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Using traditional biometrical data to distinguish West Palearctic wild boar and domestic pigs in the archaeological record: new methods and standards

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Traditionally, the separation of domestic pig remains from those of wild boar in zooarchaeological assemblages has been based on the comparison of simple size measurements with those from limited numbers of modern or archaeological reference specimens and then applying poorly defined cut-off values to make the identification calls. This study provides a new statistical framework for the identification of both domestic and wild *Sus scrofa* using standard molar tooth lengths and widths from a large modern comparative collection consisting of 407 West Palearctic wild boar and domestic pigs. Our study continues to rely upon so-called 'cut-off' values that correspond to the optimal separation between the two groups, but based upon a measure and visualisation of the error risk curves for erroneous identifications. On average, wild boar have larger teeth than domestic pigs and cut-off values were established for maximum tooth length and width, respectively as follows: 2.39 cm and 1.85 cm for second upper molar, 3.69 cm and 2.13 cm for third upper molar, 2.26 cm and 1.50 cm for second lower molar, 3.79 cm and 1.75 cm for third lower molar. Specimens below and above these cut-offs are most likely to be, respectively, domestic pig and wild boar and the risk of providing a wrong identification will depend on the distance to the cut-off value following a relative risk curve. Although likely containing high risk of inherent statistical error, nonetheless this basic metrical identification-tool (based only on recent specimens), is here shown to correctly re-identify 94% of the Neolithic pigs from Durrington Walls (England) as domestic pig. This tool could be employed not only to systematically re-evaluate previous identifications of wild or domestic *Sus scrofa*, but also to establish new identifications where more powerful and reliable approaches such as Geometric Morphometrics cannot be applied.

1. Introduction

The domestication of certain plants and animals at the beginning of the Holocene epoch beginning some 10,000 years ago heralded perhaps one of the most significant biocultural steps in the history of mankind. As a result, the study of the origins and spread of farming, through the palaeobotanical and zooarchaeological record provides the baseline datasets for understanding not only crucial aspects of complex evolutionary history of the species involved in their transition from wild to domesticated organisms, but also crucial biocultural evidence linked with the shift from hunting and gathering to early farming.

Separating 'wild' from 'domestic' in the early zooarchaeological record is therefore one of the most important challenges facing researchers studying domestication, yet it remains one of the most

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difficult. Charles Darwin was the first to notice a range of morphological and phenotypic traits common to many domestic animals yet different to their wild ancestors (Darwin, 1868), These include e.g. an obvious decrease in brain and body size, changes in some body proportions, and modification of external morphological characters such as emergence of piebald coat colour, wavy or curly hair, rolled and shortened tails, or floppy ears (Trut, 1999; O'Regan and Kitchener, 2005). Many of the phenotypic and behavioural changes linked with domestication are inaccessible from zooarchaeological assemblages, where only skeletal and dental remains are available for study. New techniques of ancient DNA analyses are providing novel information about phenotype (e.g., the coat colour of mammals, Ludwig et al., 2009), but these data are not routinely available, due to poor preservation and analytical costs. The zooarchaeological record is often very fragmented, and usually dominated by teeth that are more easily identified using morphological or biometric criteria (von den Driesch, 1976; Payne and Bull, 1988). Identifying domestication using distinct morphological markers is therefore of prime interest for zooarchaeologists and is one of the principal approaches used extensively to do so over the last decades.

In the west Palaearctic, domestic forms of three taxa are particularly difficult to recognise in the archaeological record: cows (*Bos taurus*), dogs (*Canis familiaris*) and pigs (*Sus scrofa*). These three species are more difficult to recognise than, e.g., sheep (*Ovis aries*) or goat (*Capra aegagrus hircus*), because of the ubiquitous presence of their wild ancestors across western Eurasia (Aulagnier et al., 2008). For instance, we now know from recent ancient DNA research that the history of pig domestication is complex, and includes several processes of both local domestication, dispersal and introgression of wild and domestic forms (e.g., Larson et al., 2005, 2007; Ottoni et al., 2013; Larson and Burger, 2013; Krause-Kyora et al., 2013). Objective and accurate criteria are therefore necessary to disentangle the wild and domestic forms of these species during the Holocene. In this context, the identification of wild and domestic pigs from archaeological remains have been commonly assessed using traditional size measurements of teeth and bones (e.g. Vigne et al., 2005). For pigs (and other domestic taxa), small individuals are commonly identified as 'domestic' and large as 'wild' (Albarella et al., 2006; Rowley-Conwy et al., 2012) even if an important overlap in size does exist between the two groups (e. g. Payne and Bull, 1988; Evin et al., 2013).

Identification of zooarchaeological remains is often undertaken using a framework of 'reference' individuals of known geographic origin and or wild/domestic status. To identify the biometrical affinity of *S. scrofa* remains from archaeological sites in Europe, the most commonly used reference datasets are either modern Turkish wild boar (Payne and Bull, 1988) or late Neolithic domestic pigs from the UK site of Durrington Walls (Albarella and Payne, 2005). These biometrical datasets are first and foremost limited both in their geographic and temporal extent and so their relevance or applicability to zooarchaeological collections from differeing times or places should be questioned. Additionaly, a wild boar reference dataset should consist of more than a single population since wild boar are known to be very variable in size across their geographic range (e.g., Groves, 1981; Albarella et al., 2009; Rowley-Conwy et al., 2012).

More recently, studies have employed the more powerfull approach of geometric morphometrics to study morphological change in pig domestication (e.g., Cucchi et al., 2009, 2011; Evin et al., 2013). In one study, molar size was shown to be a much poorer indicator of wild or domestic status in modern *S. scrofa* than shape variables (Evin et al., 2013). Indeed, the size of wild and domestic modern West Palaearctic pigs largely overlaps and does not show a bimodal distribution, which implies inevitable high classification error rates (Payne and Bull, 1988; Evin et al., 2013). On the other hand, geometric morphometric analyses of molar shape provide much better identification paired with higher classification probabilities. Sadly, geometric morphometric approaches have yet to become routinely applied in zooarchaeological studies. When compared to traditional techniques, they require learning new techniques about multivariate statistics and morphometrics, usually more sophisticated and expensive tools for data acquisition, and they require more time to measure and analyse the collections than traditional methodologies used by zooarchaeologists over the last decades of research. In addition, geometric morphometric (GMM) techniques do not allow the re-examination of previously published data without full re-analysis of the original archaeological (and relevant reference) specimens.

From this perspective, this study aims to provide:

1) a new biometric framework for size measurements of modern domestic pig breeds and wild boars from a large geographic area, in order to provide descriptive statistics based on larger datasets than those already available;
2) statistically-controlled and more objective criteria to identify wild and domestic pigs using standard measurements of Maximum Tooth Length (MTL) and Maximum Tooth Width (MTW) on the 2nd and 3rd upper and lower molars.

This approach relies on the definition of cut-off values that correspond to the optimal separation between the two groups based on a measure and visualisation of the error risk curves for erroneous identifications.

In order to validate the identification-tool proposed, the results obtained were compared to the published measurements of the *Sus* specimens from the Late Neolithic site of Durrington Walls (Wiltshire, southern England), for which the measurements were published with the aim of being used as a standard of archaeological domestic pigs (Albarella and Payne, 2005).

2. Material

The comparative specimens used in this study are the same as those in Evin et al. (2013), and correspond to 407 modern wild and domestic specimens represented by 327 upper M2 (M^2), 163 upper M3 (M^3), 311 lower M2 (M_2) and 171 lower M3 (M_3) (Table 1). Wild boar specimens originate from North Africa (Algeria, Morocco), Europe (France, Switzerland, Germany, Poland), Near East (Turkey, Syria, Iran, Iraq) and Russia (see SI-1 for sample sizes). Domestic specimens belong to the following breeds: Berkshire, Cornwall, Deutsches Edelschwein, Corsican, Sardinian, Tamworth, Middle White, Hannover Braunschweiger Landschwein, Veredeltes Landschwein and Mangalitza (see SI-2 for sample sizes). All specimens are adults and from both sexes. Standard zooarchaeological tooth measurements – i.e. Maximum Tooth Length (MTL) and Maximum Tooth Width (MTW) – measured in centimetres, were extracted from the geometric morphometric data presented in Evin et al. (2013). MTL and MTW were measured as the distance, automatically extracted, between the Cartesian coordinates of the most anterior and the most posterior semi-landmarks, and the most labial and lingual semi-landmarks, respectively. To confirm that the Estimated MTL (EMTL) and Estimated MTW (EMTW) are accurate estimates of the traditional measurements of the MTL and MTW, direct and estimated measures of lengths and widths (MTL-EMTL and MTW-EMTW) were compared for a subsample of 100 specimens based on pictures using TpsDig2 v2.16 (Rohlf, 2010).

In their paper on the Neolithic pigs from Durrington Walls, Albarella and Payne (2005) published not only the summary of the