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Pigs in Sight: Late Bronze Age Pig Husbandries in the Aegean and Anatolia

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ABSTRACT

This paper explores pig husbandry across the Aegean and Anatolia based on zooarchaeological data and ancient texts. The western Anatolian citadel of Kaymakçı is the departure point for discussion, as it sits in the Mycenaean-Hittite interaction zone and provides a uniquely large assemblage of pig bones. NISP, mortality, and biometric data from 38 additional sites across Greece and Anatolia allows observation of intra- and interregional variation in the role of pigs in subsistence economies, pig management, and pig size characteristics. Results show that, first, pig abundance at Kaymakçı matches Mycenaean and northern Aegean sites more closely than central, southern, and southeastern Anatolian sites; second, pig mortality data and biometry suggest multiple husbandry strategies and pig populations at Kaymakçı, but other explanations cannot yet be excluded; and, third, for the Aegean and Anatolia during the Late Bronze Age more generally, pig data suggests pluriformity, which challenges the use of "pig principles" in this region.

KEYWORDS

Kaymakçı; zooarchaeology; pig husbandry; Hittite; Mycenaean

Introduction

In early state societies, domestic animals supported growing populations, enabled the accumulation of wealth, fueled hierarchical systems, and fulfilled symbolic roles (e.g., DeFrance 2009; Russell 2011; Zeder 1991). Late Bronze Age (LBA, ca. 1650–1200 B.C.) societies in Greece and Anatolia met the growing demand for animal resources by centralizing and intensifying their animal economies, resulting in large-scale production and distribution of meat, wool, hides, working oxen, and other animal goods (Halstead 1993, 2011; Shelton 2010; Berthon 2017). The ubiquity of sheep, goats, and cattle in LBA texts and faunal assemblages suggests that these animals formed the backbone of Mycenaean and Hittite economies (e.g., Halstead 1999; Dörfler et al. 2011). Pigs, although highly efficient meat providers, were not always a recognized part of these economic systems. Pigs feature sporadically in the Mycenaean and Hittite texts, and their bones occur less frequently in faunal assemblages than sheep, goat, and cattle bones (Trantalidou 1990; Halstead 1999; Dörfler et al. 2011).

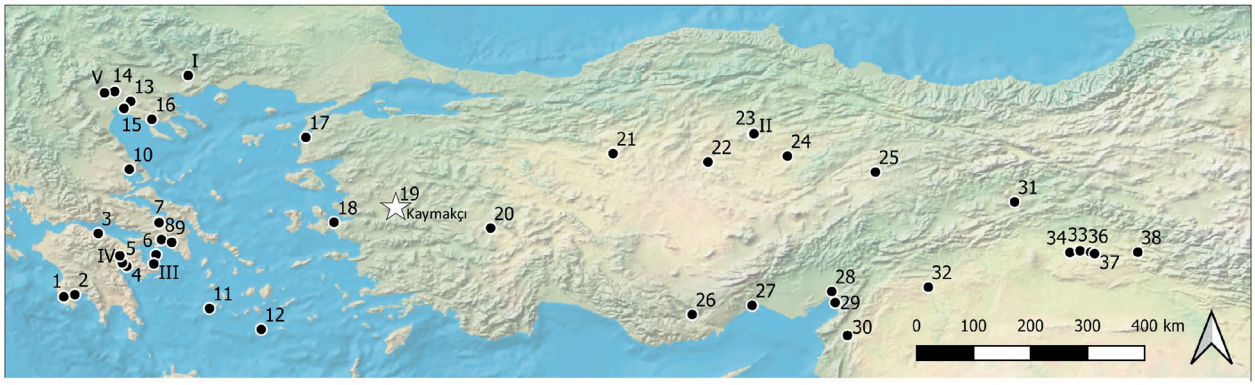
For Near Eastern early state societies, the scarcity of pig bones has been explained by "pig principles," summarized by Hesse and Wapnish (1998, 125–126). These include the unattractiveness of pigs in centralized systems, physiological/behavioral complications of pig herding, and a pork taboo (Zeder 1991, 1998; Redding 1991, 2015). Pigs were instead considered a more suitable food source for rural and/or remote settlements, which relied on locally and loosely organized forms of subsistence (e.g., Zeder 1991, 1998; Price, Grossman, and Paulette 2017). Only recently, studies in northern Mesopotamia demonstrated that the economic importance of pigs was wider spread across early urban contexts than previously thought (Grigson 2007; Berthon 2014; Price and Evin 2017; Gaastra, Greenfield, and Greenfield in press).

The "pig principles" appear to have explicitly and implicitly shaped pig research in both the Aegean and Anatolia (e.g., Arbuckle 2009; Berthon 2014; Fillios 2007; Grigson 2007; Macheridis 2018). Together with the relatively small numbers of pig bones, excavations predominantly taking place at large settlements, and ancient texts emphasizing administrative concerns only (Halstead 1999, 2003), pigs in the Aegean and Anatolian LBA have therefore received little scholarly attention. It is, however, unclear whether the "pig principles" are applicable to the Aegean and Anatolia. Investigating this issue becomes more pressing from the Middle Bronze Age onwards, firstly because Greece and Anatolia have recently become hot spots for ancient DNA (aDNA) studies investigating the introduction of European pigs into Anatolia and the Levant in the Bronze Age (e.g., Ottoni et al. 2013; Frantz et al. 2019), and secondly because much remains unknown about husbandry strategies in Greece and Anatolia prior to the heavily debated environmental and political changes around 1200 B.C. (e.g., Drake 2012; Kaniewski et al. 2013; Knapp and Manning 2016). At the same time, investigating pig husbandry in this region has become more feasible. Zooarchaeological methods are advancing, with the potential to extract more information from less material, and recent and ongoing excavations increase the quantity of faunal assemblages available for regional comparison.

The pig bones retrieved from recent excavations at the LBA citadel of Kaymakçı in western Anatolia form a unique starting point to address the characteristics of pig husbandry in this region. Kaymakçı is a key site in this investigation for two reasons. Firstly, Kaymakçı is the largest currently known and excavated citadel site in western Anatolia, and it provides an intermediary point of investigation for animal husbandry across the Aegean and Anatolia because of its location in the Hittite-Mycenaean interaction interface (Roosevelt et al. 2015, 2018). Secondly, work at Kaymakçı has followed high standards for faunal recovery and analysis (Roosevelt et al. 2018).

We recently demonstrated how animal subsistence in Kaymakçı depended on mixed husbandry, fishing, hunting, and, to a lesser degree, fowling, but pig exploitation was a

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1. Pylos
2. Nichoria
3. Aigeira
4. Asine
5. Tiryns
6. Aegina Kolona
7. Eleon
8. Eleusis
9. Athenian Agora
10. Magula Pevkakia
11. Phylakopi
12. Akrotiri
13. Toumba Thessaloniki
14. Kastanas
15. Angelochori
16. Olynth
17. Troy
18. Klazomenai
19. Kaymakçı
20. Beycesultan
21. Gordion
22. Kaman Kalehöyük
23. Boğazköy
24. Çadır Höyük
25. Kuşaklı
26. Kilise Tepe
27. Yumuktepe
28. Tatarlı Höyük
29. Kinet Höyük
30. Tell Atchana
31. Korucutepe
32. Lidar Höyük
33. Kavuşan Höyük
34. Ziyaret Tepe
35. Giriciano
36. Müslümantepe
37. Hirbemerdon Tepe
38. Türbe Höyük
I. Sitagroi
II. Yazılıkaya
III. Agios Konstantinos
IV. Mycenae
V. Archontiko

Figure 1. Sites mentioned in the text. Data from sites 1–38 was included in the analysis; sites I–V are only mentioned in text.

dominant component (Roosevelt et al. 2018). This is intriguing, because Kaymakçı's environs could well have sustained pastoralist systems with large sheep, goat, and cattle herds, a feature often associated with large regional Bronze Age centers in southwest Asia (e.g., Arbuckle and Hammer 2019). In this paper, we examine the characteristics of pig husbandry in Kaymakçı and extend our analysis to an exploration of pig husbandry in 38 archaeological sites across LBA Greece and Anatolia (Figure 1; see Supplemental Material 1 for references to sites). We embed our study in an overview of textual references to pigs and previous zooarchaeological research on pig husbandry in the region. Relative abundance, kill-off, and biometric data allow us to investigate the role of pigs in subsistence, strategies to manage them, and the appearance of pig populations, whereas the synthesis of textual references allows us to reflect on the applicability of "pig principles" in the Aegean and Anatolia. Results show, first, that pig abundance at Kaymakçı matches Mycenaean and northern Aegean sites more closely than central, southern, and southeastern Anatolian sites; second, mortality data and biometry suggest multiple husbandry strategies and pluriform pig populations at Kaymakçı, though other explanations cannot yet be excluded; and, third, pluriformity of pig husbandry appears to be characteristic for LBA Anatolia and Greece more generally, which challenges the assumptions of the "pig principles."

Late Bronze Age Pig Husbandry in Text and Bone

Mycenaean and northern Greece

Mycenaean texts mention sheep and goats frequently and in flocks of thousands (Halstead 1999). Because texts mention pigs considerably less frequently, they give the impression that pigs were a less numerous livestock (Halstead 1993, 1999). The zooarchaeological evidence suggests otherwise. Roughly half of the meat consumed at important Mycenaean centers such as Nichoria, Tiryns, and Pylos derived from pigs and cattle (Halstead 1993, 1999, 2003). How meat was produced, however, differed among the centers. At Tiryns, three quarters of the pig population was culled immaturely (Trantalidou 1990; von den Driesch and Boessneck 1990). At Pylos, most pigs were adult when culled, and, based on canine counts, males outnumbered females by 2.5:1 (Nobis 1993), precluding intensive pork exploitation strategies. This evidence has been alternatively interpreted as mismanagement or lack of know-how (Nobis 1993).

Pigs in Linear B texts from Pylos, Tiryns, and Mycenae are specified by age and sex (male, female, possible castrates; Rougemont 2006). The written record is also clear about centers levying pigs for slaughter, pig fat, and pig hides from small local authorities as taxation, suggesting at least some pigs were produced away from regional centers and provisioned to the cities (Halstead 2011). Fattened pigs (*sialos* = "fattened animal," *a-se-so-si* = "fattening," *(h)opa* = "to apply to," SUS + KI = "fattened pig") were allocated to banquets, festivities, and offerings, underlining that pigs fulfilled symbolic, as well as economic, roles (Rougemont 2006; Halstead and Isaakidou 2017). Archaeological evidence for pig offerings and cult meals were found at Ayios Konstantinos (Hamilakis and Konsolaki 2004), in the Cult Center complex at Mycenae (Price, Krigbaum, and Shelton 2017), and possibly in the Palace of Nestor at Pylos (Isaakidou et al. 2002).

Texts detail diets to fatten pigs, which include barley and other vegetal ingredients (Rougemont 2006). Isotope analysis of pig remains in Mycenaean Greece may provide interesting insights into these fattening practices. In Mycenae, $\delta^{15}N$ values in pig bones from the Cult Center indicate a vegetal diet for sacrificial pigs, whereas the elevated $\delta^{15}N$ values of the pigs from the industrial residence of the Petsas House are consistent with an enriched diet (Price, Krigbaum, and Shelton 2017). Whereas differences in $\delta^{15}N$ may indicate dietary differences between wild boar and domestic pigs, vegetal diets may likewise designate controlled fattening practices (Price, Krigbaum, and Shelton 2017) or herding. The enriched diets of Petsas House pigs indicate they were likely scavenging on settlement waste or reared in households (e.g., Hamilton, Hedges, and Robinson 2009; Balasse et al. 2018). Household rearing of pigs in Greece was also suggested for Akrotiri by Gamble (1978, 752; 1982).

Subsistence in northern Greece, where no texts have been found, differed from the Mycenaean mainland, relying more on wild animals and mixed animal husbandry in which pigs were very common (Becker 1986; Creuzieux et al. 2014; Vasileiadou 2009). In Archontiko and Thessaloniki Toumba, differential access of pigs to herbivorous and omnivorous diets, inferred from $\delta^{15}N$ values, suggests different pig husbandry systems may have co-existed locally (Nitsch et al. 2017).

Central and southeastern Anatolia

In the Hittite realm, the scarcity of pig bones has led scholars to suggest that pig husbandry was limited (Dörfler et al. 2011). Especially at the Hittite capital of Boğazköy and the large cult center at Kuşaklı, pig bones were rare (less than 5% of identified specimens; von den Driesch and Vagedes 1997; von den Driesch and Pöllath 2004). As recently suggested by Berthon (2017), Hittite pig husbandry may have been more varied. Pigs were, for example, reared and consumed at Kaman Kalehöyük (17% of identified specimens; Hongo 1996, 67), a large agricultural center (Hongo 1996, 154; Fairbairn and Omura 2005). The frequencies of pig bones appear low in sites south of the Hittite heartland, too, between 4–16% (Baker 2008; Ikram, Çakırlar, and Kabiatar forthcoming; Minniti 2014; Silibolatlaz and Serdar Girginer 2018), but on the southern and southeastern fringes of the Hittite realm, in Alalakh, Lidar Höyük, and Korucutepe, pig bones appear to occur more frequently (14–25%) (Boessneck and von den Driesch 1975; Çakırlar et al. 2014; Kussinger 1988). Beyond the eastern border of the Hittite realm, Berthon (2014) reported a structural inclusion of pigs (between 20–40%) in subsistence strategies at Mitannian centers in rural and well-watered areas.

Although pig bones are rare in most Hittite assemblages, Hittite texts provide ample information about the social connotations, economic uses, husbandry strategies, and symbolic roles of pigs in the Hittite world (Hoffner 1974, 64). The Hittite Law Code prohibited physical contact with and consumption of pigs that scavenged on street waste, whereas other pigs were reared on grain and kept in special enclosures to produce fat and meat ($LÚ^{MEŠ}$ SIPAD.ŠAḪ) (Collins 2006; Hoffner 1974, 65; Klengel 2007). Price lists for pig fat (Ì.ŠAḪ.DÙG.GA = "good pork fat", 1 shekel), used in perfume production and medicine, suggest pig fat trade was important enough to be centrally administered (Alparslan 2013, 511; Klengel 2007, 161). Pig management also required central regulation: pig theft and damage to fields caused by pigs were fined (Collins 2006; Klengel 2007).

Piglet sacrifice (or clay/bread substitutes) appears to have been a favored medium during festivals and magic rituals to heal diseases and impurity, stimulate fertility and arability, absolve law offenders, and ward off evil (Hoffner 1974; Collins 2006; Mouton 2017). In some cases, black-coated piglets were specifically prescribed (Collins 2006). A piglet burial at Yazılıkaya probably represents one of these ritual uses (Hauptmann 1975).

Western Anatolia

Western Anatolia was an important interaction zone for cultural exchange, competition, and conflict between the Mycenaean and Hittite worlds (e.g., Mountjoy 1998; Greaves 2012; Roosevelt et al. 2018). Local kingdoms in western Anatolia negotiated diplomatic relations with Hittite and Mycenaean traders and troops, though much remains unknown about the cultural affiliations and habits of the people that lived in the region itself. Archaeological investigations into the LBA in western Anatolia long lagged behind those in Greece and central Anatolia, but recent and ongoing excavations are slowly shedding new light on this interaction zone (e.g., Dedeoğlu and Abay 2014; Erkanal 2008; Günel 2010; Mangaloğlu-Votruba 2015; Meriç and Öz 2015; Pavúk 2014; Roosevelt and Luke 2017).

The Kaymakçı Archaeological Project (KAP) plays a leading role in reconstructing protohistoric western Anatolia. If current understandings of LBA historical geography are correct, the Marmara Lake basin and the Gediz River valley, which Kaymakçı overlooks (Figure 2), composed the core of the Seha River Land, an indigenous kingdom of the Arzawa Lands of western Anatolia that eventually became a Hittite vassal around the 14th century B.C. (Hawkins 1998; Mac Sweeney 2010; Gander 2017). According to the Boğazköy archives, the kings of the Seha River Land continuously negotiated a buffer position between Hittite and Ahhiyawan (or Mycenaean) interests in western Anatolia (Bryce 1989, 2012; Roosevelt 2010; Roosevelt and Luke 2017). Kaymakçı is at present the best candidate for their capital.

EXCAVATIONS AT KAYMAKÇI

Kaymakçı is just one of 34 sites dating to the 2nd millennium B.C. located in the Marmara Lake Basin (Luke et al. 2015). Most of these sites are small and dispersed across the landscape with no clear relation to each other. Five clustered settlement nodes in the lowlands, however, and six fortified citadels in the uplands were observed (Luke and Roosevelt 2016, 2017; Roosevelt and Luke 2017). Kaymakçı is the largest (8.6 ha) of these citadels and possibly in western Anatolia. The size and the complexity of the settlement plan suggests hierarchical and functional differentiation, setting it apart from other citadels in the region (Roosevelt et al. 2018).

Excavations at Kaymakçı commenced in 2014 to explore the chronology, spatial organization, production activities, interregional interactions, paleoenvironment, and subsistence economies of the site, with particular attention to its intermediary position between the Hittite and Mycenaean worlds (Roosevelt et al. 2018). Kaymakçı is the only excavation in this area focusing on the Middle and Late Bronze Ages. Creating robust primary datasets with reproducible environmental data (e.g., archaeobotanical and zooarchaeological), which were notably scarce in the archaeology of the Gediz River Valley, is one of the primary aims of the project (Roosevelt et al. 2018).

For the nearby Iron Age city of Sardis, ancient Greek authors have written that the rivers and lakes of Lydia abounded in wild fish, fowl, and other game and that sheep, goats, and cattle grazed in fields in valleys and highland pastures (Roosevelt 2009, 53–54, 70). Preliminary reports on fauna at Sardis concur with this depiction (e.g., Deniz, Çalışlar, and Özgüden 1964; Hanfmann and Foss 1983, 6) and suggest that the Gediz Valley supported a wide variety of wild animals and plants and allowed multiple strategies for animal husbandry.

Material and Methods

Kaymakçı

Faunal samples primarily derive from waste deposits in the inner citadel, the southern terrace, and around the



Figure 2. View from the inner citadel of Kaymakçı to the southeast, with the Marmara Lake basin to the left and Gediz River Valley to the right (© Gygaia Projects).

fortification wall excavated between 2014 and 2017 (Table 1, Figure 3); from a selection of these deposits additional samples were excavated and studied in 2018 and 2019. We excluded animal remains from symbolic contexts; in the case of pigs, this concerned piglets found in relation to intramural human infant burials (Roosevelt et al. 2018). Analyzed animal bones were collected through handpicking and dry sieving (4 mm mesh) to minimize recovery bias against medium-sized and small vertebrates (Payne 1972). Consistent percentages of unidentified specimens per area suggest that handpicked and sieved samples were similarly fragmented, but percentages of unidentified specimens were generally higher for samples from around the settlement's fortification wall, possibly due to heavier fragmentation caused by downslope wash.

Samples were studied using a comparative collection containing several pigs, sheep, and goats of neonate, juvenile, and adult ages, cattle, roe-, red-, and fallow deer, marten, dog, fox, hare, carp, catfish, and various identification manuals (e.g., Schmidt 1972). We recorded taxonomy, element, side, completeness, sex (canine morphology; Schmidt 1972), tooth wear stages following Grant (1982), epiphyseal fusion (unfused, fusion line visible, fusion line not visible), biometric dimensions

Table 1. Overview of identified specimens per excavation area.

Context	Inner Citadel and Surrounding Slopes			Southern Terrace			Fortification System	
Excavation area coordinates	93.545	97.541	98.531	99.526	108.522	109.523	81.551	95.555
Hand-picked								
Identified	864	727	85	1034	383	410	409	157
Unidentified mammals	1561	943	76	1677	684	1023	1174	721
Unidentified bone	15	65	60	195	252	1	432	21
Total	2440	1735	221	2906	1319	1434	2015	899
% Identified	35%	42%	39%	36%	29%	29%	20%	17%
% Unidentified mammals	64%	54%	34%	58%	52%	71%	58%	80%
% Unidentified bone	1%	4%	27%	7%	19%	0%	21%	2%
Total	100%	100%	100%	100%	100%	100%	100%	100%
Sieved								
Identified	226	244	128	206	108	86	107	129
Unidentified mammals	369	473	49	270	285	281	402	376
Unidentified bone	5	1	100	51	107	1	263	1
Total	600	718	277	527	500	368	772	506
% Identified	38%	34%	46%	40%	22%	24%	14%	25%
% Unidentified mammals	62%	66%	18%	51%	57%	76%	52%	74%
% Unidentified	1%	0%	36%	10%	21%	0%	34%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%

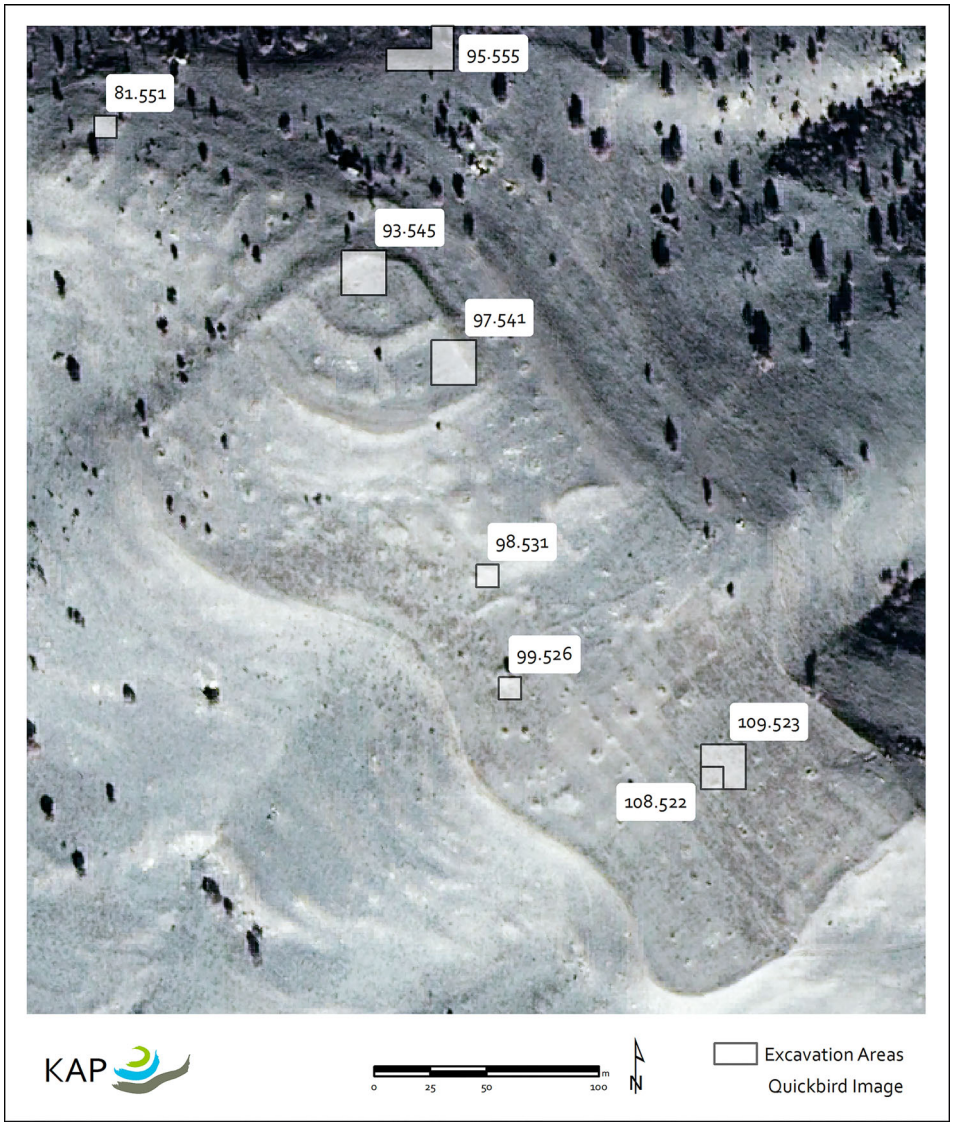


Figure 3. Plan of the citadel of Kaymakçı showing the eight excavation areas opened from 2014–2017 (© Gygaia Projects).

(following von den Driesch 1976; Payne and Bull 1988), traces of pathological conditions, and taphonomic markers. Elements with diagnostic features such as articular surfaces (sensu Watson 1979) were identified to species when possible.

Data analysis aimed to estimate relative abundance, reveal kill-off patterns, and reconstruct body and molar size for pigs. Relative abundance of taxa was calculated based on the Number of Identified Specimens (NISP) (Davis 1987, 35) to infer the economic significance of taxa. Kill-off patterns were reconstructed based on tooth wear and epiphyseal fusion using Lemoine and colleagues (2014) and Zeder, Lemoine, and Payne (2015); ages of perinatal pigs were estimated using Habermehl (1975). Seasonality was inferred following Wright and colleagues (2014). Differential targeting of sexes was investigated through counts of sexually dimorphic canines and body size.

Investigating bone and tooth size in archaeological populations is useful in determining the presence of domestic and wild animals and sex ratios at culling (Payne and Bull 1988; Albarella and Payne 2005). As bone dimensions are influenced by growth and sexual dimorphism, they can be used to estimate sex ratios within a single population (Payne and Bull 1988; Albarella and Payne 2005). Tooth dimensions can detect variation between populations more reliably than bone measurements, as teeth dimensions are less affected by age, sex, and health, and preserve better; however, severe wear and developmental problems may distort tooth size, and wild and domestic sizes may overlap (e.g., Payne and Bull 1988; Albarella 2002; Albarella and Payne 2005; Albarella, Dobney, and Rowley-Conwy 2009; Evin et al. 2013, 2015; Balasse et al. 2016). Here we excluded measurements of immature bones to minimize the effects of growth.

Measurements were computed into Logarithmic Size Indices ($LSI = \log(x/m)$), sensu Meadow (1999), where x represents the specimen measurement and m represents the dimension of a standard, in this case the average size of modern central Anatolian male and female wild boar (Payne and Bull 1988). Size characteristics of the population were assessed through the shape and spread of LSI distributions. The presence of different size groups was investigated with cluster analysis of raw measurements; for this, a Gaussian Mixture analysis was run in *R*, which uses a probabilistic model-fitting algorithm to estimate clusters based on a Bayesian Information Criterion (mclust; Scrucca et al. 2016). Finally, we estimated the range of variation within Kaymakçı's pig teeth measurements through Pearson's Coefficient of Variation ($CV = s/\bar{x}$). CV values between 4 and 6, reflecting normal genetic and phenotypic variation within a single animal population, were expected (Simpson et al. 1960, 259–265; Albarella and Payne 2005; Albarella, Dobney, and Rowley-Conwy 2009).

Comparative data

Comparative analysis is based on published zooarchaeological data from Greece and Turkey and primary data from Kaymakçı, Troy, and Klazomenai in western Anatolia and Gordion in central Anatolia. To get an impression about the relative and differential importance of pigs in diet and economy across Greece and Turkey, we looked at the relative abundance of pig bones (in comparison to sheep, goats, and cattle) in terms of NISP. For this, we took the quantitative units "specimen count," "fragment count," and "*Fundzahl*" used by various researchers to mean NISP. These units are traditionally well-published across various faunal studies in Greece and Anatolia and therefore altogether provide the largest comparative dataset. The disadvantages of using this type of data with different sample sizes coming from varied contexts and generated by different analysts are well-known (Cannon 2013), but there are simply no other comparative datasets to rely on. To mitigate biases imposed by contextual differences, data from known sanctuary and burial contexts were excluded, and only assemblages representing settlement waste were included in the analysis.

Summaries of kill-off and biometric data complemented the NISP data. Different recording techniques prohibited direct comparison, but tooth eruption and wear-based mortality data from 24 sites could be converted to Lemoine and colleagues' simplified A-system (2014). For publications pre-dating Grant's tooth wear scheme (1982), tooth eruption (erupting or erupted) and wear data (light, moderate, or heavy) were directly converted to this system. When pig mortality was presented only in age categories, these were compared to Payne stages (Payne 1987) and matched to Lemoine and colleagues' simplified A-system (2014).

Teeth and bone measurement data were available for 22 sites. Issues such as small sample size, inter-analyst measurement error, differing measurement procedures, and characteristics of assemblages can obstruct reconstructing size (Albarella 2002). Smaller samples were included for the sake of completeness. Measurements for Kastanas and Sitagroi were published for the EBA–EIA as a single period; these measurements were interpreted with caution, because throughout the Bronze Age, a size decline in pigs is observed in the northern Aegean (Becker 1986; Gardeisen 2010). Raw measurements were transformed into LSI values as explained above. Differences in size distributions of post-cranial bones and molars were tested using one-way ANOVAs ($\alpha = 0.05$). Finally, the CV value was calculated for molar size to investigate intra-population variation for sites with > 50 measurements (Kastanas, Tiryns, Troy, Klazomenai, Kaymakçı, and Lidar Höyük). CV for molar measurements at Neolithic Durrington Walls and the Kızılcahamam modern wild boar were added as reference assemblages.

Results

Kaymakçı

RELATIVE ABUNDANCE

Remains of domestic taxa form 75–82% of the identified specimens in Kaymakçı's hand-collected and dry-sieved assemblage, including pigs (*Sus scrofa domesticus*), sheep (*Ovis aries*), goats (*Capra hircus*), cattle (*Bos taurus*), and a small number of equids (*Equus* spp.) and dogs (*Canis familiaris*) (Figure 4A). Wild taxa represent 18–25% of the total NISP. Large game (63–65%) consists mostly of fallow deer (*Dama dama*) and red deer (*Cervus elaphus*). Other identified wild taxa include hare (*Lepus europaeus*), wild boar (*Sus scrofa*), fox (*Vulpes vulpes*), marten (*Martes martes*), and tortoise (*Testudo* sp.). Additionally, a mandible and tibia fragment of a brown bear (*Ursus arctos*) and a tibia and first phalanx of a large felid were retrieved from the inner citadel area 93.545. Fish remains make up 7–9% of the identified specimens and could be identified as either carp (Cyprinidae) or catfish (Siluridae). Of the identified mollusks, 32–42% are land snails; fresh-water mussels (Unionidae) and marine taxa also occur (see also Roosevelt et al. 2018). These relative amounts suggest that while the animal-based economy and diet at Kaymakçı depended primarily on husbandry, wild resources complemented farming substantially.

Of the main domesticates, remains of domestic pig (see the section on size below) dominate the specimen counts in both hand-picked and sieved samples from all excavation areas (NISP and Diagnostic Zone counts) by 45–47% (Figure 4B) and occur in similar abundance over all excavation areas. Fetal and neonate pigs were twice as common in sieved samples as hand-picked samples (respectively, 10% and 4.5%). Sheep and goats are the second-most abundant at 38–44%, with sheep identified more often than goat by a ratio of 1.8:1. Cattle remains are least frequent, with 16% in hand-picked samples and 9% in sieved samples. Sheep and goat husbandry at Kaymakçı targeted mixed wool/fleece, milk, and meat, whereas the longevity of cattle indicated their value as working animals rather than as primarily meat stock (Roosevelt et al. 2018).

CULLING STRATEGIES

Mortality based on epiphyseal fusion shows a steep decline of the pig population from birth until 1.5 years old (Figure 5). After this, the population declines at a slower pace. Mortality rates based on mandibular and maxillary tooth eruption and wear show a similar pattern: 60% of the pig population was culled during Lemoine and colleagues' simplified A-system-stages 1–5, followed by a slow decline during stages 5–10. Season-of-death data, recorded in three month intervals for the first three years, demonstrates heightened mortality of 6–12 month-old pigs. If these pigs were born in spring, such culling may have taken place during autumn and winter. For 12–36 month-old pigs, specific mortality seasons were not detected.

The emphasis on culling young pigs at Kaymakçı indicates intensive husbandry, a strategy that generally includes culling immature pigs for (tender) pork while reserving more females than males for reproduction (Redding 1991, 2015). The ratios of male to female pig canines in the Kaymakçı assemblage are equal, however, with 17 male and 17 female specimens recorded. Not included in the mortality data in Figure 5 are 117 remains of fetal and neonate individuals, which were most frequently retrieved from the inner citadel (Areas 93.545 and 97.541) and the southern terrace (Area 99.526) (Supplemental Material 2). The abundance of these suggests that pregnant sows were kept within the settlement perimeter.

POSTCRANIAL BONE AND MOLAR SIZE

Postcranial bone and tooth size indices indicate that nearly all pig specimens were of domestic size (Figure 6). Wild boar-sized specimens occur sparsely. The postcranial bone size distribution is left-skewed and overlaps with the smaller sized molars in the assemblage. This indicates that most pigs

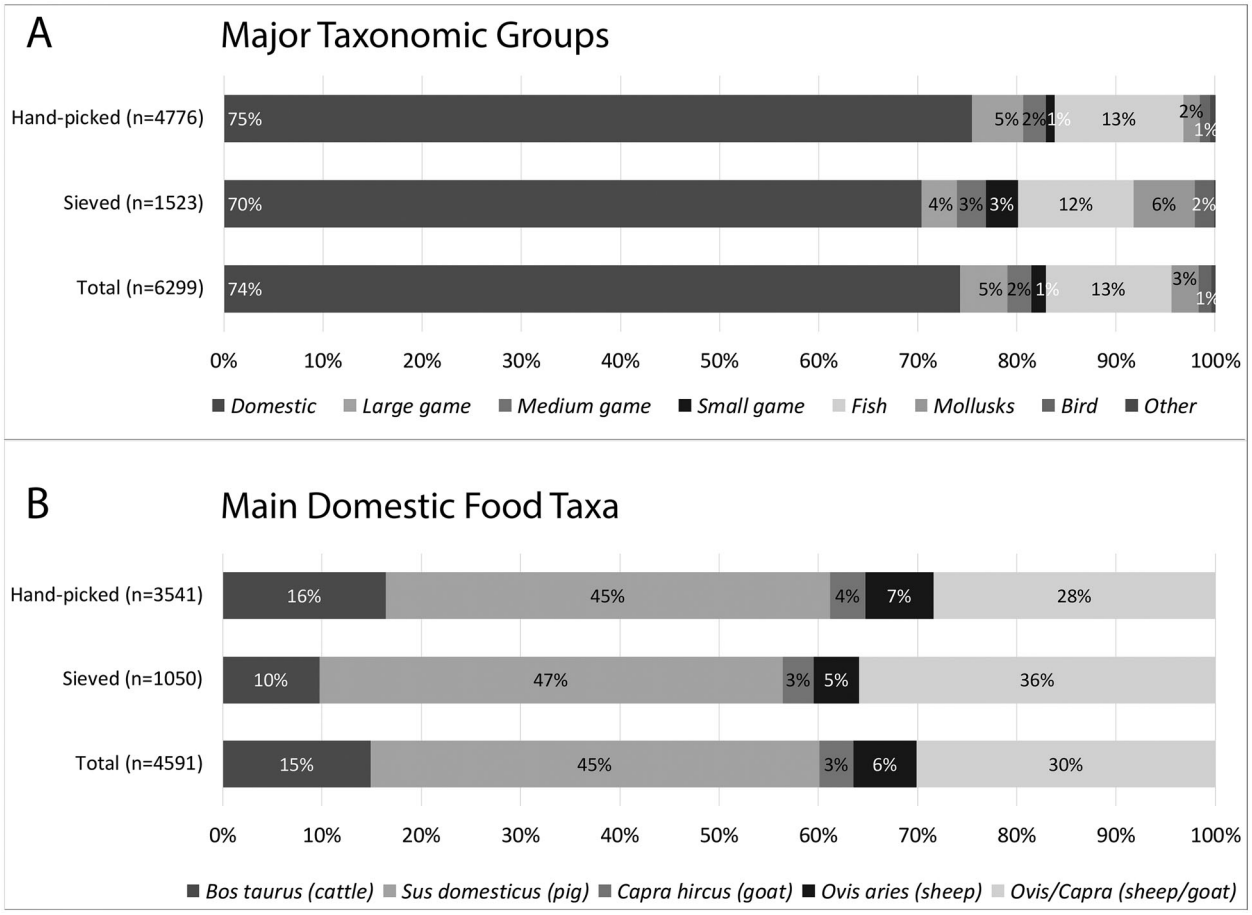


Figure 4. Taxonomic abundance based on NISP. A) Major taxonomic groups; B) Main domestic food taxa.

were small-bodied, representing either a larger portion of females or possibly young animals, because early fusing elements are common in the assemblage (Figure 6I). The molar size distributions resemble the postcranial size shape and range. Most molar dimensions fall between -0.12 and -0.05, with left tails ranging between -0.12 and -0.20. Molars larger than -0.05 are infrequent, but more often occur in first molars than second and third, suggesting animals of this size were culled before their second and third molars were formed (Figure 6C–D). Whereas these larger sized animals may represent males or wild suids, neither the left tails observed in the upper molars and first and second lower molars nor the additional modes in the second and lower third molar distributions formed by these smaller specimens are distinct.

GAUSSIAN MIXTURE AND PEARSON'S COEFFICIENT OF VARIATION

Gaussian mixture analysis defines multiple clusters in Kaymakçı's pig molar dimensions for all molars except the lower first molar, suggesting that the domestic-sized pig molars of Kaymakçı are phenotypically heterogeneous (Figure 7). Minimal overlap among molar dimensions and clear distance between modern wild boar and Kaymakçı's specimens make it difficult to interpret the apparent patterns as related to the presence of one domestic and one wild boar population. These different domestic-sized pig clusters are difficult to explain as sexual dimorphism, as overlap between the clusters is low, and molar size is supposedly only modestly sexually dimorphic in wild boar and domestic pig populations (Albarella and Payne 2005; Evin et al. 2015; Payne and Bull 1988). The Gaussian mixture analysis therefore appears to display separate domestic pig populations. Pearson's CV values for molars concur with this inference, as most CV values fall between 8 and 12, exceeding normal variation expected within a single population (Supplemental Material 3). Only the CV values for deciduous and permanent upper third molar lengths fall within the boundaries of a single population; width measurements for these elements, however, also show CV values of 8–11.

Comparative data

RELATIVE ABUNDANCE

The relative abundance of pigs across various assemblages are displayed in Figure 8. Although sample sizes vary strongly, regional trends can be discerned. Proportions of pig bones in Mycenaean assemblages vary between 15–33%. The northern Aegean assemblages contain overall larger proportions of pigs (Toumba Thessaloniki: 38%; Kastanas: 34%; Anchelochori: 40%; Olynth: 24%). In western Anatolia, pig bones form 16–17% of domesticates at Troy and Beycesultan; however, the proportion of pigs at Kaymakçı (48%) and Klazomenai (35%) show values comparable to Mycenaean and northern Aegean assemblages. In central Anatolia, pigs are overall scarcer at Gordion (7%) and nearly absent at the Hittite centers of Boğazköy and Kuşaklı (2–4%), though the assemblages at Kaman-Kalehöyük and Çadır Höyük contain 17–18% pig remains. Proportions of pig bones remain low (< 8%) in southern Anatolia (8%), except at Yumuktepe (16%), Tell Atchana (25%), and Lidar Höyük (18%). In southeastern Anatolia, pig abundance increases regionally (between 16–38% in all assemblages).

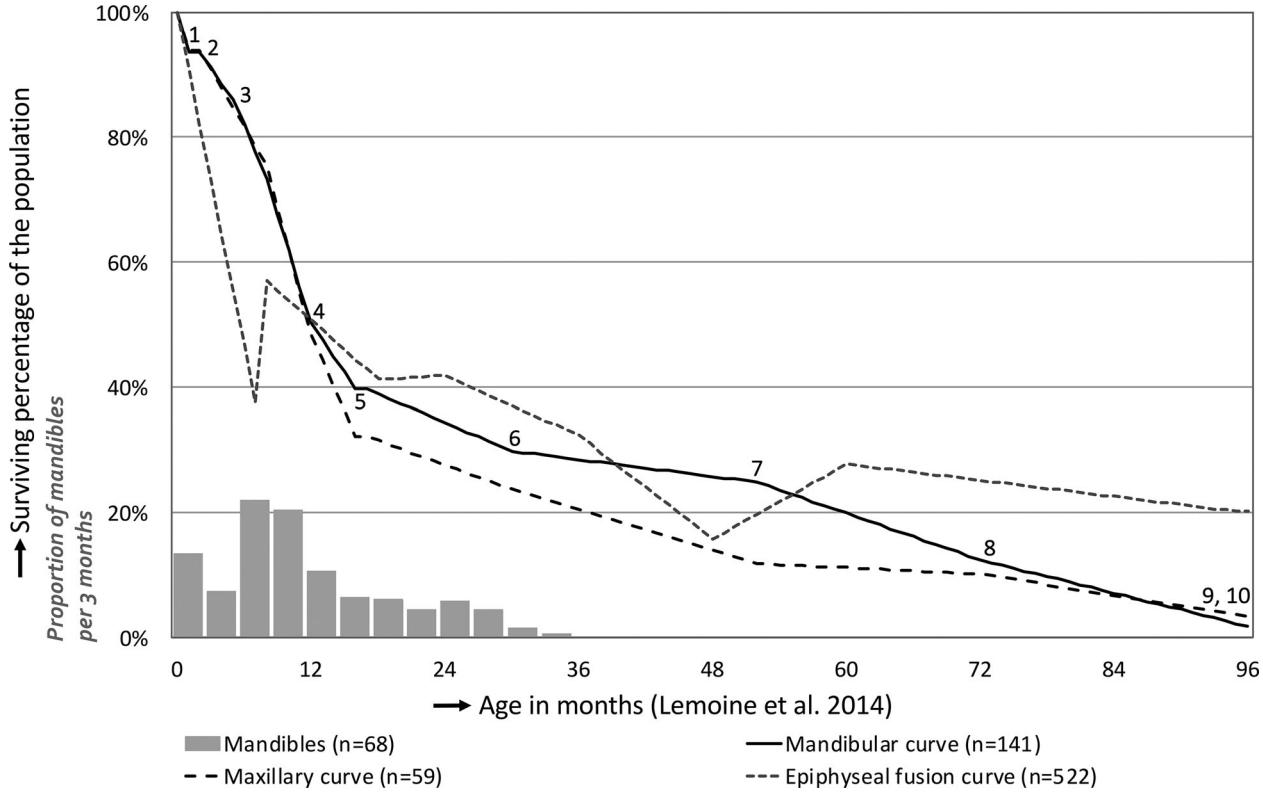


Figure 5. Mortality data for pigs based on epiphyseal fusion (Zeder, Lemoine, and Payne 2015) and mandibular and maxillary tooth eruption and wear (classified A-system of Lemoine et al. 2014). Grey bars represent the season of death over the first three years, following Wright and colleagues (2014).

CULLING STRATEGIES

Kill-off patterns vary across and within regions, ranging from steady declines in pig population throughout the first two years to gradually decreasing populations (Figure 9). In the Mycenaean heartland, at Nichoria, Tiryns, Eleusis, Magula Pevkakia, and Asine, over 50% of the pigs were culled before third molars started erupting, suggesting most pigs were killed between 0–16 months old (following Lemoine et al. 2014). From Nichoria and Magula Pevkakia, no pigs beyond this age were reported. In contrast, the majority of pigs at Pylos were culled as adults.

In the northern Aegean, the sharp decline of pig population between 0 and 16 months at Thessaloniki Toumba is similar to most Mycenaean sites. However, at Olynth, Anchelochori, and Kastanas, larger portions of the pig populations reached adulthood. At Olynth, culling targeted juveniles and subadults, not infants. In Anchelochori and Kastanas, some pigs were culled (or died) as piglets, but intensive culling did not start before the lower second molar started erupting (8–12 months), possibly indicative of autumn/winter culling.

The situation in western Anatolia is different from Greece, as considerably larger portions of the populations reached adulthood. In Klazomenai, culling strategies were similar to Kaymakçı, focusing on pigs between 8–16 months. In Troy, however, pigs were targeted during the first half year of their life, but after that time, culling was spread over pigs of adult ages.

In central Anatolia, at Gordion, Çadır Höyük, and Kaman-Kalehöyük, 20–40% of the pigs were young piglets, and the remainder of the population was culled before the third molar erupted. Boğazköy's assemblage differs: roughly half the pigs found in the assemblage had erupted third molars, and no remains of piglets younger than half a year old were recorded.

Southern and southeastern Anatolian sites uniformly show declining pig populations at young ages, with erupted third molars witnessed in only 10% of the population. Minor deviations are visible in the timing of culling activity. At Kavuşan Höyük and Giriciano, culling was directed at animals with erupting second molars (8–12 months old); at Korucutepe and Lidar Höyük, culling was spread evenly over pigs aged 0–2 years old, while at Tell Atchana, pigs aged 6–12 months old appear to have been targeted.

POSTCRANIAL BONE AND MOLAR SIZE

Logarithmic size indices indicate that compared to modern Anatolian wild boar, all assemblages from southeastern Anatolia to Greece are dominated by remains from morphologically domestic pigs (Figure 10; see Supplemental Material 4 for ANOVA). Wild boar-sized individuals are sparsely present in assemblages from Pylos, Asine, Troy, Kaymakçı, Gordion, Boğazköy, Lidar Höyük, and Hirbemerdon Tepe. The assemblages from Sitagroi and Kastanas include more wild boar, but measurements for these sites were published as lump samples spanning the EBA–EIA. Mycenaean pigs are uniform in body and molar sizes, except at Magula Pevkakia, where pigs were significantly smaller-bodied than at Tiryns and Pylos ($p = 0.0017$; $p = 0.0000$). Additionally, the mean size is smaller than the median for Magula Pevkakia, but also for Eleon, Asine, and Pylos. This skewing towards smaller individuals could suggest an overrepresentation of females, but may also be a result of young culling ages. In contrast, the closeness of the mean to the median at Tiryns, and the bimodal postcranial distribution for this site, despite intensive culling activity, suggests the Tiryns assemblage contains both males and females.

Discussing general trends in size for the northern Aegean is not possible, because LBA measurements were only

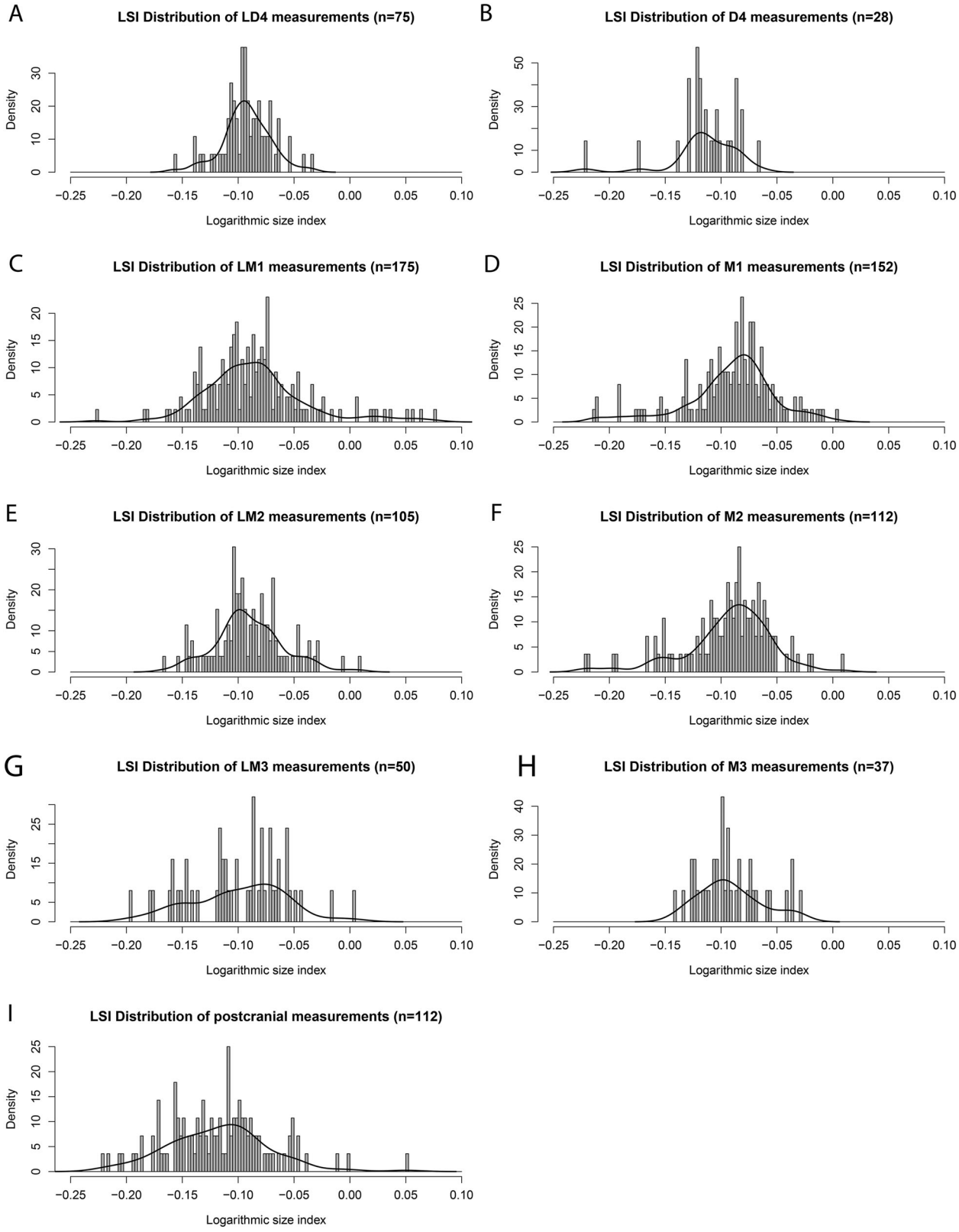


Figure 6. Kernel density estimations for pig size at Kaymakçı plotted over distributions of logarithmic size indices (LSI). A) Postcranial dimensions. B–I) Molar dimensions. LD = lower deciduous molar, D = deciduous molar, LM = lower molar, M = upper molar, n = number of measurements included.

published from Olynth. Olynth measurements are similar to those from Mycenaean Greece. Measurements in the multi-period sample from Sitagroi are significantly larger than those from Olynth (molar $p = 0.022$; postcranial $p = 0.0005$), reflecting diachronic variability in body and molar size.

In western Anatolia, postcranial and molar dimensions display inconsistent patterns. Pigs at Troy are generally larger-bodied than pigs at Klazomenai ($p < 0.001$), but molar size at Troy and Klazomenai is similar. The size range of pig bones and molars at Kaymakçı overlaps with both these sites, though, on average, molars are larger at Kaymakçı than at Troy and Klazomenai ($p = 0.01$; $p < 0.001$).

The mean body size of central Anatolian pigs appears smaller than pigs from other regions. This difference is significant for pigs in the Hittite capital Boğazköy (Pylos: $p = 0.024$; Tiryns: $p = 0.001$; Troy: $p < 0.001$; Kaymakçı: $p =$

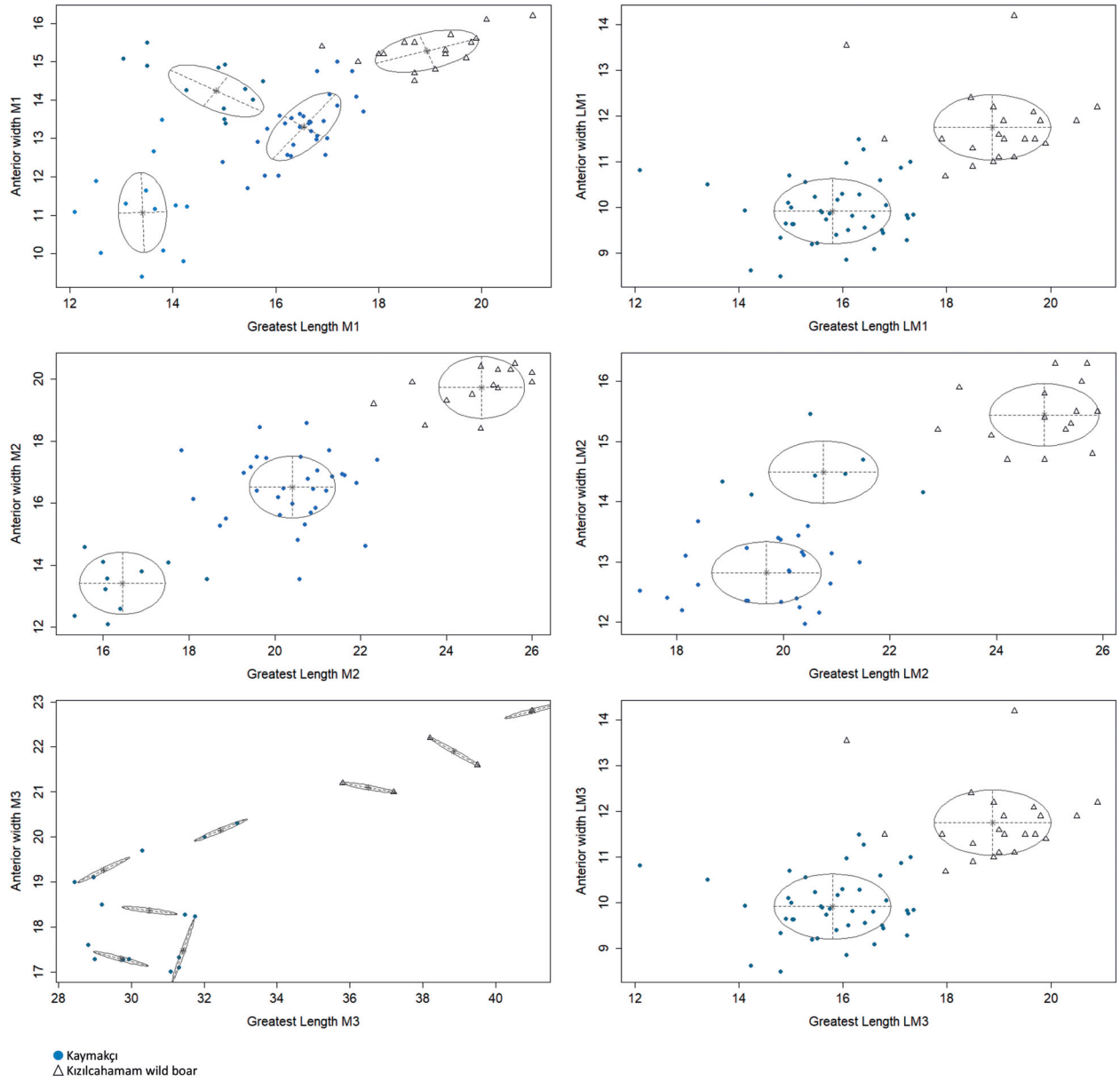


Figure 7. Gaussian mixture analysis fitting anterior width and greatest length measurements of permanent pig molars from Kaymakçı and modern wild boar from Kızılcahamam.

0.04; and, Lidar Höyük: p = 0.001), and pigs are also smaller in Gordion than at Tiryns (p = 0.025) and Troy (p > 0.001). This difference may partially be due to the occurrence of some very small specimens in Boğazköy and Gordion. Petite pigs also occurred in small numbers in Greek Magula Pevkakia and Eleon and western Anatolian Klazomenai and Kaymakçı, but they are more numerous in Gordion and Boğazköy. Von den Driesch and Vagedes (1997, 131) noted that at Kuşaklı, pig bones were even smaller than at Boğazköy, but they did not provide measurements. Despite body size variation, molar size in Hittite pigs does not substantially vary from other sites, except between Gordion and Kaman Kalehöyük, where molars are smaller than at Kaymakçı (p = 0.020; p = 0.019).

Sample sizes from southern and southeastern Anatolian sites were generally small. Postcranial measurements for pigs in these regions show no significant differences to other Anatolian sites. Molar sizes vary, however. Pig teeth at Müslümantepe and Kavuşan Höyük are significantly smaller than most western and central Anatolian sites and sites in their proximity (e.g., to Lidar Höyük [p < 0.001; p < 0.000], Hirbemerdon Tepe [p = 0.013; p = 0.011]) and Turbe Höyük (to Müslümantepe, p = 0.027).

PEARSON'S COEFFICIENT OF VARIATION

Comparison of Pearson's Coefficient of Variation (CV) for pig molars from selected LBA assemblages, archaeological reference data from Durrington Walls (UK), and reference data from modern wild boar from Kızılcahamam are displayed in Figure 11. For these reference assemblages, as well as the LBA assemblages from Kastanas and Tiryns, CVs adhere to normal phenotypic variation expected within a taxonomic group. The LBA assemblages from Klazomenai and Lidar Höyük show slightly elevated values for the majority of the measurements, with CV increasing up to 7.5. Lower third molar measurements in Troy vary strongly too, but, based on the occurrence of wild boar-sized bones in the assemblage, it is possible that wild boar and domestic specimens mingled. The CV of 8–12 for pigs at Kaymakçı contrasts strongly with the reference and LBA pig assemblages, underlining that this is an unusual phenomenon that cannot be explained by sample size alone.

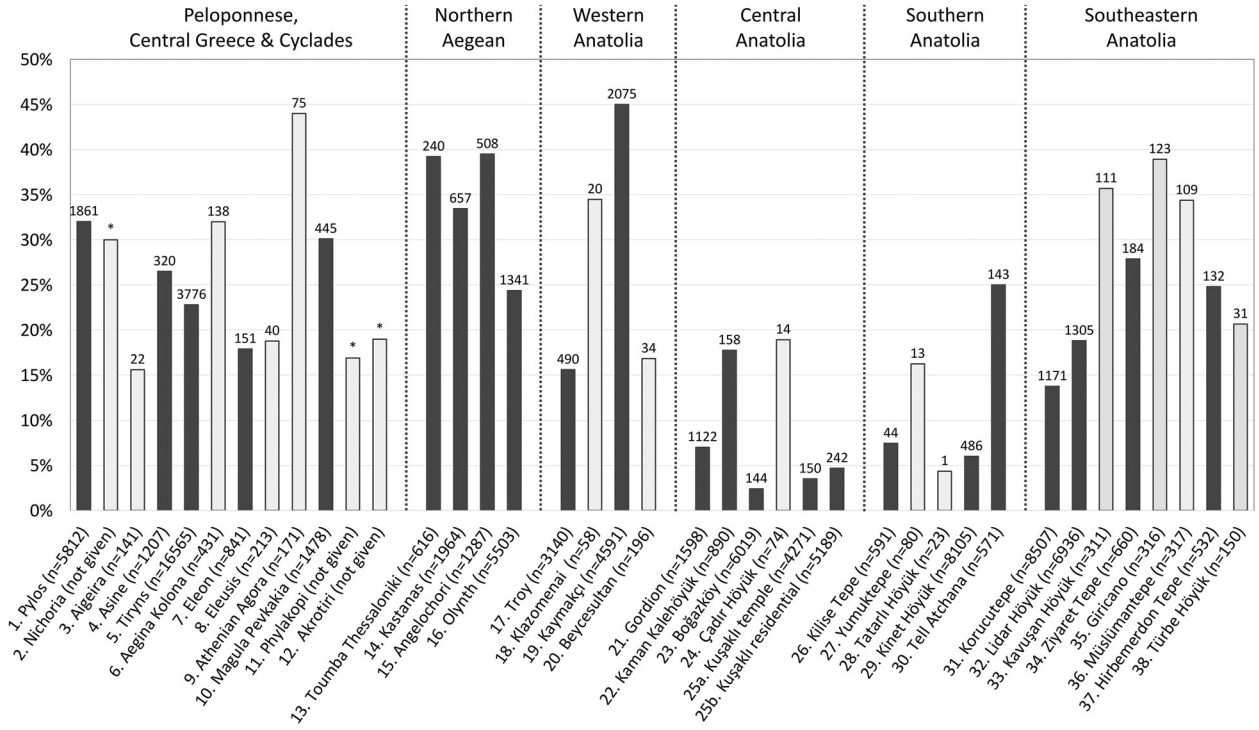


Figure 8. Relative and absolute abundance of pig remains compared to sheep, goat, and cattle in LBA assemblages based on NISP. The total sample size is given in the legend. Empty bars indicate sample size < 500; *no absolute numbers provided.

Discussion

Pigs at Kaymakçı

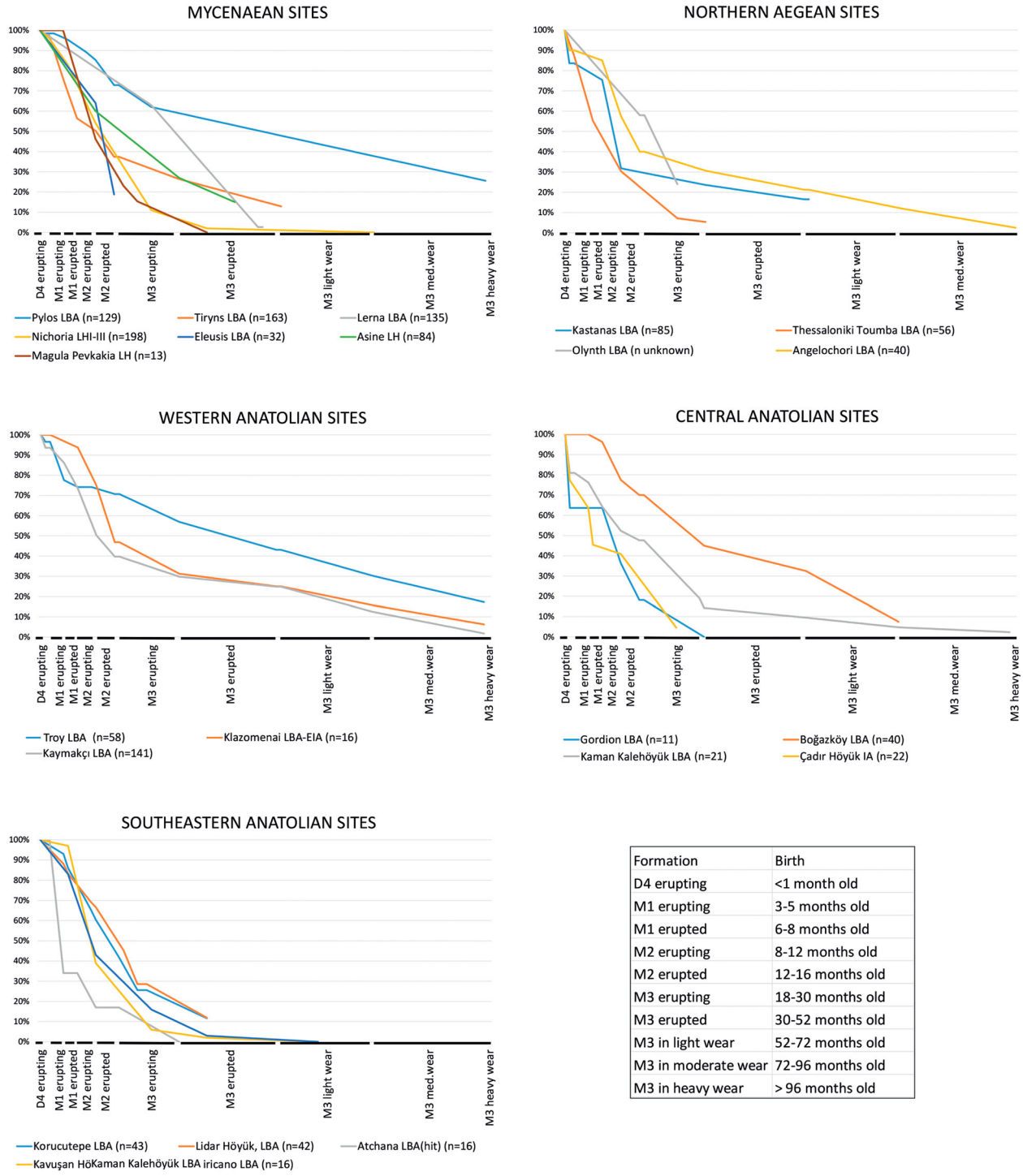
Across large LBA centers in the Aegean, Anatolia, and Mesopotamia, the role of pig husbandry varied and usually did not exceed the economic importance of sheep, goat, and cattle. The layout of Kaymakçı resembles these centers in several ways, most notably in its concentric fortifications. Even though Kaymakçı was intermediary to Hittite and Mycenaean politics and exchange, the animal economy in Kaymakçı differed. Although the economy contained elements of mixed sheep, goat, and cattle husbandry, it was largely dominated by pig husbandry.

Pigs at Kaymakçı must have been a frequent sight in both the built and the natural environment. The large number of young pigs in the assemblage may have been locally bred, procured off-site, or provisioned to the settlement. The large number of perinatal piglets suggests some (pregnant) pigs were kept within the confines of the settlement, possibly on a household level and/or roaming the streets, whereas the presence of adult male and female pigs of various ages suggests other pigs were loosely, probably extensively, managed. It is possible that one, or both, of these husbandry systems were related to autumn/winter activity, when dependency on protein from juvenile pigs of 8–12 months (born in spring) became more pressing, or preferred, in alternation with summer activity, when fat-rich protein could be procured from fish (Griffin 1998). When food is abundant, pigs can, however, farrow at a younger age and more than once a year (e.g., Massei et al. 1997; Albarella, Manconi, and Trentacoste 2011), which, in the case of free-ranging sounders (typically consisting of a few sows and their numerous offspring), may have overpopulated the valley and necessitated crowd-control of animals in these age groups.

These different husbandry strategies are reflected in the excessive variation in body and molar size, which indicates pigs in Kaymakçı were phenotypically pluriform. CV values indicate that molar dimensions are too diverse to occur within a single animal population, and the Gaussian mixture analysis identified more than one phenotypic group within Kaymakçı's pigs. Whereas body size is known to vary considerably as a result of age, sexual dimorphism, nutrition, and husbandry conditions, molar size is typically determined by genetic disposition. The variation in molar size is therefore likely to reflect genetic variation, which can appear by combination and/or hybridization of more than one population through selective breeding, domestication, and/or feralization (e.g., Evin et al. 2015; Rowley-Conwy and Zeder 2014; Balasse et al. 2016; Price and Evin 2017).

Size is one of the first characteristics researchers look at to distinguish between wild boar and domestic pig populations in archaeological assemblages. Discerning the presence of wild boar in Kaymakçı is problematic, however, because wild boar size baselines for Mesolithic, Bronze Age, and modern western Anatolia still need to be developed, and the sizes of wild and domestic pigs can overlap (Payne and Bull 1988; Mayer, Novak, and Brisbin Jr 1998; Evin et al. 2013). Large dimensions reported from the northern Aegean, the early Neolithic in northwestern Anatolia, and modern wild boar in central Anatolia (Bökönyi 1986; Payne and Bull 1988; Boessneck and von den Driesch 1979) suggest that boar in this region can become substantially larger than Kaymakçı's pigs. Therefore, we are currently left to assume that size variation at Kaymakçı occurs within domestic pigs and that our data thus reveals heterogenous, if not different, domestic populations.

The size variation in Kaymakçı's assemblage may correspond to intensive and extensive pig husbandry practiced in parallel. Extensively managed pigs tend to become generally larger because they can express natural breeding and feeding behavior and interbreed with wild boar (e.g., Evin et al. 2015). The concept of different pig husbandry styles was not



Formation	Birth
D4 erupting	<1 month old
M1 erupting	3-5 months old
M1 erupted	6-8 months old
M2 erupting	8-12 months old
M2 erupted	12-16 months old
M3 erupting	18-30 months old
M3 erupted	30-52 months old
M3 in light wear	52-72 months old
M3 in moderate wear	72-96 months old
M3 in heavy wear	> 96 months old

Figure 9. Dentition-based pig mortality data for various LBA assemblages from Greece and Anatolia. Age estimations follow Lemoine and colleagues (2014).

unknown in LBA Anatolia. Hittite texts describe pigs kept in enclosures, as well as courtyard pigs and pigs scavenging streets (Collins 2006; Klengel 2007). Different husbandry styles affected the economic value of these pigs. Grain-fed pigs were prized double that of courtyard pigs, while in Boğazköy-Hattusa, street-scavengers were considered impure (Hoffner 1974). As previous zooarchaeological studies have not yet filled out this picture from the texts, the zooarchaeological identification of multiple populations of pigs at Kaymakçı might be the first to reflect such a conceptual and practical division of domestic pig populations in Anatolia. The reason why this manifests so clearly at Kaymakçı is likely because of the large sample size and fine-grained analysis. Differential breeding and husbandry practices resulting in different animal varieties have, however, been reported outside Anatolia for sheep and cattle in LBA–EIA Italy (Gaastra 2014) and for pigs in ancient Egypt and Bronze Age Switzerland (Bertini and Cruz-Rivera 2014; Bopp-Ito et al. 2018).

Additionally, it is possible that the variation in Kaymakci's pigs results from mixing with non-local pig populations. Western Anatolia is the most plausible entry point for pigs with European haplotypes which appear in Anatolia and the Levant from the Middle Bronze Age onwards (Ottoni et al. 2013). The phenotypic heterogeneity in Kaymakçı's pigs might reflect such an introduction. The slightly elevated CV values in Klazomenai, known for its Mycenaean connections (Vaessen 2016), and Lidar Höyük, where the first pig

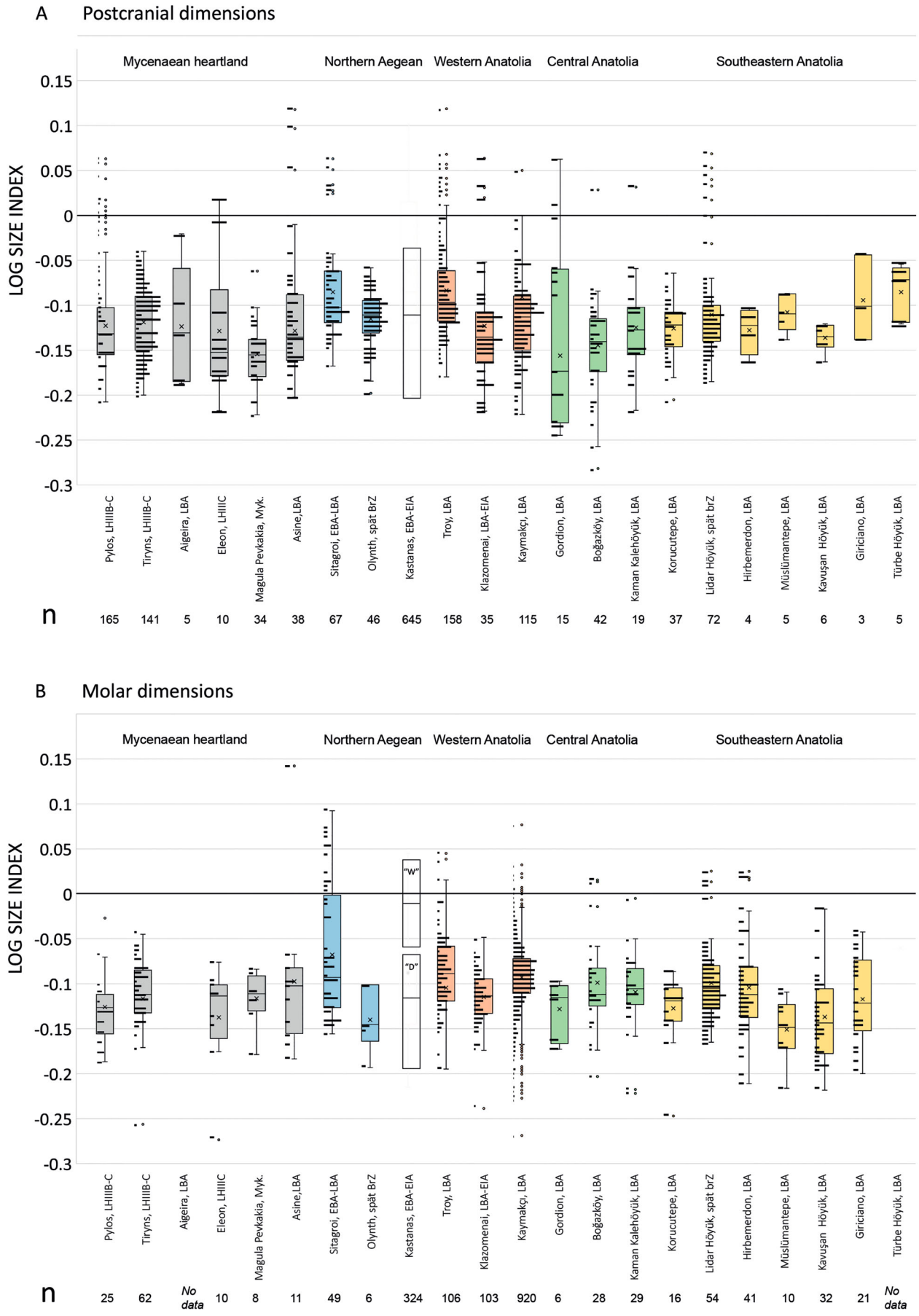


Figure 10. Boxplots and histograms of logarithmic size indices of pig measurements recorded at 2nd and 1st millennium B.C. sites in Greece and Turkey. The second and third quartiles are colored and separated by the median; x displays the mean. A) Postcranial measurements; B) Molar measurements. EBA = Early Bronze Age; LBA = Late Bronze Age; LHIIIB = Late Helladic IIIB; LHIIIC = Late Helladic IIIC; Spät BrZ = Späte Bronzezeit. Kastanas data is available as descriptive statistics only.

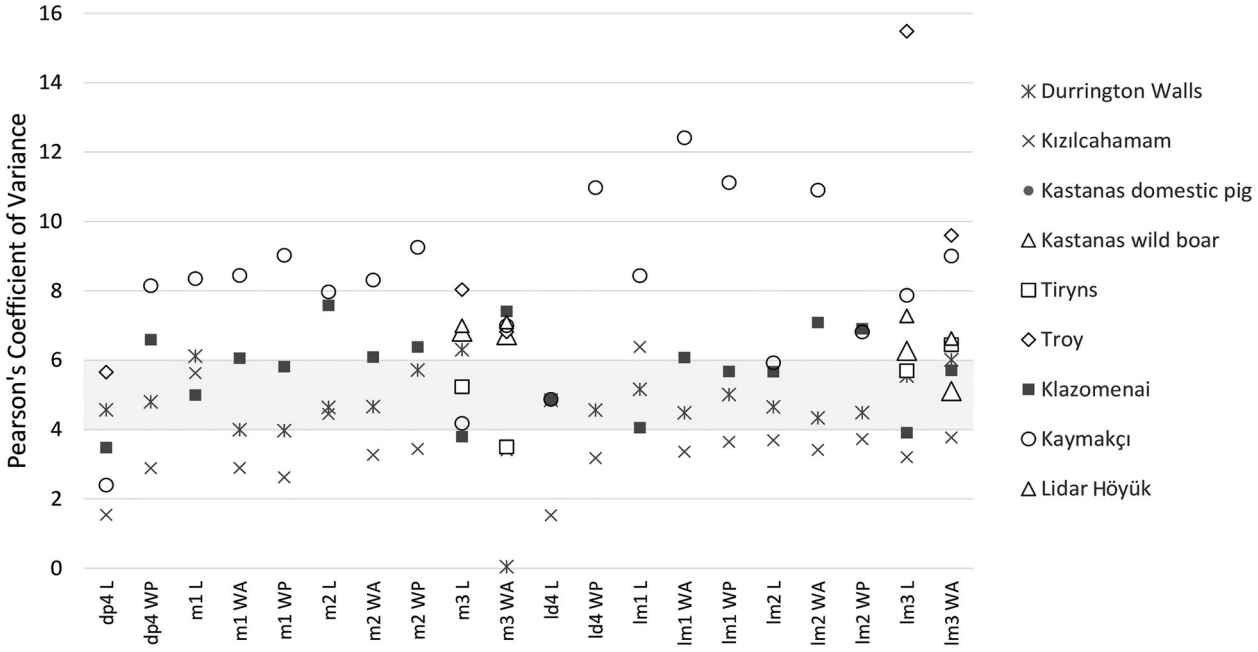


Figure 11. Pearson's Coefficient of Variation for molar dimensions from Kaymakçı compared to modern and archaeological pig populations. The grey bar covers expected variation (4–6) within a single population.

specimen with a European haplotype was identified in Middle Bronze Age layers (Ottoni et al. 2013), could likewise reflect such introductions. Pigs from LBA western Anatolia have, however, not yet been analyzed in studies mapping ancient pig genetics (e.g., Frantz et al. 2019; Ottoni et al. 2013), leaving this option currently open.

Late Bronze Age pig husbandry in the Aegean and Anatolia

Pigs were an integral part of Mycenaean economies, an essential component of subsistence in the northern Aegean and western Anatolia, variably rare in the Hittite realm and southern Anatolia, and well-incorporated in southeastern Anatolian economies. These regional differences cannot be explained by environmental variation alone. Pig physiology can constrain husbandry in hot and arid conditions (Spinka 2009), but our study region is characterized by sufficient water availability, vegetation, and temperate climates. Coastal and mountainous microclimates in the Mycenaean heartland provided ample woodlands and water sources (Zerefos and Zerefos 1978). In the northern Aegean, alluvial and coastal plains created elaborate forest cover (Becker 1986; Becker and Kroll 2008). The mild sea climate in western Anatolia similarly created a suitable habitat, with interchanging park landscapes and oak canopy (Zeist and Bottema 1991). In central Anatolia, seasonal differences in temperature and humidity are stronger, but in the north, where the sites included in our study are located, vegetation cover is varied and precipitation higher (Zeist and Bottema 1991; von den Driesch and Vagedes 1997). The humid southern coast of Anatolia was covered with olive trees and evergreen oak. In Bronze Age southeastern Anatolia, deciduous woodlands and medium temperatures prevailed (Zeist and Bottema 1991). These conditions are all suitable habitats for wild and domestic pigs.

Without large-scale environmental constraints limiting pig husbandry potential in Greece and Anatolia, variations in the economic importance and role of pigs appear to result from economic choices and cultural preferences. In most Mycenaean sites, pig husbandry was local and aimed at pork from young piglets, probably year-round. The culling activity and petite size of pigs at Magula Pevkakia, Eleon, and Asine indicate intensive husbandry. At Magula Pevkakia and Nichoria, the lack of reproductive adults might represent provisioning, as indicated by Linear B texts (Rougemont 2006). Interestingly, provisioning of pigs to palatial centers is less evident at palatial centers themselves, such as Tiryns and Pylos. At Tiryns, many pigs were culled during their first year, yet the presence of both male and female adults is uncharacteristic of intensive pork production (von den Driesch and Boessneck 1990). At Pylos, Nobis (1993) reported that the majority of domestic pigs were adults of various ages. In combination with the interest in Pylos for wild boar, the inhabitants apparently procured full-grown pigs through provisioning, extensive husbandry, and/or hunting. Both these palatial sites thus demonstrate demands for a mix of pig products.

In the northern Aegean, animal husbandry reflects the egalitarian, autonomous nature of this region suggested by Andreou (2001, 160). Pigs were vital components of subsistence strategies. At Kastanas and Anchelochori (Becker 1986; Creuzieux et al. 2014), culling may have intensified over the autumn and winter, and extensive husbandry strategies enabled many pigs to survive into adulthood. In contrast, pigs were more closely controlled at Thessaloniki Toumba (Vasileiadou 2009). No mortality data was available for Olynth, but males and females in this assemblage were equally represented (Becker and Kroll 2008). Tooth sizes of pigs in Olynth conform to pigs on the Greek mainland, but the pigs in Olynth were bigger-bodied, suggesting that they were extensively managed as well.

Pig husbandry in western Anatolia strongly varied between Troy, Klazomenai, and Kaymakçı. Piglets were culled both very young or as full adults at Troy, and the large body size suggests pigs at Troy were likely free-ranging or feral. At Klazomenai, pigs are considerably smaller-bodied and -toothed. At Kaymakçı, we demonstrated above that the larger and smaller pigs are unlikely to manifest in a single

population and that intensive and extensive husbandry may have co-existed. Culling patterns at Klazomenai and Kaymakçı strongly resemble each other, suggesting the practice of extensive husbandry at both sites.

The scarcity of pigs in Hittite settlements already observed by Dörfler and colleagues (2011) is reflected in our data, as central Anatolian assemblages contain fewer pig bones than assemblages from outside the borders of the Hittite heartland. Within the Hittite realm, pig husbandry shows variation (Berthon 2017). For all sites except Boğazköy, mortality data indicate intensive pig husbandry, which suggests that pig husbandry was more common than is indicated by the relative abundance of pig bones alone. Pigs in Hittite assemblages are small, raising the question of whether size may relate to the conceptual division of Hittite pigs discussed above. At Boğazköy, this consideration might be relevant, as kill-off patterns show that the majority of pigs were full-grown (von den Driesch and Boessneck 1981). Might this anomalous pattern in Boğazköy be related to scavenging urban pigs that perished within the settlement, or is it perhaps evidence of intensively controlled, grain-fed pigs raised for lard? Available evidence cannot yet resolve such questions.

In southern Anatolia, pig bones are rare. For these sites, fine-grained data is not available. In Tell Atchana and Lidar Höyük, however, pigs were numerous and culled young. Across the eastern border of the Hittite Empire, pigs were also common. Berthon (2014) suggests that high frequencies of pigs in the villages along the Tigris and Euphrates reflect differential access to regional economic animal products. Pigs are, however, equally common in the regional center of Ziyaret Tepe. Size variation in pig molars is quite large in this small region, but sample sizes are too small to detect clear patterns. Culling patterns were unanimously intensive at all sites, suggesting a structural inclusion of pork in the diet of both villages and cities.

Comparing these different regions shows three major patterns. Firstly, the number of pig bones across Greece and Anatolia are relatively high, except in Hittite central Anatolia, but even there, pigs were a common sight. Secondly, intensive culling appears common in the Mycenaean and Hittite realms and southeastern Anatolia, whereas extensive strategies appear to be the norm in northern Greece and western Anatolia. Thirdly, and somewhat at odds with reconstructed culling strategies, the high variation in pig size in Anatolia contrasts with the uniform size of Greek pigs. This might mirror a wider range of husbandry strategies in Anatolia. However, high variability in size might alternatively reflect the co-existence, possibly mixing, of different phenotypes that may or may not be husbanded in different ways, as a result of intensive interactions of LBA Anatolia, intra- and interregional.

Understanding LBA pig husbandry in the Aegean and Anatolia remains hampered by the varying quality of published faunal data. The differential chronological and contextual resolution with which they have been presented does not allow investigating patterns that may be caused by the functional and organizational differences between sites, especially after 1400 B.C. In the Mycenaean world, animal husbandry may have changed during the rise and demise of palatial economies (Shelton 2010), whereas in central Anatolia, the expansion of the Hittite Empire combined a multitude of different traditions with differing attitudes towards pigs (Collins 2006). Towards the final phase of the LBA, environmental changes and socio-political instability may have likewise affected agricultural stability on local and regional scales (e.g., Drake 2012).

Pig principles in LBA Greece and Anatolia

The "pig principles" posit that pigs were an unattractive resource in urban, centralized animal economies in Mesopotamia and suggest that pig rearing and consumption were largely bound to households and rural areas (Hesse and Wapnish 1998). Pig husbandry at Kaymakçı and comparative regional data suggest that the "pig principles" do not fit the context of early state societies in Greece and Anatolia.

Kaymakçı takes a unique position in this analysis, as a large citadel in western Anatolia, intermediary to the predominantly Hittite central Anatolia and Mycenaean Aegean. Pig husbandry here diverges from expectations of large centers for two reasons. First, unlike many other LBA sites, pigs formed a primary component of subsistence. Secondly, intensive pig husbandry, characteristic of LBA citadels in Greece and Anatolia, and extensive strategies, characteristic for western Anatolia and the northern Aegean, co-existed here. The practice of extensive husbandry does not necessarily imply that Kaymakçı had no central system(s) of animal husbandry, but that the "pig principles" do not sufficiently apply to Kaymakçı.

The "pig principles" do not fit the large centers of LBA Greece and Anatolia well either. Pig husbandry in Greece and Anatolia was not limited to rural households. Pig bones are abundant in nearly all assemblages from large centers, except at Hittite sites. Even for the Hittite realm, however, both historical texts and mortality data suggest that pigs were incorporated in centrally regulated, specialized production. Texts specify objectives for specialized pig husbandry, including meat and lard production, and the production of pigs designated for feasts, festivals, and rituals. It is very likely that these specialized productions co-existed with other systems, such as household pig keeping, but data from smaller centers are rare in Greece and Anatolia. These multiple systems demonstrate that LBA pig husbandry in Greece and Anatolia can best be understood as a story of multiple pig husbandries, shaped by the complex social, ritual, and economic demands of LBA societies.

Conclusion

In Kaymakçı, pigs were a common sight both within and outside the built environment. Culling patterns suggest both intensive and extensive pig husbandry were vital to the economy at this LBA center. These husbandry strategies and the heterogeneous size of pigs in Kaymakçı suggest pig husbandry and pigs themselves were pluriform. Further investigation is necessary to address whether this previously unattested phenomenon in LBA Anatolia reflects co-existing husbandry strategies, the region's dynamic cultural interactions involving introductions of new animal varieties, or the high quality of our data.

Our bottom-up exploration of pig data across LBA Greece and Anatolia likewise reveals considerable variability in pig husbandry purposes and strategies within and across subregions. This variation in LBA pig husbandry in Greece and Anatolia is not entirely surprising in light of Mycenaean and Hittite texts that describe multiple social connotations and

economic uses for pigs. The zooarchaeological identification of multiple pig husbandries and pig varieties in Kaymakçı, which probably reflects the co-existence of conceptual and practical meanings for pigs as seen in texts, might be a first. However, it may just as well only show that many features of past pig husbandry remain invisible when the utility of pigs is only measured by pig bone frequencies in archaeological assemblages and pig mentions in ancient texts.

The variation in pig husbandries revealed in this study complicates the application of the "pig principles" as an explanatory model for LBA Greece and Anatolia and shows that more nuanced approaches are necessary to understand pig husbandry in this region. Future pig studies will, in our opinion, benefit from combining traditional zooarchaeological methods on well-contextualized assemblages with developing techniques to trace palaeo-genomes, morphotypes, and diet studies to further explore the socio-economic, environmental, and cultural dynamics of LBA pig husbandry across the Aegean and Anatolia.

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No potential conflict of interest was reported by the author(s).

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References

Albarella, U. 2002. "Size Matters: How and Why Biometry is Still Important in Zooarchaeology." In *Bones and the Man. Studies in Honor of Don Brothwell*, edited by K. Dobney and T. O'Connor, 51–62. Oxford: Oxbow Books.

Albarella, U., K. Dobney, and P. Rowley-Conwy. 2009. "Size and Shape of the Eurasian Wild Boar (*Sus scrofa*), with a View to the Reconstruction of its Holocene History." *Environmental Archaeology* 14 (2): 103–136.

Albarella, U., F. Manconi, and A. Trentacoste. 2011. "A Week on the Plateau: pig Husbandry, Mobility and Resource Exploitation in Central Sardinia." In *Ethnozooarchaeology. The Present and Past of Human-Animal Relationships*, edited by Umberto Albarella and Angela Trentacoste, 143–159. Oxford: Oxbow Books.

Albarella, U., and S. Payne. 2005. "Neolithic Pigs from Durrington Walls, Wiltshire, England: A Biometrical Database." *Journal of Archaeological Science* 32 (4): 589–599.

Alparslan, M. 2013. "Bir Imparatorlugu Ayakta Tutabilmek Ekonomi ve Ticaret - Sustaining an Empire: Economy and Trade." In *Hititler: Bir Anadolu Imparatorlugu. Hittites: An Anatolian Empire*, edited by M. Doğan-Alparslan, 506–517. Yapi Kredi Yayinlari.

Andreou, S. 2001. "Exploring the Patterns of Power in Bronze Age Settlements of Northern Greece." In *Urbanism in the Aegean Bronze Age, Sheffield Studies in Aegean Archaeology*, edited by K. Branigan, 160–173. Sheffield Academic Press.

Arbuckle, B. 2009. "Chalcolithic Caprines, Dark Age Dairy, and Byzantine Beef: A First Look at Animal Exploitation at Middle and Late Holocene Çadır Höyük, North Central Turkey." *Anatolica* XXXV: 179–224.

Arbuckle, B. S., and E. L. Hammer. 2019. "The Rise of Pastoralism in the Ancient Near East." *Journal of Archaeological Research* 27: 391. https://doi.org/10.1007/s10814-018-9124-8.

Baker, P. 2008. "Economy, Environment and Society at Kilise Tepe, Southern Central Turkey–Faunal Remains from the 1994–1998 Excavations." *Publications de la Maison de l'Orient et de la Méditerranée* 49 (1): 407–430.

Balasse, M., T. Cucchi, A. Evin, A. Bălăşescu, D. Frémondeau, and M.-P. Horard-Herbin. 2018. "Wild Game or Farm Animal? Tracking Human-Pig Relationships in Ancient Times through Stable Isotope Analysis." In *Hybrid Communities. Biosocial Approaches to Domestication and Other Trans-Species Relationships*, edited by C. Stéphanov and J. D. Vigne, 81–96. London: Routledge Studies in Anthropology.

Balasse, M., A. Evin, C. Tornero, V. Radu, D. Fiorillo, D. Popovici, R. Andreescu, K. Dobney, T. Cucchi, A. Bălăşescu, et al. 2016. "Wild, Domestic and Feral? Investigating the Status of Suids in the Romanian Gumelniţa (5th mil. cal BC) with Biogeochemistry and Geometric Morphometrics." *Journal of Anthropological Archaeology* 42: 27–36. https://doi.org/10.1016/j.jaa.2016.02.002.

Becker, C. 1986. "Kastanas: Ausgrabungen in einem Siedlungshügel der Bronze-und Eisenzeit makedoniens 1975–1979. Die Tierknochenfunde." PhD diss. Volker Spiess.

Becker, C., and H. Kroll. 2008. *Das Prähistorische Olynth, Band 22. Prähistorische Archäologie in Südosteuropa*. Raden/Westfalen: Verlag Marie Leidorf GmbH.

Berthon, R. 2014. "Small But Varied. The Role of Rural Settlements in the Diversification of Subsistence Practices as Evidenced in the Upper Tigris River Area (Southeastern Turkey) During the Second and First Millennia BCE." *Journal of Eastern Mediterranean Archaeology and Heritage Studies* 2 (4): 317–329.

Berthon, R. 2017. "Herding for the Kingdom, Herding for the Empire. The Contribution of Zooarchaeology to the Knowledge of Hittite Economy." *Byzas* 23: 175–184.

Bertini, L., and E. Cruz-Rivera. 2014. "The Size of Ancient Egyptian Pigs." *Bioarchaeology of the Near East* 8: 83–107.

Boessneck, J., and A. von den Driesch. 1975. "Tierknochenfunde vom Korucutepe bei Elazığ in Ostanatolieri." In *Korucutepe: Final Report on the Excavations of the Universities of Chicago, California (Los Angeles) and Amsterdam in the Keban Reservoir, Eastern Anatolia, 1968–1970*, vol. *1*, edited by M. N. van Loon, 1–220. Amsterdam/Oxford/New York.

Boessneck, J., and A. von den Driesch. 1979. *Die Tierknochenfunde aus der Neolithischen Siedlung auf dem Fikirtepe bei Kadiköy am Marmarameer*. München: Universität München, Institut für Palaeoanatomie, Domestikationsforschung und Geschichte der Tiermedizin.

Bopp-Ito, M., T. Cucchi, A. Evin, B. Stopp, and J. Schibler. 2018. "Phenotypic Diversity in Bronze Age Pigs from the Alpine and Central Plateau Regions of Switzerland." *Journal of Archaeological Science: Reports* 21: 38–46.

Bökönyi, S. 1986. "The Faunal Remains." In *Excavations at Sitagroi 1, Vol. 1*, edited by C. Renfrew, M. Gimbutas, and E. S. Elster, 63–96. Cotsen Institute of Archaeology Press.

Bryce, T. R. 1989. "The Nature of Mycenaean Involvement in Western Anatolia." *Historia: Zeitschrift Für Alte Geschichte* H1: 1–21.

Bryce, T. R. 2012. "The Late Bronze Age in the West and the Aegean." In *The Oxford Handbook of Ancient Anatolia: (10,000–323 BCE)*, edited by G. McMahon and S. Steadman. Oxford University Press.

Cannon, M. D. 2013. "NISP, Bone Fragmentation, and the Measurement of Taxonomic Abundance." *Journal of Archaeological Method and Theory* 20 (3): 397–419.

Collins, B. J. 2006. "Pigs at the Gate: Hittite Pig Sacrifice in its Eastern Mediterranean Context." *Journal of Ancient Near Eastern Religions* 6 (1): 155–188.

Creuzieux, A., A. Gardeisen, E. Stefani, G. Touchais, R. Laffineur, and F. Rougemont. 2014. "L'Exploitation du Monde Animal en Grèce Septentrionale Durant le Bronze Récent: L'Exemple D'Angelochori." In *Physis. L'Environmet Naturel et la Relation Homme-Milieu Dans le Monde Égéen Protohistorique*, 409–414. Leuven/Liege, Peeters.

Çakırlar, C., L. Gourichon, S. Pilaar Birch, R. Berthon, M. Akar, and K. Aslıhan Yener. 2014. "Provisioning an Urban Center Under Foreign Occupation: Zooarchaeological Insights in the Hittite Presence in Late Fourteenth-Century BCE Alalakh." *Journal of Eastern Mediterranean Archaeology and Heritage Studies* 2 (4): 259–276.

Davis, S. J. M. 1987. *The Archaeology of Animals*. London: Routledge.

Dedeoğlu, F., and E. Abay. 2014. "Beycesultan Höyük Excavation Project: New Archaeological Evidence from Late Bronze Age Layers." *Arkeoloji Dergisi* 19: 1–39.

DeFrance, S. D. 2009. "Zooarchaeology in Complex Societies: Political Economy, Status, and Ideology." *Journal of Archaeological Research* 17 (2): 105–168.

Deniz, E., T. Çalışlar, and T. Özgüden. 1964. "Osteological Investigations of the Animal Remains Recovered from the Excavations of Ancient Sardis." *Anatolia* 8: 49–64.

Dörfler, W., C. Herking, R. Neef, P. Pasternak, and A. von den Driesch. 2011. "Environment and Economy in Hittite Anatolia." In *Insights into Hittite History and Archaeology, Colloquia Antiqua 2*, edited by H. Genz and D. P. Mielke, 99–124. Walpole: Peeters.

Drake, B. L. 2012. "The Influence of Climatic Change on the Late Bronze Age Collapse and the Greek Dark Ages." *Journal of Archaeological Science* 39: 1862–1870.

Erkanal, H. 2008. "Geç Tunç Çağı'nda Liman Tepe." In *Batı Anadolu ve Doğu Akdeniz Geç Tunç Çağı Kültürleri Üzerine Yeni Araştırmalar*, edited by A. Erkanal-Öktü, S. Günel, and U. Deniz, 91–100. Ankara: Hacettepe Üniversitesi Yayınları.

Evin, A., T. Cucchi, A. Cardini, U. S. Vidarsdottir, G. Larson, and K. Dobney. 2013. "The Long and Winding Road: Identifying Pig Domestication through Molar Size and Shape." *Journal of Archaeological Science* 40 (1): 735–743.

Evin, A., K. Dobney, R. Schafberg, J. Owen, U. S. Vidarsdottir, G. Larson, and T. Cucchi. 2015. "Phenotype and Animal Domestication: A Study of Dental Variation between Domestic, Wild, Captive, Hybrid and Insular *Sus scrofa*." *BMC Evolutionary Biology* 15: 6.

Fairbairn, A., and S. Omura. 2005. "Archaeological Identification and Significance of ÉSAG (Agricultural Storage Pits) at Kaman-Kalehöyük, Central Anatolia." *Anatolian Studies* 55: 15–23. doi:10.1017/S0066154600000636.

Fillios, M. A. 2007. "Measuring Complexity in Early Bronze Age Greece: The Pig as a Proxy Indicator of Socio-Economic Structures." PhD diss. John and Erica Hedges Ltd.

Frantz, L. A. F., J. Haile, A. T. Lin, A. Scheu, C. Geörg, N. Benecke, M. Alexander, et al. 2019. "Ancient Pigs Reveal a Near-Complete Genomic Turnover Following their Introduction to Europe." *Proceedings of the National Academy of Sciences* 116 (35): 17231–17238. doi:10.1073/pnas.1901169116.

Gaastra, J. S. 2014. "Shipping Sheep or Creating Cattle: Domestic Size Changes with Greek Colonisation in Magna Graecia." *Journal of Archaeological Science* 52: 483–496.

Gaastra, J. S., H. J. Greenfield, and T. Greenfield. In press. "Constraint, Complexity and Consumption: Zooarchaeological Meta-Analysis Shows Regional Patterns of Resilience across the Metal Ages in the Near East." *Quaternary International*, Available online: 23 May 2019. DOI: 10.17632/ks2df7fw59.1.

Gamble, C. S. 1978. "The Bronze Age Animal Economy from Akrotiri: A Preliminary Analysis." In *Thera and the Aegean World I*, edited by C. Doumas, 745–753. London: Thera Foundation.

Gamble, C. S. 1982. "Animal Husbandry, Population and Urbanisation." In *An Island Polity: The Archaeology of Exploitation on Melos*, edited by C. Renfrew and J. Wagstaff, 161–71. Cambridge: Cambridge University.

Gander, M. 2017. "The West: Philology." In *Handbook of Oriental Studies. Hittite Landscape and Geography*, edited by M. Weeden and L. Z. Ullmann, 262–280. Leiden: Brill.

Gardeisen, A. 2010. "Approche Comparative de Contextes du Bronze Moyen à Travers les Données de L'archéozoologie." In *Mesohelladika, la Grèce Continentale au Bronze Moyen, Mar 2006, Athènes, Grèce. Bulletin de Correspondence Hellénique Supplément52*, edited by A. Philippa-Touchais, G. Touchais, S. Voutsaki, and J. Wright, 721–732. Athens: École Française d'Athènes.

Grant, A. 1982. "The Use of Tooth Wear as a Guide to the Age of Domestic Animals." In *Ageing and Sexing Animal Bones from Archaeological Sites*, edited by B. Wilson, C. Grigson, and S. Payne, 91–108.

Greaves, A. M. 2012. "The Greeks in Western Anatolia." In *The Oxford Handbook of Ancient Anatolia: (10,000–323 BCE)*, edited by G. McMahon and S. Steadman. Oxford University Press.

Griffin, P. B. 1998. "An Ethnographic View of the Pig in Selected Traditional Southeast Asian Societies." In *Ancestors for the Pigs. MASCA Research Papers in Science and Archaeology*, edited by S. M. Nelson, 27–75. UPenn Museum of Archaeology.

Grigson, C. 2007. "Culture, Ecology, and Pigs from the 5th to the 3rd Millennium BC Around the Fertile Crescent." In *Pigs and Humans: 10,000 Years of Interaction*, edited by U. Albarella, K. Dobney, A. Ervynck, and P. Rowley-Conwy, 83–108. Oxford: Oxford University Press.

Günel, S. 2010. "Mycenaean Cultural Impact on the Çine (Marsyas) Plain, Southwest Anatolia: the Evidence from Çine-Tepecik." *Anatolian Studies* 60: 25–49.

Habermehl, K. H. 1975. *Altersbestimmung Haus- und Labortieren*. Berlin: Verlag Paul Parey.

Halstead, P. 1993. "The Mycenaean Palatial Economy: Making the Most of the Gaps in the Evidence." *Proceedings of the Cambridge Philosophical Society* 38: 57–86.

Halstead, P. 1999. "Texts, Bones and Herders: Approaches to Animal Husbandry in Late Bronze Age Greece." *Minos* 33–34: 149–189.

Halstead, P. 2003. "Texts and Bones: Contrasting Linear B and Archaeozoological Evidence for Animal Exploitation in Mycenaean Southern Greece." In *Zooarchaeology in Greece: Recent Advances, Britisch School at Athens Studies, Vol.9*, edited by E. Kotjabopoulou, Y. Hamilakis, P. Halstead, C. Gamble, and P. Elefanti, 257–261. London: British School at Athens.

Halstead, P. 2011. "Redistribution in Aegean Palatial Societies. Terminology, Scale, and Significance." *American Journal of Archaeology* 115 (2): 229–235.

Halstead, P., and V. Isaakidou. 2017. "Sheep, Sacrifices, and Symbols: Animals in Later Bronze Age Greece." In *The Oxford Handbook of Zooarchaeology*, edited by U. Albarella, M. Rizzetto, H. Russ, K. Vickers, and S. Viner-Daniels, 114–126. Oxford: Oxford University Press.

Hamilakis, Y., and E. Konsolaki. 2004. "Pigs for the Gods: Burnt Animal Sacrifices as Embodied Rituals at a Mycenaean Sanctuary." *Oxford Journal of Archaeology* 23 (2): 135–151.
Hamilton, J., R. E. M. Hedges, and M. Robinson. 2009. "Rooting for Pigfruit: Pig Feeding in Neolithic and Iron Age Britain Compared." *Antiquity* 83 (322): 998–1011.
Hanfmann, G. M. A., and C. Foss. 1983. "The City and Its Environment." In *Sardis from Prehistoric to Roman Times. Results of the Archaeological Exploration of Sardis, 1958–1975*, edited by G. M. A. Hanfmann, 1–16. Cambridge, MA: Harvard University Press.
Hauptmann, H. 1975. "Die Felsspalte D." In *Das Hethitische Felsheiligtum Yazılıkaya*, edited by K. Bittel. Berlin: Gebrüder Mann Verlag.
Hawkins, J. D. 1998. "Tarkasnawa, King of Mira: 'Tarkondemos,' Boğazköy Sealings and Karabel." *Anatolian Studies* 48: 1–31.
Hesse, B., and P. Wapnish. 1998. "Pig Use and Abuse in the Ancient Levant: Ethnoreligious Boundary- Building with Swine." In *Ancestors for the Pigs: Pigs in Prehistory, MASCA Research Papers in Science and Archaeology 15*, edited by S. Nelson, 123–135. Philadelphia: Museum of Archaeology and Anthropology, University of Pennsylvania.
Hoffner, H. A. 1974. "Alimenta Hethaeorum, Food Production in Hittite Asia Minor." In *Am Orient Ser 55*. New Haven: American Oriental Society.
Hongo, H. 1996. "Patterns of Animal Husbandry in Central Anatolia from the Second Millennium BC through the Middle Ages: Faunal Remains from Kaman-Kalehoyuk, Turkey." PhD diss. Harvard University.
Ikram, S., C. Çakırlar, and R. Kabatiar. Forthcoming. "The Fauna of Kinet Höyük." *JEMAHS*.
Isaakidou, V., P. Halstead, J. Davis, and S. Stocker. 2002. "Burnt Animal Sacrifice at the Mycenaean 'Palace of Nestor', Pylos." *Antiquity* 76 (291): 86–92.
Kaniewski, D., E. Van Campo, J. Guiot, S. Le Burel, and T. Otto. 2013. "Environmental Roots of the Late Bronze Age Crisis." *PLoS ONE* 8 (8): e71004.
Klengel, H. 2007. "Studien zur Hethitischen Wirtschaft, 3: Tierwirtschaft und Jagd." *Altorientalische Forschungen* 34 (1–2): 154–173.
Knapp, A. B., and S. W. Manning. 2016. "Crisis in Context: The End of the Late Bronze Age in the Eastern Mediterranean." *American Journal of Archaeology* 120 (1): 99–149.
Kussinger, S. 1988. "Tierknochenfunde vom Lidar Höyük (Südostanatolien)." Unpublished PhD diss. University of Munich.
Lemoine, X., M. A. Zeder, K. J. Bishop, and S. Rufolo. 2014. "A New System for Computing Dentition-Based Age Profiles in *Sus Scrofa*." *Journal of Archaeological Science* 47: 179–193.
Luke, C., and C. H. Roosevelt. 2016. "Memory and Meaning in Bin Tepe, the Lydian Cemetery of a 'Thousand Mounds." In *Tumulus as Sema: Proceedings of an International Conference on Space, Politics, Culture, and Religion in the First Millennium BC*, edited by O. Henry and U. Kelp, 407–28. TOPOI Excellence Cluster Series 27. Berlin: De Gruyter.
Luke, C., and C. H. Roosevelt. 2017. "Cup-marks and Citadels: Evidence for Libation in 2nd-Millenium BCE Western Anatolia." *BASOR* 378: 1–23.
Luke, C., C. H. Roosevelt, P. J. Cobb, and W. Çilingiroğlu. 2015. "Composing Communities: Chalcolithic through Iron Age Survey Ceramics in the Marmara Lake Basin, Western Turkey." *Journal of Field Archaeology* 40 (4): 428–449.
Mac Sweeney, N. 2010. "Hittites and Arzawans: A View from Western Anatolia." *Anatolian Studies* 60: 7–24.
Macheridis, S. 2018. "Waste Management, Animals and Society. A Social Zooarchaeological Study of Bronze Age Asine." PhD diss. Lund University.
Mangaloğlu-Votruba, S. 2015. "Liman Tepe During the Late Bronze Age." In *NOSTOI: Indigenous Culture, Migration and Integration in the Aegean Islands and Western Anatolia During the Late Bronze and Early Iron Age*, edited by N. C. Stampolidis, Ç Maner, and K. Kopanias, 647–68. Istanbul: Koç University Press.
Massei, G., P. V. Genov, B. W. Staines, and M. L. Gorman. 1997. "Factors Influencing Home Range and Activity of Wild Boar (*Sus scrofa*) in a Mediterranean Coastal Area." *Journal of Zoology* 242: 411–423.
Mayer, J. J., M. Novak, and I. L. Brisbin Jr. 1998. "Evaluation of Molar Size as a Basis for Distinguishing Wild Boar from Domestic Swine: Employing the Present to Decipher the Past." In *Ancestors for the Pigs. MASCA Research Papers in Science and Archaeology*, edited by S. M. Nelson, 39–53. UPenn Museum of Archaeology.
Meadow, R. H. 1999. "The Use of Size Index Scaling Techniques for Research on Archaeozoological Collections from the Middle East." In *Historia Animalium ex Ossibus: Beiträge auf Paläoanatomie, Archäologie, Ägyptologie, Ethnologie und Geschichte der Tiermedizin*, edited by C. Becker, H. Manhart, J. Peters, and J. Schibler, 285–300. Rahden/Westf: Verlag Marie Leidorf.
Meriç, R., and A. K. Öz. 2015. "Bademgediği Tepe (Puranda) Near Metropolis." In *NOSTOI: Indigenous Culture, Migration and Integration in the Aegean Islands and Western Anatolia During the Late Bronze and Early Iron Age*, edited by N. C. Stampolidis, Ç Maner, and K. Kopanias, 609–26. Istanbul: Koç University Press.
Minniti, C. 2014. "The Role of Animals in the Economy of South-Eastern Anatolia: Food and Commensalism at Mersin-Yumuktepe." In *Paleonutrition and Food Practices in the Ancient Near East, towards a Multidisciplinary Approach. History of the Ancient Near East XIV*, edited by L. Milano, 95–108. Padova: S.A.R.G.O.N.
Mountjoy, P. A. 1998. "The East Aegean-West Anatolian Interface in the Late Bronze Age: Mycenaeans and the Kingdom of Ahhiyawa." *Anatolian Studies* 48: 33–68. doi:10.2307/3643047.
Mouton, A. 2017. "Animal Sacrifice in Hittite Anatolia." In *Animal Sacrifice in the Ancient Greek World*, edited by S. Hitch and I. Rutherford, 239–252. Cc: Oxford University Press.
Nitsch, E., S. Andreou, A. Creuzieux, A. Gardeisen, P. Halstead, V. Isaakidou, A. Karathanou, et al. 2017. "A Bottom-Up View of Food Surplus: Using Stable Carbon and Nitrogen Isotope Analysis to Investigate Agricultural Strategies and Diet at Bronze Age Archontiko and Thessaloniki Toumba, Northern Greece." *World Archaeology* 49: 105–137.
Nobis, G. 1993. "Archäozoologische Untersuchungen von Tierrresten aus dem Palast des Nestor bei Pylos in Messenien, SW-Peloponnes." *Zeitschrift für Archäologie* 27: 151–173.
Ottoni, C., L. G. Flink, A. Evin, C. Geörg, B. De Cupere, W. Van Neer, L. Bartosiewicz, et al. 2013. "Pig Domestication and Human-Mediated Dispersal in Western Eurasia Revealed through Ancient DNA and Geometric Morphometrics." *Molecular Biology and Evolution* 30 (4): 824–832.
Pavúk, P. 2014. *Troia VI Früh und Mitte: Keramik, Stratigraphie, Chronologie*. Studia Troica Monographien 3. Bonn: Habelt.
Payne, S. 1972. "Partial Recovery and Sample Bias: The Results of Some Sieving Experiments." In *Papers in Economic Prehistory*, edited by S. E. Higgs, 49–64. University Press: Cambridge.
Payne, S. 1987. "Reference Codes for Wear Stages in the Mandibular Cheek Teeth of Sheep and Goats." *Journal of Archaeological Science* 14: 609–614.
Payne, S., and G. Bull. 1988. "Components of Variation in Measurements of Pig Bones and Teeth." *Archaeozoologica* 2: 27–66.
Price, M. D., and A. Evin. 2017. "Long-Term Morphological Changes and Evolving Human-Pig Relations in the Northern Fertile Crescent from 11,000 to 2000 CAL B.C." *Archaeological and Anthropological Sciences* 111: 237–251.
Price, M., K. Grossman, and T. Paulette. 2017. "Pigs and the Pastoral Bias: The Other Animal Economy in Northern Mesopotamia (3000–2000 BCE)." *Journal of Anthropological Archaeology* 48: 46–62.
Price, G. C., J. Krigbaum, and K. Shelton. 2017. "Stable Isotopes and Discriminating Tastes: Faunal Management Practices at the Late Bronze Age Settlement of Mycenae, Greece." *Journal of Archaeological Science: Reports* 14: 116–126.
Redding, R. W. 1991. "The Role of the Pig in the Subsistence System of Ancient Egypt: A Parable on the Potential of Faunal Data." *Animal Use and Culture Change* 8: 20–30.
Redding, R. W. 2015. "The Pig and the Chicken in the Middle East: Modeling Human Subsistence Behavior in the Archaeological Record Using Historical and Animal Husbandry Data." *Journal of Archaeological Research* 23 (4): 325–368. https://doi.org/10.1007/s10814-015-9083-2.
Roosevelt, C. H. 2009. *The Archaeology of Lydia, from Gyges to Alexander*. Cambridge: Cambridge University Press.
Roosevelt, C. H. 2010. "Lydia Before the Lydians." In *The Lydians and their World. Catalogue of an Exhibit at the Yapı Kredi Vedat Nedim Tör Museum, İStanbul*, edited by N. D. Cahill, 37–73. Istanbul: Yapı Kredi Culture, Art, and Publishing.

Roosevelt, C. H., P. Cobb, E. Moss, B. R. Olson, and S. Ünlüsoy. 2015. "Excavation Is Digitization: Advances in Archaeological Practice." *Journal of Field Archaeology* 40 (3): 325–46.

Roosevelt, C. H., and C. Luke. 2017. "The Story of a Forgotten Kingdom? Survey Archaeology and the Historical Geography of Central Western Anatolia in the Second Millennium BC." *EJA* 20 (1): 120–47.

Roosevelt, C. H., C. Luke, S. Ünlüsoy, C. Çakrlar, J. M. Marston, C. R. O'Grady, P. M. Pavuk, et al. 2018. "Exploring Space, Economy, and Interregional Interaction at a Second-Millennium B.C.E. Citadel in Central Western Anatolia: 2014–2017 Research at Kaymakçı." *American Journal of Archaeology* 122 (4): 645–688.

Rougemont, F. 2006. "Les Porcs Dans la Documentation Mycénienne." In *De la Domestication au Tabou. Le Cas des Suidés au Proche-Orient Ancient*, edited by B. Lion and C. Michel, 115–129. Paris: De Boccard.

Rowley-Conwy, P., and M. Zeder. 2014. "Wild Boar or Domestic Pigs? Response to Evin et al." *World Archaeology* 46 (5): 835–840.

Russell, N. 2011. *Social Zooarchaeology: Humans and Animals in Prehistory*. Cambridge University Press.

Schmidt, E. 1972. *Atlas of Animal Bones: for Prehistorians, Archaeologists and Quaternary Geologists*. Amsterdam: Elsevier Publishing Company.

Scrucca, L., M. Fop, T. B. Murphy, and A. E. Raftery. 2016. "Mclust 5: Clustering, Classification and Density Estimation Using Gaussian Finite Mixture Models." *The R Journal* 8 (1): 205–233.

Shelton, K. 2010. "Citadel and Settlement: A Developing Economy at Mycenae, the Case of Petsas House." In *Political Economies of the Aegean Bronze Age: Papers from the Langford Conference, Florida State University, Tallahassee, 22–24 February 2007*, edited by D. J. Pullen, 184–204. Oxbow Books.

Silibolatlaz, D., and K. Serdar Girginer. 2018. "Tatarlı Höyük Faunal Calismari." *Anadolu - Anatolia* 44: 53–74.

Simpson, G. G., A. Roe, R. C. Lewontin, and R. C. 1960. *Quantitative Zoology*. Mineola, New York: Dover Publications INC.

Spinka, M. 2009. "Behaviour of Pigs." In *The Ethology of Domestic Animals, 2nd Edition. An Introductory Text*, 2nd edition, edited by P. Jensen, 177–191. CAB International 2009.

Trantalidou, K. 1990. "Animals and Human Diet in the Prehistoric Aegean." In *Thera and the Aegean World, Vol. II*, edited by H. David, 392–405. London: Thera Foundation.

Vaessen, R. 2016. "Cosmopolitanism, Communality and the Appropriation of Mycenaean Pottery in Western Anatolia." *Anatolian Studies* 66: 43–65.

Vasileiadou, A. 2009. "Ανάλυση και ερ3ηνεία του ζωοαρχαιολογικού υλικού από το κτήριο Α της Τούπας Θεσσαλονίκης της Ύστερης Εποχής του Χαλκού." MA thesis, Aristotle University of Thessaloniki.

von den Driesch, A. 1976. *A Guide to the Measurement of Animal Bones from Archaeological Sites*. Peabody Museum Bulletins 1. Harvard: Peabody Museum of Archaeology and Ethnology.

von den Driesch, A., and J. Boessneck. 1981. "Reste von Haus- und Jagdtieren aus der Unterstadt von Boğazköy-Hattuša. Grabungen 1958-1977." In *Boğazköy-Hattuša. Ergebnisse der Ausgrabungen 11*, edited by K. Bittel, 1–71. Berlin: Gebr. Mann.

von den Driesch, A., and J. Boessneck. 1990. "Die Tierreste von der Mykenischen Burg Tiryns bei Nauplion/Peloponnes." In *Tiryns: Forschungen und Berichte, Band 11*, edited by H. J. Weisshaar, I. Weber-Hiden, A. von den Driesch, J. Boessneck, A. Rieger, and W. Böser, 87–164. Mainz: P. von Zabern.

von den Driesch, A., and N. Pöllath. 2004. *Vor- und Frühgeschichtliche Nutztierhaltung und Jagd auf Büyükkaya in Boğazköy-Hattuša, Zentralanatolien. Boğazköy-Berichte*. Mainz am Rhein: P von Zabern.

von den Driesch, A., and K. Vagedes. 1997. "Archaozoologische Untersuchungen in Kuşaklı." In *Untersuchungen in Kuşaklı 1996*, edited by A. Müller-Karpe, *MDOG* 129,103, 122–134.

Watson, J. P. N. 1979. "The Estimation of the Relative Frequencies of Mammalian Species: Khirokitia 1972." *Journal of Archaeological Science* 6 (2): 127–137.

Wright, E., S. Viner-Daniels, M. Parker Pearson, and U. Albarella. 2014. "Age and Season of Pig Slaughter at Late Neolithic Durrington Walls (Wiltshire, UK) as Detected through a New System for Recording Tooth Wear." *Journal of Archaeological Science* 52: 497–514.

Zeder, M. A. 1991. *Feeding Cities: Specialized Animal Economy in the Ancient Near East*. Washington DC: Smithsonian Institution Press.

Zeder, M. A. 1998. "Pigs and Emergent Complexity in the Ancient Near East." In *Ancestors for the Pigs. Pigs in Prehistory. MASCA Research Papers in Science and Archaeology, 15*, edited by S. E. Nelson, 109–122. Philadelphia: UPenn Museum of Archaeology and Anthropology.

Zeder, M. A., X. Lemoine, and S. Payne. 2015. "A New System for Computing Long-Bone Fusion Age Profiles in *Sus scrofa*." *Journal of Archaeological Science* 55: 135–150.

Zeist, W., and S. Bottema. 1991. *Late Quarternary Vegetation of the Near East, Wiesbaden* (Beheifte zum Tübinger Atlas des Vorderen Orients (A18)).

Zerefos, C. S., and E. C. Zerefos. 1978. "Climatic Change in Mycenaean Greece: A Citation to Aristotle." *Archiv für Meteorologie Geophysik und Bioklimatologie (Series B)* 26: 297–303.