope analysis of human remains from York supported this scenario, leading the authors to sample pig remains directly in order to determine whether they were fed a mostly herbivorous or carnivorous diet. The findings in this paper reinforce the importance of sampling archaeological animal remains from the same temporal and geographic contexts as humans in order to fully consider the diversity of animal management strategies in the past.

Strontium isotope analysis has traditionally been used to investigate mobility and provenance, as in Arnold et al.'s paper, "Domestic cattle mobility in early farming villages in southern Africa: Harvest profiles and strontium ($^{87}\text{Sr}/^{86}\text{Sr}$) isotope analyses from Early Iron Age sites in the lower Thukela River valley of South Africa". Arnold et al. establish a local baseline for $^{87}\text{Sr}/^{86}\text{Sr}$ using biological markers, but this is less useful for the establishment of nuanced seasonal patterns of mobility and more useful, in the case of one specimen, to establish the potential for longer-distance cattle trade. This is especially intriguing since cattle are a socially important and economically valuable good. In addition to the strontium data, the authors construct age curves based on cattle teeth, a long-used method for reconstructing herd management. The combination of both isotopic and osteological evidence by the authors is integral to the investigation of seasonal transhumance in this study.

Fisher and Valentine analyse $^{87}\text{Sr}/^{86}\text{Sr}$ as well as $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ in their paper, "Resource depression, climate change, and mountain sheep in the eastern Great Basin of western North America". Their inventive approach combines isotopic data with faunal analysis to investigate whether the driver of local resource depression was hunting pressure or environmental factors. They use $^{87}\text{Sr}/^{86}\text{Sr}$ to track the potential origin of prey and $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ to reconstruct the climatic background, while using an *Ovis* index based on faunal analyses to track resource decline. This approach highlights the potential of three different lines of data to complement, and also complicate, each other.

Finally, in "Regional ecological variability and impact of the maritime fur trade on nearshore ecosystems in southern

Haida Gwaii (British Columbia, Canada): Evidence from stable isotope analysis of rockfish (*Sebastes* spp.) bone collagen”, Szpak et al. use $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis in a marine context in order to establish the diet of pre-contact and contact period rockfish. These values are in turn used as a proxy for sea otter population levels to understand the implications of the fur trade through time. This well-integrated study depends on a thorough knowledge of a marine ecosystem functioning in addition to the behaviour of the isotopes in marine environment, emphasising the importance of knowledge of complex ecological systems in interpreting isotopic data.

The importance of understanding both variability and meaningful outliers was a key point that arose during the conference and is also apparent across the papers presented within this volume. Sample size is critical in identifying real patterns in the data and in establishing a basis for comparison of results across datasets. A consideration of the zooarchaeological data is imperative for the determination of various influences on the faunal assemblage, including excavation, preferential preservation, human vs. natural accumulation, and bone diagenesis.

What is truly integrated? The papers in this volume vary in their reliance on zooarchaeological data for the interpretation of stable isotope results, and they also vary in their degree of integration of the two methods to address the research questions. Zooarchaeological knowledge is especially critical for appropriate sample selection and sampling strategy to be employed. It is also the necessary foundation upon which the interpretation of stable isotope data must build. Stable isotope analyses can be used to more fully explore as well as challenge previous interpretations that were once limited by more traditional osteological techniques. Finally, it is important to consider the results of zooarchaeological and stable isotope analyses within their broader environmental and social contexts in order to interpret animal and human behaviour in the past.

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