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Early Pig Management in the Zagros Flanks: Reanalysis of the Fauna from Neolithic Jarmo, Northern Iraq

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ABSTRACT In this paper, we present a reanalysis of pig (*Sus scrofa*) remains from the Neolithic site of Qalat Jarmo, originally excavated in the 1940s and 1950s. Employing modern zooarchaeological techniques, not available during the initial analyses, we explore the nature of swine exploitation strategies and demonstrate that pigs were most likely managed by the early 7th millennium (Pottery Neolithic) and perhaps earlier. Comparing biometric data with those from other sites in the region, we show that the Jarmo pigs exhibit evidence for size decrease associated with intensive management, but had not yet achieved the degree of dental or post-cranial size reduction seen in later Neolithic domestic populations. Although samples from the earliest (Pre-Pottery) occupation of the site are small, there is some evidence to suggest that domestic pigs were present at Jarmo as early as the late 8th millennium cal. BC. In either case, Jarmo likely represents the earliest appearance of pig husbandry along the Zagros flanks, and we discuss the mechanisms by which Neolithic technologies, including domesticated animals, spread to new regions. This project emphasises the value of curated faunal assemblages in shedding new light on the spread of Neolithic economies. Copyright © 2013 John Wiley & Sons, Ltd.

Key words: pigs; *Sus*; domestication; animal management; Zagros; Jarmo; Near East; Neolithic; Iraq

Introduction

Although Southwest Asia has long been identified as an early centre of pig (*Sus scrofa*) domestication (Reed, 1959; Flannery, 1983), the temporal and geographic contexts of the origins and spread of swine management remain a major focus of ongoing research (Peters *et al.*, 2005; Albarella *et al.*, 2007; Larson *et al.*, 2007; Rowley-Conwy *et al.*, 2012). Although excavations in Southwest Asia continue to add to our understanding of the origins of animal husbandry, research has shown that approaching old faunal collections with new zooarchaeological methods is also an important source of new information (Zeder, 2001; Arbuckle, 2008; Atici *et al.*, in press). In this paper, we explore the long-term evidence for phenotypic changes related to domestication in pigs in Southwest Asia by reanalysing faunal remains from the site of Jarmo in northern Iraq. We use the term *domestication* in this paper to refer the process by which certain species acquire heritable phenotypic adaptions to anthropogenic niches as a direct result of human *management strategies* (or husbandry practices), intended to facilitate exploitation of the animal or plant species (Hammer, 1984; Zeder, 2012: 228). Because domestication is a process, phenotypic changes accrue over time rather than appearing suddenly.

Recent research in the Taurus foothills and Syrian plain (Figure 1) suggests that pig domestication occurred in the Taurus region in the mid-9th millennium cal. BC (Ervynck *et al.*, 2001; Peters *et al.*, 2005; Helmer, 2008; Hongo *et al.*, 2009; Zeder, 2011), although evidence from the site of Hallan Çemi and from the island of Cyprus suggests that management of wild boar may have its roots in the terminal Pleistocene (Peasnall *et al.*, 1998; Vigne *et al.*, 2012). The process of pig domestication is best exemplified at Çayönü Tepesi in the Upper Tigris drainage, where a gradual shift towards culling younger animals and a decrease in size (evidenced in both post-cranial and dental measurements) has been documented from the 10th to 8th millennium cal. BC (Hongo and Meadow, 1998; Ervynck *et al.*, 2001). Although the Zagros region is located close to this epicentre of early

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Figure 1. Map showing locations of archaeological sites mentioned in the text. This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

pig domestication, the only comprehensive study of pig domestication in this region was undertaken by Flannery (1961; 1983; see also Stampfli, 1983) who argued that domestic pigs first arrived with pottery in the mid-7th millennium cal. BC at the site of Qalat Jarmo.

Given archaeological evidence for exchange and interaction between the northern Levant and Zagros regions (Hole, 1983), the late introduction of pigs to the Zagros piedmont is somewhat surprising and raises questions concerning the mechanisms and motivations behind the uneven spread of animal management technologies across Neolithic Southwest Asia. Given the importance of this site for understanding the spread of Neolithic technologies into the eastern wing of the Fertile Crescent, we conducted a reanalysis of the Jarmo fauna, using modern zooarchaeological methods to address the nature and timing of the appearance of pig management, and situating our results within a larger regional body of data.

Qalat Jarmo

Qalat Jarmo is a 1.3 ha Neolithic site located near the modern city of Chemchemal in Iraqi Kurdistan (35.55°N, 44.95°E), with both late Pre-Pottery Neolithic (PPN) and Pottery Neolithic (PN) occupations. The site was excavated over the course of three field seasons, from 1948 to 1955, by a team led by the late Robert Braidwood of the Oriental Institute of the University of Chicago (Braidwood and Howe, 1960; Braidwood, 1983) (Figure 1). Jarmo lies at an elevation of 800 masl along the steep bank of the Wadi Cham-Gawra (Braidwood, 1983) in an area characterised today by dry summers and wet winters (~300 mm mean annual rainfall). It is likely that the local environment was less marginal in the early Holocene than it is today; charcoal and faunal remains reveal that the Neolithic settlement was located in proximity to both oak–pistachio woodlands and rich grassland plains (Braidwood and Howe, 1960: 47; Stampfli, 1983).

Previous studies of the Jarmo pigs

Several researchers have previously studied the Jarmo faunal remains (Reed, 1960; Flannery, 1983; Stampfli, 1983). In both PN (N_{total} = 3450) and PPN (N_{total} = 1416) periods, domestic goats were the dominant taxon (59% $NISP_{PPN}$ and 40% $NISP_{PN}$), followed by domestic sheep (35% $NISP_{PPN}$ and 24% $NISP_{PN}$)

and aurochs (9% $NISP_{PPN}$ and 3% $NISP_{PN}$). Gazelle, deer, hemiones, fox, dog, lion, leopard, lynx, badger and hare remains were also recovered. Pig remains made up 2% of PPN assemblage, increasing to 7% NISP in the PN (see Table 1, Supporting information). Despite the small number of remains, the *Sus* specimens generated interest in the process of pig domestication.

Flannery, in an unpublished master's thesis (1961), later published (1983), argued that domestic pigs were absent in the earliest levels at Jarmo, arriving only with the appearance of pottery. He based this conclusion on two lines of evidence. First, he cited the increase in the number of *Sus* remains between PPN and PN levels (see also Stampfli, 1983: 447). Although often used in zooarchaeological studies of animal domestication (Bökönyi, 1969; Davis, 1987), increases in the frequency of a taxon do not directly address the status, domestic or wild, of an animal population. Selective hunting practices may also explain such shifts (e.g. Bar-Oz *et al.*, 2011). Second, Flannery argued that the lengths of *Sus* molars in PN contexts, but not PPN ones, were significantly smaller than those of modern wild boar. However, his conclusion that the PPN specimens represented wild boar is problematic: of 14 dental measurements, five were erroneously assigned to PPN contexts (see Stampfli, 1983: 447), and eight were taken on M1 and M2 lengths, which have since been shown to be unreliable indicators of domestic status in pigs (Payne and Bull, 1988; Mayer *et al.*, 1998; Evin *et al.*, 2013).

Although these early investigations provide an important starting point, recent developments in zooarchaeological methodology have much to add to our understanding of pig husbandry at Jarmo, particularly analyses of kill-off patterns and dental and post-cranial metrics (Albarella and Payne, 2005; Hongo *et al.*, 2007; Albarella *et al.*, 2009; Rowley-Conwy *et al.*, 2012). With these new datasets, our reanalysis aims to (i) interpret evidence for swine management at Jarmo, (ii) address, if possible, when domesticated pigs first appeared at Jarmo, and (iii) contextualise the patterns from Jarmo within the Neolithic Zagros region.

Materials and methods

The excavations at Jarmo were groundbreaking for their time, incorporating modern excavation and recovery techniques including sieving and the collection of faunal remains (Braidwood *et al.*, 1983: 2); however, it is unclear what proportion of the faunal remains derive from sieved contexts. Faunal remains were sorted onsite by specialists, and diagnostic specimens were shipped to Chicago for analysis (Stampfli, 1983: 432). In total, this collection consists of 6649 identified specimens (Stampfli, 1983: Table 25). Currently, the Jarmo faunal assemblage is curated by the Department of Geology at the Field Museum of Natural History in Chicago. One of us (M. D. P.) analysed the sheep, goat, cattle and pig remains from the collection, with a focus on collecting biometric and demographic data (Table 1).

Zooarchaeological evidence for pig management

Biometric data

Domestic animals often exhibit a suite of morphological changes, the so-called domestication syndrome, resulting from human management practices that isolate populations and create novel selection factors (Hammer, 1984; Zeder, 2012). It is widely acknowledged that domestic swine tend to be smaller-bodied than wild boar, particularly in cranial and dental elements (Rütimeyer, 1862; Winge, 1900; Rowley-Conwy *et al.*, 2012). Thus, biometric data pertaining to skeletal and dental size may be used to indicate the presence of morphologically domesticated animals. However, it is important to acknowledge that morphological changes do not always result from human management, especially early in the domestication process, and that management practices likely preceded the appearance of the 'domestication syndrome' (Zeder, 2012).

For this study, we measured dental and post-cranial elements. Breadth (bucco-lingual) measurements were taken on all *Sus* molars and dP4s, while lengths were recorded for maxillary and mandibular M3s. These measurements provide the best metrical discrimination between *Sus* populations (Payne and Bull, 1988; Kusatman, 1991; Mayer *et al.*, 1998) because pigs do not exhibit a high degree of sexual dimorphism in post-canine dental metrics (Payne and Bull, 1988: 30). Breadth and depth measurements were also recorded on post-cranial remains. We employed the log-size index (LSI) method to overcome sample size issues in addition to detailed comparisons of individual measurements (Meadow, 1999). As our LSI standards, we used a female wild boar shot in 1964 near Elazig, Turkey, for post-cranial remains (Hongo and Meadow, 1998: 88; Hongo and Meadow, 1998), and the mean values of a sample of modern wild boar from Kizilcahamam, Turkey, for dental metrics (Payne and Bull, 1988: 40-41) (see Supporting information).

Kill-off data

Demographic data are used to identify the origins and nature of animal management in archaeofaunal collections

Table 1. Fragment counts of Sus remains analysed in this study, organised by context (excavation levels are in rows, main trenches are in columns). Dark-shaded cells represent fragment counts from Pre-Pottery contexts, light-shaded cells represent early Pottery contexts, white cells represent later Pottery contexts (see Dating Jarmo).

Level	JI	JII	JIII	J-B	J-D	2x2 Test Trenches
Surface-1				1	2	21
1		47	1			27
1-2				2		
2		52				18
3	14	7				24
4		7				2
4-6	2					
5	9	4				
6		3				
7	1					
Trench Total	**26**	**120**	**1**	**3**	**2**	**92**

(e.g. Payne, 1973). Herd management ensures the continued productivity of a livestock population, and, as a result, culling tends to focus on surplus young, whereas hunting practices tend to target adults (Payne, 1973; Hesse, 1978; Meadow, 1989). Although it is important to note that hunting wild boar can lead to juvenile-heavy assemblages, with perhaps as many as 50–60% of the remains belonging to individuals under 2 years old (Benecke, 1993; Albarella *et al.*, 2006: 217; Rowley-Conwy *et al.*, 2012: 23-28), kill-off patterns of managed domestic pig populations in the prehistoric Southwest Asia are often composed predominantly (~85–100%) of animals under 2 years of age (e.g. Zeder, 1994; Monahan, 2000; Haber and Dayan, 2004; Grigson, 2006; Buitenhuis, 2008; De Cupere *et al.*, 2008). For this study, age-at-death was assessed using tooth wear and epiphysial fusion, which were recorded (following Bull and Payne, 1982; Grant, 1982), and were categorised into age classes following the criteria of Ervynck *et al.* (2001).

Dating Jarmo

Braidwood's excavations at Jarmo revealed late PPN and PN occupations. Although radiocarbon dates obtained by Braidwood for the Jarmo sequence are highly problematic, ranging from 11,240 to 6300 uncal. BP (see Supporting information), both PPN and PN levels include artefact parallels that link Jarmo to other sites in the Zagros. For example, stone bowl and chipped stone industries from the PPN levels at Jarmo have clear parallels to levels at Ali Kosh and Tepe Guran dated to the 8th millennium cal. BC (Meldgaard *et al.*, 1963; Hole *et al.*, 1969; Adams, 1983; Hole, 1983; Zeder, 2008). For the PN phases, ceramics first appear in trench JII, levels 3–5. Typologically, these earliest ceramics bear similarities to the 'tadpole ware' of Tepe Sarab and Guran, radiocarbon dated to 7000–6800 cal. BC (Zeder, 2008). A later phase of the PN at Jarmo, exemplified in JII levels 1–2 (Adams, 1983), exhibits parallels at Tell Sotto (Bader, 1993), Guran (levels O–H, radiocarbon dated to 6980–6550 cal. BC) (Meldgaard *et al.*, 1963; Hole, 1987; Zeder, 2008: Table 3), and the Mohammed Jaffar phase of the Deh Luran sequence (Hole *et al.*, 1969: Fig. 43; Hole, 1987) providing a range from the early to mid-7th millennium cal. BC for the Jarmo PN occupation.

In order to clarify the radiocarbon chronology of the site, we submitted 14 bone samples for dating to Woods Hole Oceanographic Institute (NOSAMS). Because of poor collagen preservation, however, only one sample provided a date (8240 $\pm$ 65 uncal. BP, ∂ 13C = −27.65; 7445–7143 cal. BC (2-sigma) (Bronk-Ransey, 2009)). This sample derives from a PPN context (locus MQ1519 level 6) and confirms for the first time that the PPN occupation of Jarmo dates to the late 8th millennium cal. BC.

Results

Kill-off patterns

The kill-off data from Jarmo were analysed for PN and PPN levels separately (Figure 2), using tooth wear data exclusively because of the small number of epiphysial

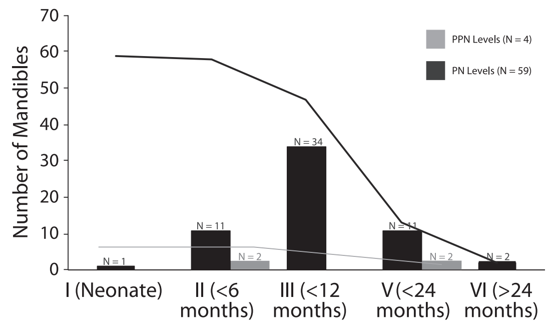

Figure 2. Kill-off patterns from Pottery Neolithic (PN) and Pre-Pottery Neolithic (PPN) levels at Jarmo based on dental eruption and wear (see Supporting information for raw data). Bars represent frequencies within age classes, and lines represent attrition curve. Age classes after Ervynck *et al.* (2001).

remains. The PN pig remains indicate an emphasis on juvenile animals, with most (78%) killed before 1 year of age and the vast majority (97%) killed before their second year. This is consistent with expectations for a managed swine population. For the PPN, interpretation of kill-off is inconclusive because of small sample size.

Biometric patterns

Comparison of the Jarmo post-cranial measurements with those from other sites in the region (Figure 3) shows the presence of small-bodied pigs in the PN. The mean, median and modal values for the Jarmo PN pigs are considerably smaller than those from wild boar in the Zagros region from earlier sites including Ganj Dareh, M'lefaat, Asiab, Nemrik 9, Karim Shahir and Palegawra (Turnbull and Reed, 1974; Bökönyi, 1977; Hesse, 1978; Turnbull, 1983; Lasota-Moskalewska, 1994) and are comparable with later domesticates from Matarrah, Banahilk and Hajji Firuz (see Table 2(A) for statistical summary). The Jarmo post-cranial measurements are also comparable with those representing some of the earliest domestic pigs from the Upper Tigris and Euphrates basins, including the Cobble phase at Çayönü and Middle and Late PPNB levels of Mezraa-Teleilat and Gritille (Monahan, 2000; Ervynck *et al.*, 2001; Ilgezdi, 2008). We therefore interpret these data as representing the presence of morphologically domestic pigs at Jarmo in the PN.

Dental measurements from Jarmo's PPN and PN levels are compared with those from neighbouring sites in Figure 4. M_1, M_2 and M_3 breadth, and M_3 length measurements from PN Jarmo are significantly smaller than those from earlier sites in the region (Asiab, Ganj Dareh and the early phases of Çayönü) as well as recent wild boar (see Table 2(C) for statistical summary). However, the Jarmo PN dental metrics are significantly larger than those from later Neolithic sites in the region (Siahbid, Banahilk, Matarrah and Hajji Firuz) as well as from the Bronze Age sample from Kaman-Kalehöyük, Turkey (Laffer, 1983; Meadow, 1983; Kusatman, 1991; Hongo, 1998). This suggests that the Jarmo dental measurements represent a dental morphology transitional between wild boar and later domesticates, which is broadly similar to the pattern seen in pig remains from the contemporaneous Large Room and PN levels of Çayönü.

The sample of dental measurements from the PPN levels of Jarmo is small, but the data presented in Figure 4 show that the samples that are available tend to fall on the smaller end of the size range for the Jarmo PN samples. This is important as it suggests the presence of 'transitional' domesticates as early as the 8th millennium BC at Jarmo.

In order to further investigate evidence for changes in dental metrics through the Jarmo stratigraphic sequence, we analysed data by level from trench JII. This trench contained 94 measured molar teeth in six excavation levels (Figure 5). Level 6 represents the PPN, as do levels 4–7 from trench JI, which were included to increase the PPN sample size. JII levels 3–5 have ceramic parallels with early 7th millennium assemblages at Tepe Sarab and Tepe Guran, and represent early PN contexts. Finally, JII levels 1–2 are considered mid-7th millennium. Interestingly, the mean LSI values on tooth breadths showed no significant differences by excavation level (one-way ANOVA: $F(4, 98) = 1.452$, $p = 0.223$). A Tukey post hoc (honestly significant difference) test found no significant differences between individual pairs of levels (all p-values > 0.15, see Table 2(B)). Although the sample size for the PN levels is small, this suggests the intriguing possibility that pigs exhibiting dental morphologies indistinguishable from the PN domesticates were present at Jarmo in the PPN dating to the 8th millennium cal. BC.

Discussion

Summary of results and the utility of reanalysis

The results of our reanalysis point to three conclusions. (i) We concur with previous studies (Flannery, 1983; Stampfli, 1983) that domestic pigs were present at PN Jarmo. Kill-off data showing intense culling of juveniles suggest management, whereas morphological changes evident in both dental and post-cranial measurements indicate phenotypic changes in response to management and population isolation. These lines of evidence support the interpretation that domestic pig husbandry was an important, if relatively small, component of the economy in the PN. (ii) Both post-cranial and dental

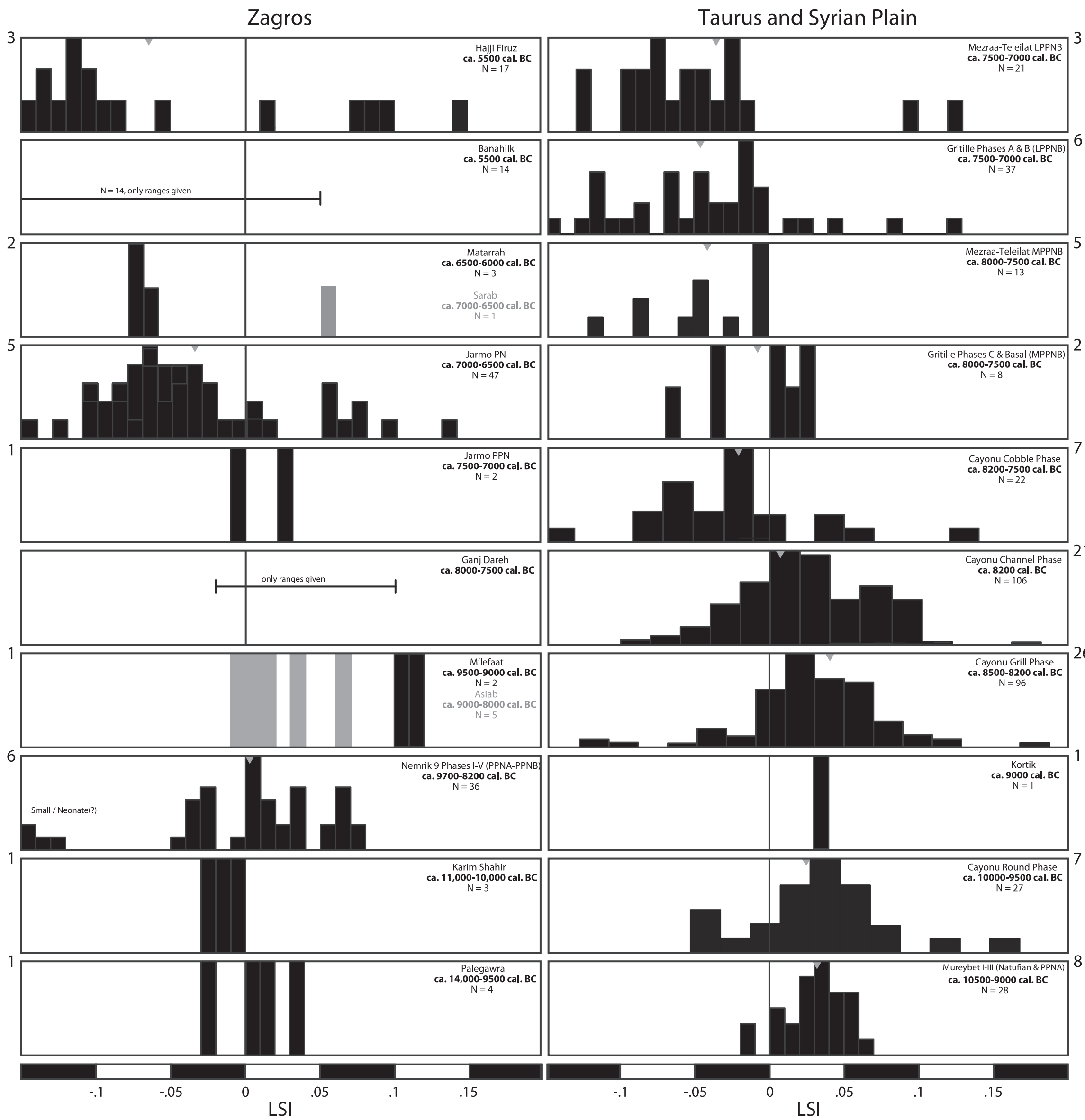

Figure 3. Comparison of Sus post-cranial log-size index (LSI) values from sites in the Taurus (right column) and Zagros (left column) regions, using standard published by Hongo and Meadow (1998a, 1998b). Sources: Mezraa-Teleilat (Ilgezdi, 2008), Gritille (Monahan, 2000), Nemrik 9 (Lasota-Moskalewska, 1994), Çayönü (Ervynck, et al., 2001), Mureybet (Gourichon and Helmer, 2008), Banahilk (Laffer, 1983), Hajji Firuz (Meadow, 1983), Sarab (Bökönyi, 1977: 75–76), Ganj Dareh (Hesse, 1978: 176), M'lefaat (Turnbull, 1983), Asiab (Bökönyi, 1977: 75–76), Matarrah (Stampfli, 1983) and Karim Shahir (Stampfli, 1983).

biometrics indicate that, although the Jarmo PN pigs were smaller than early Holocene wild boar in the Zagros, they were still larger than later Neolithic domesticates in the region. This suggests that the Jarmo pigs represent a 'transitional' morphology and that phenotypic change among domesticates continued over a period of several millennia. (iii) There is some evidence to suggest that morphologically domestic pigs were present in the PPN occupation of Jarmo. Although sample sizes are too small to confirm this, tooth breadth measurements suggest the presence of pigs with molar teeth that are smaller than or at the very bottom of the size range of ancient wild boar; if confirmed by other methods, this would suggest that domesticated pigs, and therefore pig husbandry, were present in the earliest phases of the Jarmo occupation dating to the mid to late 8th millennium cal. BC.

These new conclusions, based on datasets not studied in earlier examinations, highlight the utility of reanalysing old faunal collections. Reanalysis is an

Table 2. P-values of Tukey HSD pairwise comparisons for (A) post-cranial LSI values for pigs from Jarmo and nearby sites showing increasing diminution of body size over time, (B) post-cranial LSI values for pigs Jarmo Trench JII, showing no change over time and (C) mandibular molar dental metrics grouped as follows: ancient wild boars (Çayönü Round and Grill, Asiab, Karim Shahir, Ganj Dareh and Hallan Çemi), Jarmo PN and late domestic (Kaman Kalehöyük, Matarrah, Banahilk, and Hajji Firuz). ANOVA results for each dataset presented below each table. P-values < .05 in bold, P-values > .05 in gray.

A

Postcranial LSI	Çayönü Round Phase	M'lefaat/Asiab/ Karim Shahir/ Palegawra	Nemrik 9	Mureybet	Gritille C & Basal	Gritille A & B	Mezraa-Teleilat MPPNB	Mezraa-Teleilat LPPNB	Jarmo PN	Hajji Firuz
Çayönü Round Phase	------	.9998	.5280	> .9999	.1643	**.0002**	**.0178**	**.0004**	**.0001**	**< .0001**
M'lefaat/Asiab/Karim Shahir /Palegawra	.9998	------	> .9999	.9907	.6054	.0651	.2382	**.0436**	.0570	**.0086**
Nemrik 9	.5280	> .9999	------	.6986	.9046	.0983	.5057	.0815	.0744	**< .0001**
Mureybet	> .9999	.9907	.6986	------	.2361	**.0004**	.5057	**.0007**	**.0002**	**< .0001**
Gritille C & Basal	.1643	.6054	.9046	.2361	------	> .9999	> .9999	.9997	> .9999	.9751
Gritille A & B	**.0002**	.0651	.0983	**.0004**	> .9999	------	> .9999	> .9999	> .9999	.9562
Mezraa-Teleilat MPPNB	**.0178**	.2382	.5057	.5057	> .9999	> .9999	------	> .9999	> .9999	.9949
Mezraa-Teleilat LPPNB	**.0004**	**.0436**	.0815	**.0007**	.9997	> .9999	> .9999	------	.9998	.9409
Jarmo PN	**.0001**	.0570	.0744	**.0002**	> .9999	> .9999	> .9999	.9998	------	.9996
Hajji Firuz	**< .0001**	**.0086**	**.0126**	**< .0001**	.9562	.9751	.9949	.9996	.9409	------

One-Way Anova: F(9, 251) = 7.866, P < .0001

B

Jarmo Postcranial LSI by Level	JII, Level 1	JII, Level 2	JII, Level 3	JII, Level 4	JII, Level 6 + JI Levels 4-7
JII, Level 1		.9987	.9996	.5615	.4986
JII, Level 2	.9987		.9976	.6323	.3957
JII, Level 3	.9996	.9976		.7100	.9311
JII, Level 4	.5615	.6323	.7100		.1566
JII, Level 6 + JI Levels 4-7	.4986	.3957	.9311	.1566	

One-Way Anova: F(4, 98) = 1.452, P = .2228

C

M/1 WP	Ancient Wild Boar	Jarmo PN	Late Prehistoric Dom.
Ancient Wild Boar	------------------	**< .0001**	**< .0001**
Jarmo PN	**< .0001**	------------------	**< .0001**
Late Prehistoric Dom.	**< .0001**	**< .0001**	------------------

One-Way Anova: F(3, 159) = 32.881, P < .0001

M/2 WP	Ancient Wild Boar	Jarmo PN	Late Prehistoric Dom.
Ancient Wild Boar	------------------	**.0001**	**< .0001**
Jarmo PN	**.0001**	------------------	.1367
Late Prehistoric Dom.	**< .0001**	.1367	------------------

One-Way Anova: F(3, 137) = 21.184, P < .0001

M/3 Length	Ancient Wild Boar	Jarmo PN	Late Prehistoric Dom.
Ancient Wild Boar	------------------	.0713	**< .0001**
Jarmo PN	.0713	------------------	**.0047**
Late Prehistoric Dom.	**< .0001**	**.0047**	------------------

M3L: One-Way Anova: F(3, 93) = 25.613, P < .0001

M/3 WA	Ancient Wild Boar	Jarmo PN	Late Prehistoric Dom.
Ancient Wild Boar	------------------	**.0081**	**< .0001**
Jarmo PN	**.0081**	------------------	**.0012**
Late Prehistoric Dom.	**< .0001**	**.0012**	------------------

M3WaOne-Way Anova: F(3, 89) = 35.048, P < .0001

important part of zooarchaeological research; not only does it provide fresh perspectives on assemblages by answering new questions with modern methods but it also allows research into animal management and subsistence to progress in regions where excavation may no longer be possible or is severely limited. This study joins several others (Zeder, 2001; Albarella and Serjeantson, 2002; Arbuckle, 2008; Atici *et al.*, in press) in improving our understanding of the archaeological record without excavation.

Domesticated pigs in the Zagros

Our reanalysis of evidence for Jarmo pig management brings up questions regarding the nature and timing of pig husbandry in the Neolithic. In comparison with earlier and later sites in the region, the Jarmo biometrical data document a slow process of phenotypic change in pigs from Neolithic Zagros settlements. This long process of morphological change probably reflects the extensive nature of husbandry practices combined with occasional inter-breeding with local wild boar, for which there is ample biometric evidence in Neolithic assemblages in the form of the presence of some very large individuals (e.g. see Hajji Firuz data in Figure 4).

On a regional scale, it appears that pig management was a relatively late arrival to the Zagros region. Despite the early evidence for pig management and domestication taking place at Çayönü by the late 9th millennium cal. BC, the management of domestic pigs first appears in the Zagros piedmont at PN Jarmo by

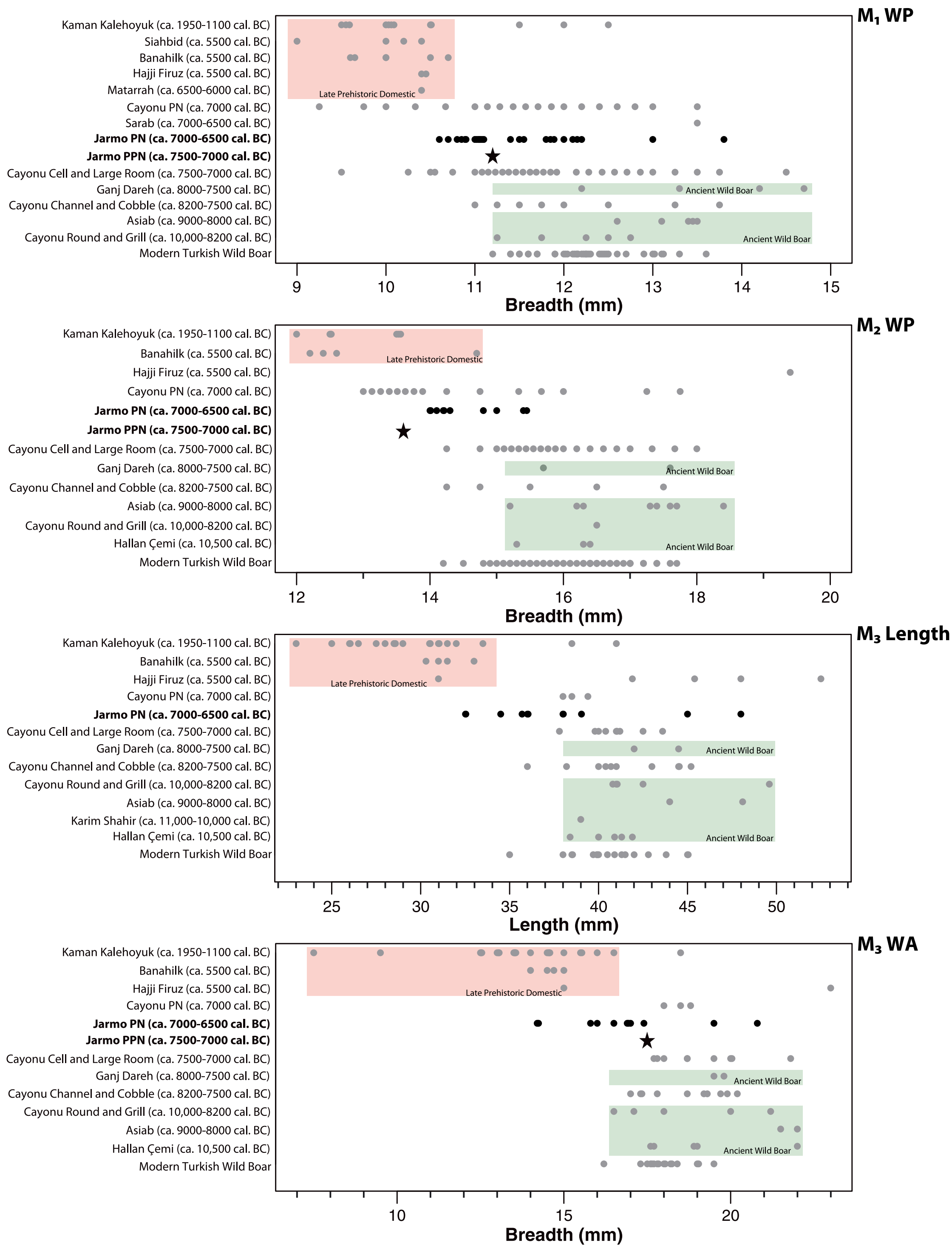

Figure 4. Dental metrics (WA = mesial cusp bucco-lingual diameter; WP = distal cusp bucco-lingual diameter; length = mesio-distal diameter) of lower molars from early and late prehistoric sites near Jarmo. Assemblages with clear small-size animals are interpreted as domestic, whereas those with large-sized animals are interpreted as wild. Data from modern wild boars from Turkey are provided for comparison. Note the intermediate size of Jarmo specimens. Also note that the Cayönü data from all periods show a large and seemingly continuous range (making it difficult to separate into domestic and wild categories), reflecting the continued importance of hunting alongside domestic pig husbandry (Ervynck, et al., 2001). See Table 2 for statistical summary. Sources: Çayönü (Ervynck, et al., 2001), Kaman Kalehöyük (Hongo, 1998), Karim Shahir (Flannery, 1983), Ganj Dareh (Hesse, 1978: 176), Asiab (Bökönyi, 1977), Hajji Firuz (Meadow, 1983), Hallan Çemi (mand. M3 lengths only, Redding and Rosenberg, 1998), Banahilk (Kusatman, 1991) and modern Turkish wild boar (Kusatman, 1991). This figure is available in colour online at wileyonlinelibrary.com/journal/oa.

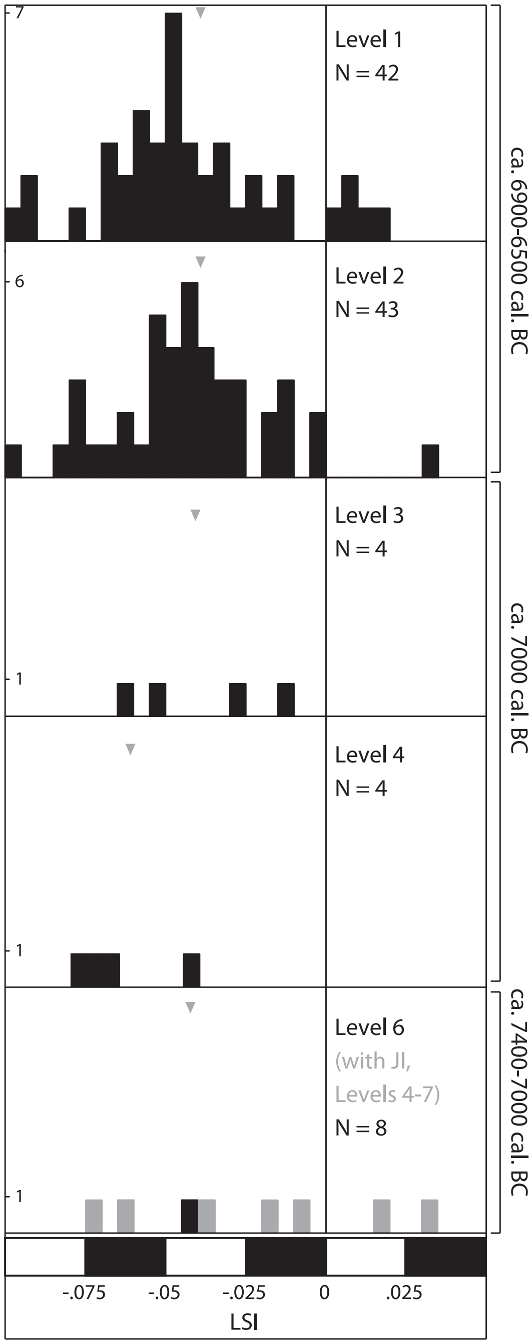

Figure 5. Log-size index (LSI) values for Sus tooth breadths from levels 6–1 in Trench JII, showing no significant difference over time (one-way ANOVA: $F(4, 98) = 1.452$, $p = 0.223$). See Table 2 for statistical summary. LSI values calculated using upper and lower dP4s, M1s, M2s and M3s, and based on standard published by Payne and Bull (1988). See Supporting information for tooth breadth measurements from Jarmo and standard measurements.

the early 7th millennium cal. BC and possibly as early as the late 8th millennium (PPN). After Jarmo, the next earliest evidence for pig husbandry in the Zagros piedmont comes from the site of Matarrah dating to the late 7th millennium cal. BC (Stampfli, 1983). Further east, domestic pigs arrive even later, with morphological domesticates identified at the 6th millennium sites of Banahilk, Hajji Firuz and Siahbid, and, most likely, the PN layers at Belt Cave (1–7) (Coon, 1951; Bökönyi, 1977; Laffer, 1983; Meadow, 1983; Stampfli, 1983). Domestic pigs have also been identified at lowland sites dating to the 6th millennium, including Choga Mami and Tell es-Sawwan (Bökönyi, 1978). In the southern parts of the Zagros, domestic pigs arrived much later, perhaps not until the Chalcolithic (Hole *et al.*, 1969: 308; Flannery, 1983), and pig husbandry was never an important feature of animal economies on much of the Iranian plateau (Mashkour, 2006).

Why, then, did pig management take so long to move into the Zagros piedmont, and why, after appearing relatively early at Jarmo, were domestic pigs absent for another millennium or more at other sites in the Zagros region? It is likely that the answers to these questions relate to a complex interplay between husbandry practices, local environment, existing agricultural regimes and cultural values.

The most likely strategy of swine management practised in the Neolithic Near East involved extensive husbandry in piedmont oak forests (Redding and Rosenberg, 1998; Ervynck *et al.*, 2001; Dobney *et al.*, 2007). Under this husbandry regime, herders maintain little control over pig reproduction, diet and mobility, allowing pigs to forage their own food and interbreed with wild boar (Figure 4). Compared with more intensive husbandry practices involving stalling, foddering and isolation from wild populations, extensive husbandry may have encouraged the relatively slow rate of phenotypic change seen in the Neolithic pigs (Figure 3 and 5).

Husbandry practices may also have been responsible for the slow spread of swine husbandry. The successful spread of domesticates to new regions can only occur when husbandry practices and environmental parameters are complementary. Extensive swine husbandry practices require specific environments, that is, ones with sufficient natural resources to sustain free-ranging pig populations. Thus, sites located in the oak piedmont region adjacent to a perennial water source, such as Jarmo, were well situated for pig husbandry, whereas sites in the southern Zagros, with higher aridity and fewer mast resources, discouraged pig production. It is likely that southern sites were only able to incorporate pig husbandry when they adopted more intensive husbandry practices, involving stall feeding and penning.

As a general rule, husbandry practices, like any technological system, must fit into local cultural conceptions of the environment, economy and cosmology in order for them to take hold in a society (Lemonnier, 1992; Skibo and Schiffer, 2008). Thus, for example, native North American groups in 17th century New England adopted swine husbandry, while rejecting sheep and cattle, because the activities involved in raising pigs fit with extant ideals about gendered division of labour, aesthetics (in this case their comparability to dogs) and political relations with Europeans (Anderson, 1994; Silverman, 2003). It is very difficult to assess how these factors influenced the adoption of pig husbandry in Zagros communities. Nevertheless, social factors, which are inextricably linked to technological and environmental variables (cf. Hodder, 2012), likely played an important role in structuring the relatively early acceptance of pig husbandry at Jarmo and its long-term rejection in much of the Zagros region.

Conclusion

This study has shown how a re-examination of old faunal collections using new methods can elucidate previously undetected patterns. In agreement with previous work by Flannery (1983) and Stampfli (1983), we argue that the PN inhabitants of Jarmo managed domestic pigs, and this likely represents the earliest example of swine husbandry in the Zagros region. However, our analysis has shown that although the Jarmo pigs are smaller than wild boar from earlier sites in the Zagros region, they do not display the level of post-cranial and dental size diminution detected at later Neolithic sites. They, therefore, represent a transitional domestic morphology also seen in pigs at the contemporaneous levels at the site of Çayönü. Moreover, analysis of the Jarmo evidence also *tentatively* suggests that domestic pigs and pig management may have been present in the PPN occupation of the site, which has been radiocarbon dated for the first time to the late 8th millennium cal. BC.

Situating Jarmo within the broader context of the Neolithic of Southwest Asia raises interesting questions about the uneven pace of the spread of Neolithic technologies and practices. How and why were domestic pigs incorporated into economies at Jarmo in the 7th and perhaps even 8th millennia cal. BC while they were rejected by other communities in the region until much later? This situation speaks to patterns evident in Neolithic economies across the Near East, and emphasises the local-level nature of subsistence practices, which reflect a complex interaction of environmental and cultural variables (Asouti and Fuller, 2012; Arbuckle, 2013). At Jarmo, local environmental features certainly favoured the adoption of pig husbandry. However, social factors must also have been in play, for Jarmo remained an isolated outpost for pig management in the Zagros for almost a millennium. Although these factors remain obscure at present, with the increasing number of excavated sites and continued reanalysis of faunal assemblages in museum collections, future researchers will be well positioned to better understand the spread of Neolithic technologies in the Zagros, Southwest Asia, and beyond.

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