

This PDF file of your paper in First Steps of Animal Domestication belongs to the publishers Oxbow Books and it is their copyright.

As author you are licenced to make up to 50 offprints from it, but beyond that you may not publish it on the World Wide Web or in any other form.

*Proceedings of the 9th Conference of the International Council
of Archaeozoology, Durham, August 2002*

Series Editors: Keith Dobney, Peter Rowley-Conwy and Umberto Albarella

First Steps of Animal Domestication

New archaeozoological approaches

Edited by

J.-D. Vigne, J. Peters and D. Helmer

© Oxbow Books 2005

ISBN 1 84217 121 6

Contents

Preface	vii
<i>Keith Dobney, Peter Rowley-Conwy and Umberto Albarella</i>	
1. New archaeological approaches to trace the first steps of animal domestication: general presentation, reflections and proposals	1
<i>Jean-Denis Vigne, Daniel Helmer and Joris Peters</i>	
Principles and concepts	
2. Experimental animal domestication and its application to the study of animal exploitation in prehistory	18
<i>Benjamin S. Arbuckle</i>	
3. The domestication of the wolf – the inevitable first?	34
<i>Werner Müller</i>	
4. Breaking the mold: a consideration of variation in the evolution of animal domestication	41
<i>Richard W. Redding</i>	
New techniques and their application	
5. Assessing the origin and diffusion of domestic goats using ancient DNA	50
<i>Helena Fernández, Pierre Taberlet, Marjan Mashkour, Jean-Denis Vigne and Gordon Luikart</i>	
6. Kernel smoothing and mixture analyses for the determination of the sex ratios at death, at the beginning of domestication of ungulates	55
<i>Hervé Monchot, Marjan Mashkour and Jean-Denis Vigne</i>	
7. Two novel methods for the study of dental morphological variation in <i>Sus scrofa</i> , in order to identify separate breeding groups within archaeological assemblages	61
<i>Sylvia Warman</i>	
Animal domestication in West Asia	
8. Pig exploitation at Hagoshrim; a prehistoric site in the Southern Levant	80
<i>Annat Haber, Tamar Dayan and Nimrod Getz</i>	
9. Identifying early domestic cattle from Pre-Pottery Neolithic sites on the Middle Euphrates using sexual dimorphism	86
<i>Daniel Helmer, Lionel Gourichon, Hervé Monchot, Joris Peters and Maria Saña Seguí</i>	
10. The upper Euphrates-Tigris basin: cradle of agro-pastoralism?	96
<i>Joris Peters, Angela von den Dreisch and Daniel Helmer</i>	
11. A View from the Zagros: new perspectives on livestock domestication in the Fertile Crescent	125
<i>Melinda A. Zeder</i>	
Animal domestication in East Asia	
12. Wild pig? Or domesticated boar? An archaeological view on the domestication of <i>Sus scrofa</i> in Japan	148
<i>Akira Matsui, Naotaka Ishiguro, Hitomi Hongo and Masao Minagawa</i>	
13. Wild boar remains from the Neolithic (Jomon Period) sites on the Izu Islands and in Hokkaido Island, Japan	160
<i>Kyomi Yamazaki, Osamu Takahashi, Hiroki Sugawara, Naitaka Ishiguro and Hideki Endo</i>	

11. A View from the Zagros: new perspectives on livestock domestication in the Fertile Crescent

Melinda A. Zeder

A reanalysis of archaeofaunal collections from the Zagros calls into question the utility of morphological change, in particular size reduction, as a leading edge marker of animal domestication. A variety of factors unrelated to domestication are shown to have a profound affect body size in both wild and domestic goats in the region, as well as on gazelle, further eroding the case for size reduction as a valid indicator of domestication. A new method for computing sex-specific demographic profiles from archaeological animal bones provides clear evidence of management of morphologically unchanged goats at the highland Zagros site of Ganj Dareh directly dated to nearly 9000 BP uncalibrated. Subsequent morphological change in the form of changes in horn form and, possibly body size reduction are not seen for 500 to 1000 years. A similar pattern seems to be emerging for sheep, pigs, cattle, and possibly once again for goats in other parts of the Fertile Crescent. These results call for a change in the conceptual approach to defining domestication, a new geographical and temporal orientation for research on this problem, as well as changes in the methods and methodological practices used to document initial stages of animal domestication in the Near East.

Introduction

In many respects methods for documenting animal domestication in the Near East have advanced little beyond those initially developed in the 1950s, 60s, and 70s by investigators working in the eastern arc of the Fertile Crescent in today's Iran and Iraq. Pioneering archaeozoologists of the day were on the forefront of methodological innovation for documenting animal domestication and they developed essentially all the primary methods used today to trace the transition from hunting to herding: changes in horn morphology and body size, demographic profiling, species abundance and zoogeography. Subsequent work in the western and central portions of the broad arc of the Fertile Crescent has produced a significant body of basic data on the domestication of four keystone livestock species – sheep, goats, pigs, and cattle (Horwitz *et al.* 1999, Peters *et al.* 1999, Vigne and Buitenhuis 1999). Basic, unresolved issues remain, however, regarding the relative value of different methods for monitoring the process of animal domestication. Of principal importance, the cause and effect relationships between human management of

animals and the various proposed archaeozoological markers of domestication still need to be established. And there are still no uniform standards of proof that would allow the consistent application of these markers by different analysts to different assemblages. There can be no real progress in understanding the course of animal domestication in the Near East until these two critical methodological issues are squarely addressed.

Take for example, changes in horn or cranial morphology, which were the first markers proposed by archaeozoologists for detecting domestication in sheep and goats (Reed 1959, 1960). In this case, there is a clear cause and effect link between the removal of selective pressure for large horns when humans assume control over breeding. And yet the archaeological community has yet to reach clear consensus on either the nature or the degree of change in horn form needed to signal domestication. How does one differentiate morphological change caused by domestication from the occasional occurrence, in a still wild population, of traits that would later be characteristic of domesticates? In addition, it is still not clear whether the development of domestic morphotypes in

horns and crania are leading edge markers of initial domestication or changes that only became fixed much later in time.

Similarly, the utility of body size reduction as a valid early, leading edge measure of initial animal domestication in the Near East remains an open question. Was a reduction in body size a virtually immediate manifestation of animal domestication as some have argued (Bökönyi 1969, Uerpmann 1978, 1979, Meadow 1989, Bar Yosef and Meadow 1995)? Or was it, like changes in horn core morphology, a physical trait selected long after initial domestication? Moreover, unlike changes in horn morphology that plainly reflect human control over the selection of breeding partners, the cause and effect relationship between initial domestication and body size reduction has not been clearly or convincingly articulated. Another largely unaddressed issue is how to distinguish and differentiate the role domestication in causing size reduction from other factors known to influence size (*i.e.*, sexual dimorphism, age, regional variation, and adjustment to post-Pleistocene climatic conditions).

Demographic profiling of target species in archaeological assemblages in order to detect initial domestication was another of the early methods developed by researchers working in the Zagros region (Perkins 1964, Hole *et al.* 1969). Here too, questions can be raised regarding the relationship between domestication and demographics, as well as about the methods used to reconstruct demographic patterns in archaeological assemblages. Modern reference class case studies and more sophisticated models of harvest strategies are needed in order to more confidently distinguish demographic profiles resulting from the slaughter of managed herd animals from those resulting from various seasonal or selective hunting strategies. However, the primary impediment in the use of demographic profiling to mark initial domestication has been in the poor resolution of the methods commonly used to construct these profiles. Detecting an emphasis on the slaughter of young caprines, for example, might be suggestive of herding. But, alternatively, it might also be interpreted as evidence of either a hunting strategy that preyed on immature animals (Hesse 1978, 1982), or the long-term impact of over-hunting of wild populations (Jarman and Wilkinson 1972). Definitive documentation of herd management in archaeofaunal assemblages requires higher resolution demographic profiles capable of detecting the culling of young males and the delayed slaughter of females, which are the keynote features of the domestic herd. The only way to do this is through the development of methods for computing sex-specific demographic profiles, something that has not been possible before now. More finely calibrated age of death determinations are also of critical interpretive value.

Similarly, claims of zoogeographic range extension as evidence of animal domestication in the Near East have often neglected the issue of whether modern day

distributions of depleted populations of wild progenitor species in fact provide appropriate analog models for the paleo-zoogeography of these animals prior to domestication. This is of course especially important in areas close to the natural habitat of wild progenitors (the most likely locales for initial domestication). Finally, using an increase in the ubiquity of a progenitor species in an archaeofaunal assemblage as a criterion for marking initial domestication obviously requires being able to rule out intensification of selective hunting of the species as the cause of the increase.

This chapter reports the comprehensive and detailed reanalysis of many of the early collections from the Zagros region and focuses on resolving some of these open questions about documenting domestication. For a number of reasons, I target goats (*Capra hircus*) as a case study species. More specifically, I evaluate the relative value of the two primary methods developed during the initial study of these collections more than three decades ago and which are still used today for detecting the earliest phases of the transition from hunting to herding: body size reduction and demographic profiling. The primary goal of this ongoing research is to provide a more complete and coherent picture of the course of animal domestication in the Zagros, and to then apply this higher resolution regional record in a broader scale to a reconsideration of the process of livestock domestication throughout the Fertile Crescent.

A return to the Zagros

The ongoing reconsideration of hunting and herding in the Zagros focuses both on developing higher resolution standards of proof for detecting caprine domestication and the application of these standards in a consistent way to all curated faunal assemblages that bracket the transition to sheep and goat herding in the region (Zeder 1999, 2001, 2003, in press a, Zeder and Hesse 2000). In order to clarify the temporal framework of the transition, a comprehensive program of AMS radiocarbon dating of animal bones has been undertaken from sites temporally situated on both sides of the transition to herding. Studies of large modern skeletal collections of mostly wild sheep and goats from Iran and Iraq, and a more limited sample of gazelle, curated by the Field Museum of Natural History in Chicago and the Smithsonian Institution in Washington D.C., have also been carried out in order to establish, for the first time, an empirical baseline for the study of size variation and demographic profiling in archaeological samples.

The modern caprines

Analysis of the modern skeletal collections has included comprehensive osteometric analysis (Zeder 2001), documentation of post-cranial fusion and tooth eruption and

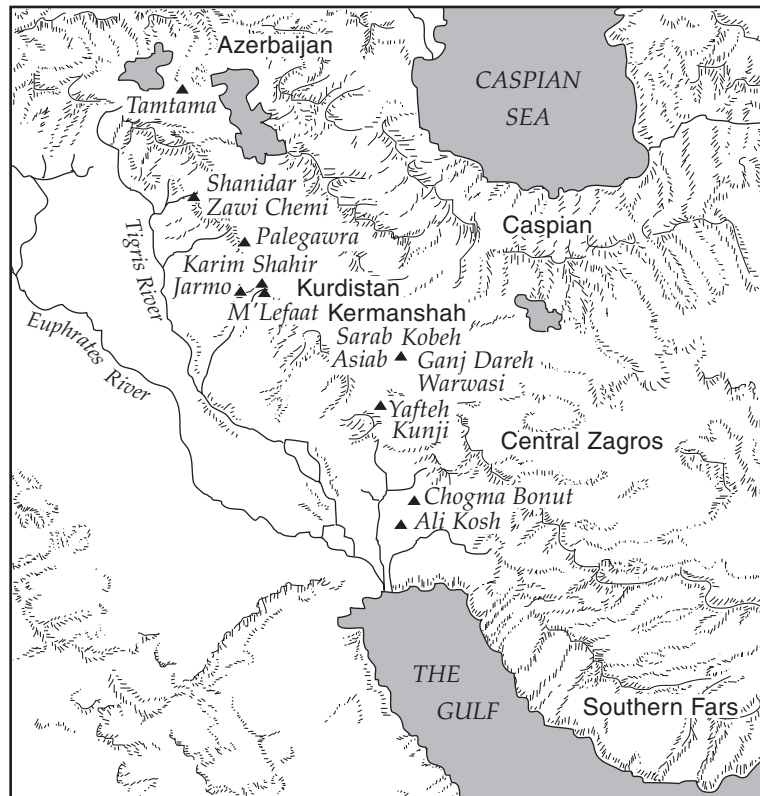


Figure 1. Map of Iran and Iraq showing locations of modern and archaeological samples.

wear patterns (Zeder in press a), development and evaluation of standard morphological criteria for distinguishing between sheep and goats (Zeder and Lapham in prep.), and sampling for DNA analysis (conducted by Gordon Luikart, CNRS, Grenoble). Results reported here based on 41 goat specimens, including 37 wild bezoar goats (*Capra aegagrus*) and four domestic goats (*Capra hircus*). The four domestic goats represent unimproved breeds collected from village and nomad herds in locations still within the natural habitat of wild goats. The sample includes 21 males and 20 females. Ages represented range from just a few months to more than 8 to 10 years of age (Zeder in press b). Regional distribution of the goat specimens extends from north central Iran in the Elburz Mountains near the Caspian, to Azerbaijan on the far northwestern border of Iran, down the spine of the Zagros through Iraqi Kurdistan, Kermanshah, Ispahan, to the far southern reaches of the Zagros at the Persian Gulf (Fig. 1).

Size variation

One of the primary goals of this analysis was to assess the impact of four general factors on the size of modern goats in the Zagros: age, sex, geography, and domestic status – in order to provide a clearer, and more accurate empirical context for the evaluation of size variation in goats in the archaeological record. Of these four general

variables, sex was the single most important factor affecting size in goats. Males over the age of 12 months are always larger than females. In all bones, there was a clear separation between male and female animals, and a striking similarity in the range of variation between males and females (Zeder 2001, Table 1). In breadth and depth measurements (Fig. 2), females consistently comprise about 40% of the total range of variation in all dimensions measured, while larger males comprise about 60%. The separation between males and females is even greater in length measurements (Fig. 3), although females here still tend to have a narrower range of variation than males.

Next to sex, environment was the second most important factor influencing size in modern goats from the Zagros, with a clear trend toward smaller body size as one moves from the colder, wetter northern part of the region to the arid southern reaches near the Gulf (Fig. 4a-c). Age, however, seems to have little impact on size. Once animals are older than one year of age, even the unfused and fusing bones of young males are larger than the fully fused bones of older females (Fig. 2, see also Zeder 2001, Figure 3). This pattern is also found in length measurements, but here there is clearly more variability in the total length of bones depending when the bones fuse in an animal's life span (Zeder in press b).

Significantly, domestic status seems to have little impact on the size of modern goats from the Zagros. This

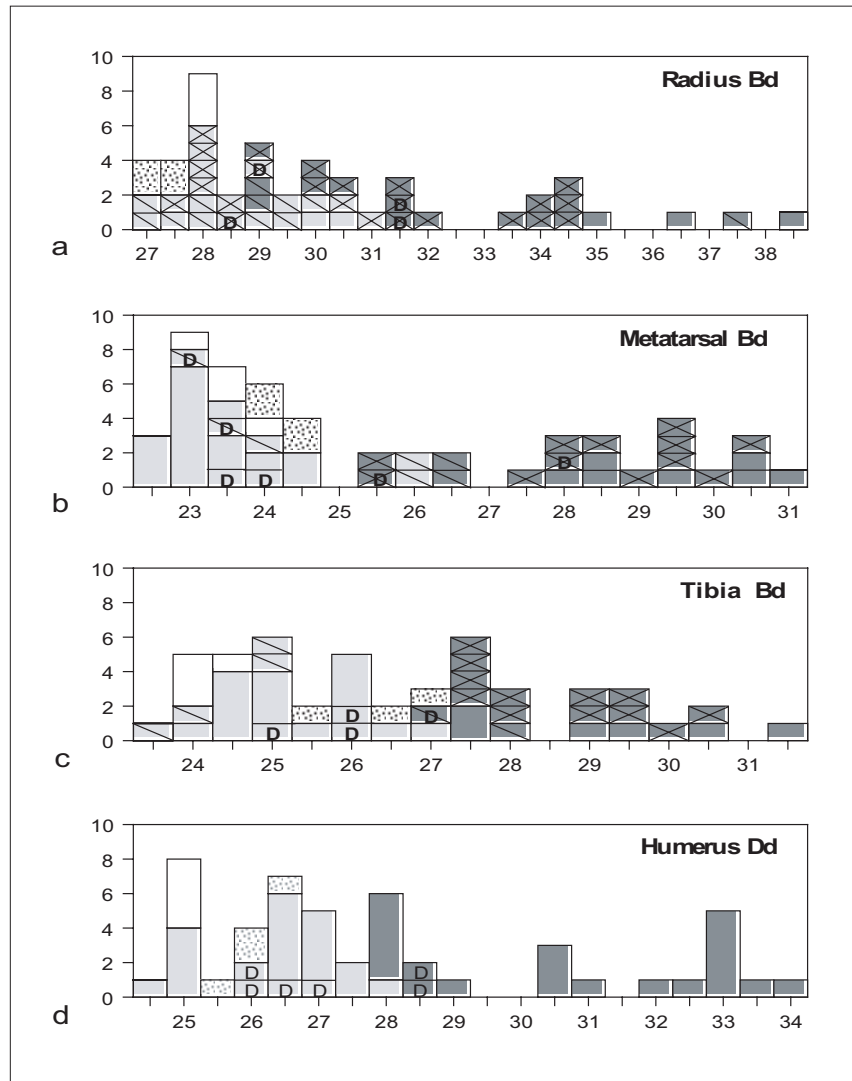


Figure 2. Modern goat breadth and depth measurements of selected long bones. X axis shows dimension in mm. Y axis shows number of specimens. Dark gray shaded bars are males older than one year of age. Stippled bars are males one year of age or younger. Light gray shaded bars are females older than one year of age. White bars are females one year of age. Diagonal hatches mark fusing bones. Crosshatches mark unfused bones. D marks bones of domestic specimens. a. Radius Bd (n=48); b. Metatarsal Bd (n=52); c. Tibia Bd (n= 48); d. Humerus Dd (n=50).

is particularly true for female goats. In both breadth and length measurements, female domestic goats in the sample fall squarely within the range of variation for wild females (Figs 2 and 3). Similarly, while the breadth and depth measurement of the post-cranial bones of domestic males tend to fall at the small end of the range of variation of wild males, they are still within the male range and outside the range of all but the largest wild females from the northern-most collecting localities. The long bones of domestic male are markedly shorter in length than their wild male counterparts, falling in all cases within the ranges of wild and domestic females (Fig. 3).

Thus neither modern male nor female domestic goats

in the Zagros sample are distinguishable from wild goats on the basis of breadth and depth measurements. Nor can female domesticates be distinguished from wild females on the basis of length measurements. The only clear difference in the size of the modern domestic and wild goats in the FMNH collections is in the length of the long bones of male domesticates, which are substantially shorter than those of wild males and indistinguishable from wild and domestic females. Given the rarity of complete long bones in archaeozoological assemblages, the potential application of this difference for distinguishing between ancient wild and domestic specimens is unfortunately quite limited. Out of the 3737 metapodials studied from the large Ganj Dareh assem-

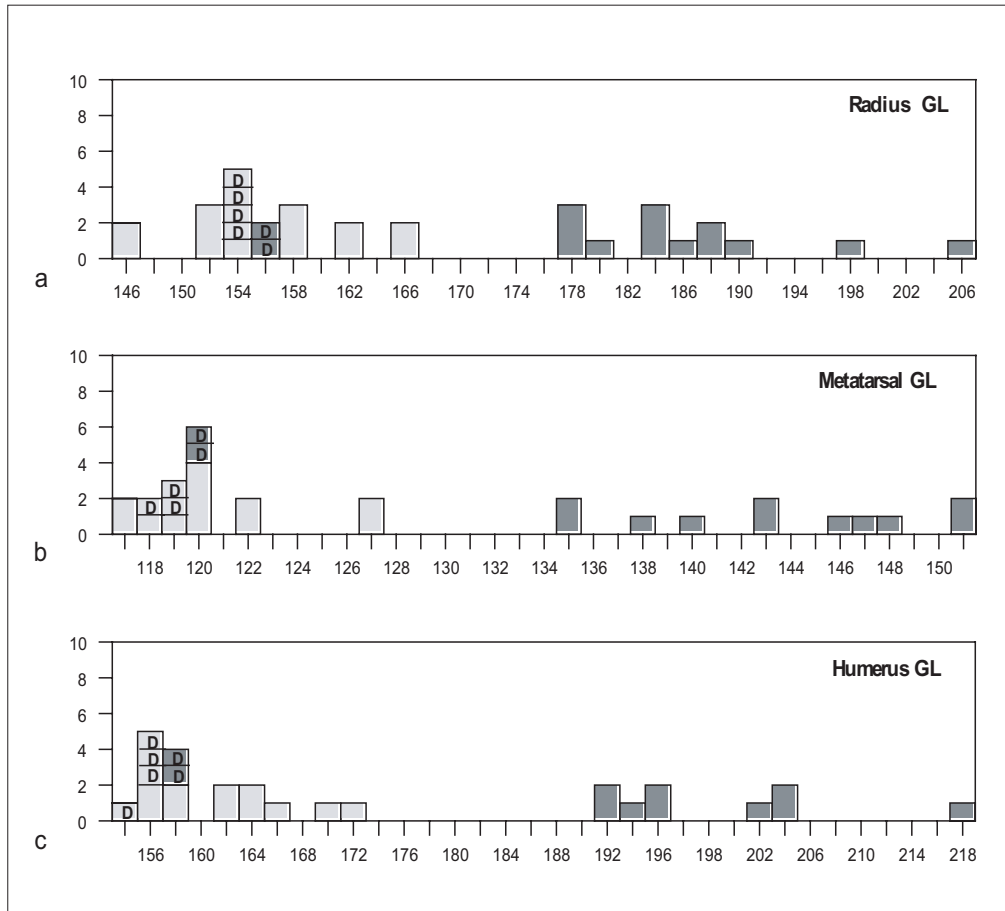


Figure 3. Modern goat length measurements of selected long bones. X axis shows dimension in mm. Y axis shows number of specimens. Dark gray shaded bars are males older than one year of age. Light gray shaded bars are females older than one year of age. D marks bones of domestic specimens. a. Radius GL (n=32); b. Metatarsal GL (n=28); c. Humerus GL (n=26).

blage, for example, only 7 were complete, and these were the only complete long bones in the entire Ganj Dareh sample of 8,717 bones analyzed for this study.

Aging the sample

Although the precise ages of death of the FMNH modern caprines are not known, a study of the sequence of post-cranial bone fusion and tooth eruption and wear of the sheep and goats in the collection has resulted in refinements of both post-cranial and dental aging protocols (Zeder in press a). The new sequence of bone fusion and the estimated ages of fusion resulting from this study are summarized in Table 1.

Archaeological caprines

The archaeological assemblages analyzed in this study are curated by the National Museum of Natural History of the Smithsonian Institution, the Field Museum, the Royal Copenhagen Museum, and the University Museum of the University of Pennsylvania (Fig. 1). The oldest

Table 1. Revised Fusion Sequence and Ages for Goats from Zeder in press b.

Age Group	Bone	Order of Fusion	Estimated Age ¹
A	P. Radius	1	0-6
B	D. Humerus	2	6-12
B	Pelvis	2	6-12
B	Scapula	2	6-12
C	2nd Phalanx	3	12-18
C	1st Phalanx	4	12-18
D	D. Tibia	5	18-30
D	D. Metacarpal	6	18-30
D	D. Metatarsal	6	18-30
E	Calcaneus	7	30-48
E	P. Femur	8	30-48
E	D. Femur	8	30-48
E	P. Ulna	8	30-48
E	D. Radius	8	30-48
E	P. Tibia	8	30-48
F	P. Humerus ²	9	48+
G	P. Humerus ³	10	48++

¹ - Age in months, ² - Bones in early fusion, ³ - Bones in late fusion or fully fused

assemblages included in this analysis were recovered from Paleolithic sites located in the highland Zagros regions of Iran and Iraq (Shanidar, Kobeh, Kunji, Bisetun, Tamtama, Warwasi, Palegawra, and Yafteh Cave). They include material that dates to the Middle Paleolithic (ca. 50,000 years ago), as well as to both the Early Upper Paleolithic, locally termed the Baradostian Period (ca. 35,000 years ago) and the Late Upper Paleolithic or Zarzian Period (ca. 15,000 years ago). Essentially all analysts accept the goats in these assemblages as wild, hunted animals, based on both their large size and demographic profiles that indicate a focus on older animals (Perkins 1964, Uerpmann 1979, Evins 1982). Epipaleolithic material included in this study comes from the sites of Asiab and Karim Shahir. Most researchers also accept these assemblages as resulting from the hunting of wild populations on the basis of both body size and demographic data (Uerpmann 1979, Bar Yosef and Meadow 1995, Stampfli 1983, but see Bökönyi 1977).

Candidate domestic goat assemblages studied include those from the highland village settlement of Ganj Dareh, widely accepted as domestic on the basis of both younger age profiles (Hesse 1978, 1982, 1984) and an apparent reduction in body size (Uerpmann 1979, Helmer 1992, Bar Yosef and Meadow 1995, Legge 1996). Another likely domestic assemblage comes from the lowland site of Ali Kosh, where changes in horn morphology, age profiles and zoogeographic evidence indicate domestic status (Hole *et al.* 1969). Other assemblages thought to lie on the domestic side of the transition between hunting and herding are from the Iranian sites of Tepe Guran and Sarab (Bökönyi 1977), and Jarmo in Iraq (Reed 1960, 1983, Stampfli 1983).

Temporal sequence

All of the sites included in this study were excavated in the early days of radiocarbon age determination, before the development of the small volume AMS radiocarbon method that allowed the direct dating of candidate domestic specimens. As a result there have long been significant questions regarding the chronological placement of sites in the region, especially those that bracket the transition from hunting to herding: Asiab, Ganj Dareh, Ali Kosh, Guran, Sarab, and Jarmo (see Hole 1987). Of particular concern has been the precise dating of Ganj Dareh and Ali Kosh, the two leading contenders for producing the earliest evidence of goat domestication in the region. Precise dating of these two sites was essential for understanding the developmental context of initial domestication of goats. Did goat domestication first take place in the highland natural habitat of wild goats where Ganj Dareh is located, or did it occur outside this region in the arid lowland steppe region where Ali Kosh is located? Two very different explanatory scenarios would be needed to account for initial domestication in these two regions (see Braidwood 1960 vs. Hole and Flannery 1967, Hole *et al.* 1969, Binford 1971). Up until

this study existing radiocarbon dates for these sites failed to clarify which held temporal precedence (see Hole 1987). Basal levels at Ganj Dareh were thought to date as far back as 11,000 BP uncalibrated, with the upper village levels, where domestic goats was thought to be present, occupied some 2000 years later. Ali Kosh basal levels were considered to be as old as 9500 BP uncalibrated, and the entire occupation of the site – which spans the transition from the Aceramic to the Ceramic Neolithic – could have extended over a span of 2000 years.

AMS dates of bone collagen and carbonized bones obtained for this study have brought new clarity to the Zagros chronology (Table 2). The Epipaleolithic site of Asiab, once thought to be contemporary with nearby Ganj Dareh, was actually occupied about 500 years earlier, at around 9500 BP uncalibrated (about 10,700 BP calibrated). Rather than having a 2000 year occupation span, Ganj Dareh can now be seen to have had only a relatively brief occupation of about 100–200 years, with all levels at the site dating to about 8900 to 8700 BP uncalibrated (9900–9700 BP calibrated). Initial occupation of basal levels at Ali Kosh can now be put at about 8500–8400 BP uncalibrated (ca. 9500–9400 BP calibrated), roughly 500 years later than the occupation of Ganj Dareh. The transition to the Ceramic Neolithic at Ali Kosh is now dated to about 8000 BP uncalibrated (9000 BP calibrated). The recently excavated lowland site of Chogha Bonut (excavated by Abbas Ali Zadeh, University of Chicago) also dates to about 8100–8000 BP uncalibrated. Basal levels at Tepe Guran date to about 8200–8000 BP uncalibrated (9200–9000 BP calibrated), and the Ceramic Neolithic levels at Guran and Sarab date to about 8000–7500/7000 (9000–8000 BP calibrated). Unfortunately, the bones from the Braidwood expeditions to Iraqi Kurdistan (most notably Jarmo) were treated with an unknown preservative that has rendered them unsuitable for radiocarbon dating. The majority of the material analyzed from Jarmo comes from upper ceramic age levels at the site and thus is likely contemporary with Iranian sites like Sarab and the upper levels at Tepe Guran.

Size variation

Figure 4 presents a deep diachronic view of size variation in Zagros goats from the Middle Paleolithic (ca. 50,000 BP) up to the present day. Unlike most archaeozoological studies of this kind, data are reported as unaltered measurements of single bones (in this case the greatest length of the second phalanx) rather than a normalized amalgam of a variety of skeletal elements following protocols laid out in Uerpmann 1979, and Meadow 1989 and 1999. Previous studies maintained that the goats from Ganj Dareh were smaller than contemporary and earlier wild goats (Uerpmann 1979, Helmer 1989, 1992, Bar Yosef and Meadow 1995, Legge 1996, 249–252). However, Figure 4 shows no change in the size of the goats from Ganj Dareh (Fig. 4f) when compared to goats

Table 2. AMS Dates on Bones from Zagros Sites.

	Beta Analytic Number	Level	Depth (cm)	C14 B.P.#	C14 Cal B.P.!	2 Sigma Cal B.P.@	1 Sigma Cal B.P.@@
Yafteh	B-177136*			32,400 ± 380			
	B-177135*			30,300 ± 320			
	B-177120		270–280	18,580±80	22,060	22,600–21,550	22,500–21,640
	B-177121		270–280	18,980±80	22,520	23,070–22,000	22,980–22,090
Palegawra	B-159546		10–20	5130±50	5910	5980–5970 5950–5740	5920–5890 5800–5770
	B-159543		20–40	12,510±90	15,100	15,530–14,150	15,480–14,240
	B-159545		60–80	8790±70	9860	10,150–9560	10,100–10,090 9920–9690
	B-159542		80–100	11,210±110	13,160	13,760–13,700 13,470–12,900	13,420–13,000
	B-159544		80–100	10,170±70	11,910	12,340–11,550 11,490–11,430	12,290–12,220 12,140–11,650
Asiab	B-159555		30–45	9480±80	10,710	11,110–10,530	11,050–10,960 10,770–10,590
	B-159554		45–60	9370±60	10,570	10,720–10,420	10,670–10,520
	B-159552		75–90	7790±60	8580	8660–8420	8610–8460
Ganj Dareh	B-108239	B	165–180	8930±60	9940	10,005–9870	9975–9905
	B-108238	A	180–200	8780±50	9850	9910–9585	9880–9805 9780–9660
	B-108240	B	220–240	8780±50	9850	9910–9585	9880–9805 9780–9660
	B-108241	B	240–260	8720±50	9650	9875–9525	9845–9725 9695–9565
	B-108242	B	280–300	8940±50	9945	10,000–9890	9975–9915
	B-108244	D	430–460	8840±50	9890	9945–9820 9765–9665	9915–9860
	B-108243	C	460–480	8920±50	9935	9990–9875	9960–9905
	B-108246	E	580–585	8870±50	9905	9960–9845 9725–9695	9935–9875
	B-108245	D	580–600	8940±50	9945	10,000–9890	9975–9915
	B-108247	E	665–675	8830±50	9880	9940–9805 9780–9660	9910–9850
	B-108248	E	700–710	8900±50	9920	9980–9865	9950–9895
	B-108249	E	765–768/70	8840±50	9890	9945–9820 9765–9665	9915–9860
Ali Kosh	B-137020*	Mohammed Jaffar	50–60	7100±70	7940	8020–7775	7970–7845
	B-177122*	Mohammed Jaffar	90–100	7550±40	8370	8400–8300	8390–8350
	B-118719*	Mohammed Jaffar	70–80	8130±70	8995	9245–8940	9185–9110 9090–8970
	B-118720*	Mohammed Jaffar	130–140	8130±70	9000	9360–8715	9215–8965
	B-118721*	Ali Kosh	180–200	8720±100	9650	9935–9480	9875–9525
	B-118722*	Ali Kosh	210–230	8110±80	8985	9245–8750	9040–8960
	B-177124*	Ali Kosh	230	8050±40	9000	9030–8970 8910–8870	9020–8990

Table 2. continued.

	Beta Analytic Number	Level	Depth (cm)	C14 B.P.#	C14 Cal B.P.!	2 Sigma Cal B.P.@	1 Sigma Cal B.P.@@
						8830–8790	
	B-137021*	Ali Kosh	250–270	8450±70	9485	9555–9270	9530–9425
	B-118723*	Ali Kosh	280–300	8490±90	9465	9565–9350	9505–9415
	B-118724*	Ali Kosh	380–400	8340±100	9375	9485–9000	9440–9220
	B-108256	Bus Mordeh	540–560	8000±50	8945	8985–8620	8965–8705
	B-122721*	Bus Mordeh	630–650	8540±90	9482	9650–9385	9530–9445
	B-137024*	Bus Mordeh	680–710	8410±50	9465	9520–9380 9370–9300	9490–9425
	B-177126*	Bus Mordeh	680	8530±40	9520	9550–9490	9540–9510
Chogha Bonut	B-177134			8040±40	9020	9100–8990	900–9000
	B-177132			8070±40	9010	9040–8980	9020–9000
	B-177133			8120±40	9020	9130–9000	9050–9010
Guran	B-147111	D		7630±60	8400	8530–8350	8430–8380
	B-147112	F		7260±40	8030	8160–7970	8140–8010
	B-177131	H		7810±40	8590	8640–8460	8610–8550
	B-147113	H		7950±40	8770	9000–8630	8980–8660
	B-147114	K		7080±60	7930	7990–7780	7960–7840
	B-147115	L		7940±40	8760	9000–8620	8980–8820 8800–8650
	B-177116	L		8130±40	9030	9140–9000	9100–9020
	B-147116	N		3690±40	4060	4150–3900	4090–3970
	B-147117	P		7890±40	8640	8970–8910 8870–8830 8790–8590	8740–8610
	B-147118	Q		8070±40	9010	9040–8980	9020–9000
	B-147119	R		8000±50	8990	9020–8650	9000–8770
	B-147122	T		8170±40	9100	9260–9020	9140–9030
	B-147120	U		8060±40	9010	9030–8980 8820–8800	9020–9000
	B-147121	V		7820±50	8600	8710–8450	8630–8550
	B-177117	V		8280±40	9280	9420–9130	9400–9360 9310–9250
Sarab	B-159547	1A		7470±70	8330	8400–8160	8360–8190
	B-159548	3		7950±60	8770	9010–8600	8990–8640
	B-159550	4		8070±60	9010	9120–8770	9030–8990
	B-159549	5		7800±60	8580	8710–8430	8620–8510

– Uncalibrated conventional ^{14}C age of specimens in ^{14}C B.P. ($\pm 1\delta$).

! – Intercept between the conventional ^{14}C age and the dendrocalibrated calendar time scale, in calendar yr B.P. (Pretoria calibration procedure program, Beta Analytic)

@ – 2δ dendrocalibrated age range for specimens, in calendar yr. B.P.

@ @ – 1δ dendrocalibrated age range for specimens, in calendar yr. B.P.

* – Date based on carbonized bone, all other dates based on collagen.

from earlier upland sites in the region (Figs 4g, h, and i). This pattern is consistently found in all bones and all dimensions measured. When the actual measurements of bones (both fused and unfused) are compared, instead of normalized profiles of amalgams of fused bones, no case can be made for variation in the size of goats in the highland Zagros region from the Middle Paleolithic up to the Aceramic Neolithic at Ganj Dareh.

Goats from lowland sites of Ali Kosh (Fig. 4e) and Chogha Bonut are significantly smaller than those from earlier upland sites. But it is difficult to know whether the smaller size of these animals reflects size diminution resulting from domestication, or simply indicates elevational clines of variation in the size of goats. The degree of difference in the size of ancient goats from Aceramic Neolithic and earlier upland sites and those from lowland Aceramic Neolithic sites is similar to that seen today when modern wild goats from the northern Iran (Fig. 4c) are compared to goats from collecting localities in the arid Southern Zagros (Fig. 4a).

On the other hand, a good case can be made for size reduction in the goats from Ceramic Neolithic sites in the Zagros highlands, after about 8000 B.P. uncalibrated (Fig. 4d), when compared to earlier goats from this same region (Fig. 4f-i). These goats are similar in size to the smaller goats from lowland Ali Kosh. But it is also interesting to note that the modern wild goats in the Zagros also show a trend toward smaller body size. Modern wild goats from the Northern and Central Zagros (Fig. 4b) are considerably smaller than the goats from Ganj Dareh and earlier upland sites, and are about the same size as the goats from Ceramic Neolithic upland (Fig. 4d) sites located in Kermanshah and Iraqi Kurdistan. Similarly, modern wild goats from the Southern Zagros (Fig. 4a) show a reduction in body size when compared to both Ceramic Neolithic upland sites and the goats from lowland Ali Kosh especially in the upper, male end of the distribution.

But are these trends toward smaller body size in the size of wild and domestic goats in the Zagros specific to only to goats, perhaps as the result of inter-breeding between wild and domestic animals? Or are there more general forces at work here that have nothing to do with domestication? Are there comparable patterns in bovid species that were never domesticated, like gazelle? Metric analysis of modern and archaeological gazelle skeletal material from Iran and Iraq was conducted as a kind of control sample for the study of the impact of domestication on caprines. A comparable time depth display of metric data (in this case the depth of the distal humerus) to that displayed for goats in Figure 4, is shown in Figure 5 for gazelle ranging in age from the Late Upper Paleolithic (ca. 15,000 years ago) to today.

As is the case in modern goats, modern gazelles show considerable regional variation in size, with gazelle from the high Iranian plateau (Fig. 5c) considerably larger than gazelle from the Zagros valleys to the west (Fig. 5b),

which are in turn considerably larger than gazelle from lowlands areas of Khuzistan in Iran and the Iraqi desert regions around Baghdad (Fig. 5a). Marked sexual dimorphism and a range of male and female size variation similar to that evident in modern goats is also apparent in the larger sample of gazelle from the Iranian Plateau (Fig. 5c).

Regional differences are also apparent in the ancient gazelles from the Zagros when gazelle from Epipaleolithic and Late Upper Paleolithic upland sites (Fig. 5f) are compared to those from lowland Ali Kosh and Chogha Bonut (Fig. 5e). This pattern echoes the difference in the size of goats from upland Ganj Dareh and lowland Ali Kosh noted above. Unlike the goats, gazelles from Ceramic Neolithic upland sites (Fig. 5d) show no difference in size when compared to their older counterparts in the upland zone. And yet, perhaps even more so than in goats, modern gazelle from the region are markedly smaller than the ancient gazelle. This trend is especially clear when the ancient gazelle from Ceramic Neolithic sites (Fig. 5d) are compared to modern gazelle from the same region (Fig. 5b), and when the ancient gazelle from lowland Ali Kosh and Chogha Bonut (Fig. 5e) are compared with the modern gazelle from the steppe and deserts of Iran and Iraq (Fig. 5a).

Thus for both goat and gazelle there is considerable sexual dimorphism and regional variability in size, as well as a temporal downward trend in body size over time. However, the marked decrease in body size of goats, evident in upland sites dating to between 8000 to 7000 BP uncalibrated, is not seen in the gazelle from these same sites. Significant reduction in body size in gazelle occurs sometime after 7000 BP. The difference in the timing of size reduction of goats and gazelle argues against a single cause for size reduction in these species (*i.e.* a uniform, region-wide response to climate change), and suggests instead that these species responded independently to factors that affect body size. Just what these factors are and the precise timing of their impact on these different species is difficult to say. Habitat degradation, over hunting, climate change, genetic isolation, selective breeding, migration of new herd stock, and introgression between wild and domestic species are all possible causal candidates. Sorting out these factors would take a much more complete temporal sampling of goat and gazelle remains from across this broad region over this long 10,000 year period. Whatever the cause or causes, the ultimate outcome has been a dramatic overall decrease in body size of domestic goats, their wild progenitors, and in gazelle, a species that has never undergone domestication.

Demographic profiling

One of the striking features of the metric data from sites with larger, more systematically collected samples (*e.g.*, Ganj Dareh and Ali Kosh) is a consistent bimodality that mirrors the dimorphism seen in male and female goats in

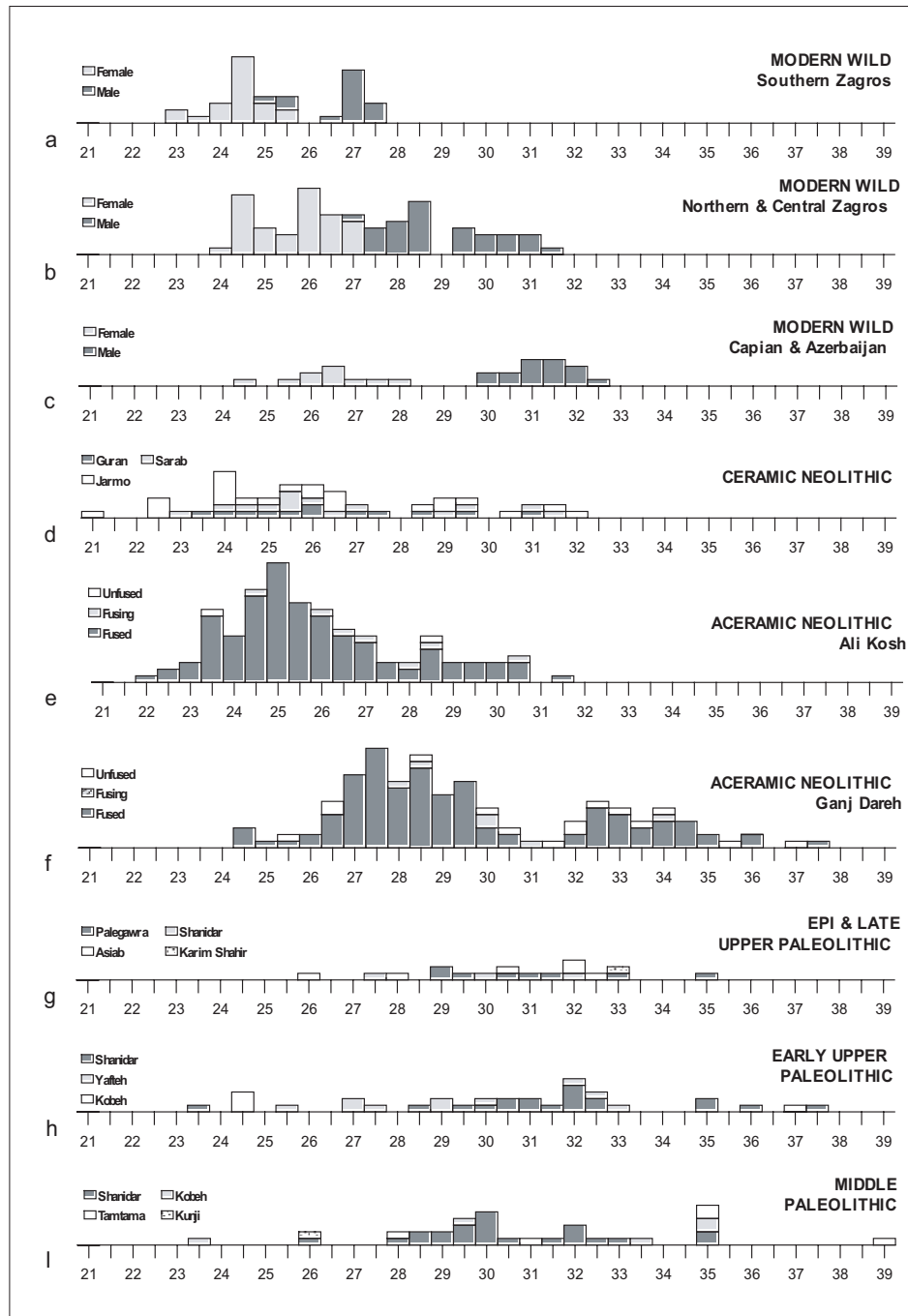


Figure 4. Diachronic view of changes in the length of the second phalanx (GL) of goats from the Middle Paleolithic to the present day. X axis shows dimension in mm. Y axis shows number of specimens. a. Modern wild goats from the southern Zagros, dark gray bars are males, light gray bars are females, (n=36); b. Modern wild goats from the northern and central Zagros, dark gray bars are males, light gray bars are females, (n=70); c. Modern wild goats from the Caspian region and Azerbaijan, dark gray bars are males, light gray bars are females, (n=96); d. Goats from Ceramic Neolithic sites (ca. 8000–7000 B.P. uncalibrated), dark gray bars are goats from Tepe Guran, light gray bars are goats from Tepe Sarab, white bars are goats from Jarmo, (n=50); e. Goats from Aceramic Neolithic levels at Ali Kosh (8500–8000 B.P. calibrated), dark gray bars are fused bones, light gray bars are fusing bones, white bars are unfused bones, (n=123); f. Goats from Aceramic Neolithic levels at Ganj Dareh (8900 B.P. calibrated), dark gray bars are fused bones, light gray bars are fusing bones, white bars are unfused bones, (n=132); g. Goats from Epi- and Late Upper Paleolithic sites (15,000–9,000 B.P. uncalibrated), dark gray bars are goats from Palegawra, light gray bars are goats from Shanidar level B, white bars are goats from Asiab, stippled bars are goats from Karim Shahir, (n=18); h. Goats from Early Upper Paleolithic sites (30,000–15,000 B.P. uncalibrated), dark gray bars are goats from Shanidar level C, light gray bars are goats from Yafteh Cave, white bars are goats from Kobeh Cave Levels C-O (n=34); i. Goats from Middle Paleolithic Sites (ca. 60,000–45,000 B.P. uncalibrated), dark gray bars are goats from Shanidar level D, light gray bars are goats from Kobeh Cave Levels P-CC, white bars are goats from Tamtama Cave, stippled bars are goats from Kunji Cave, (n=34).

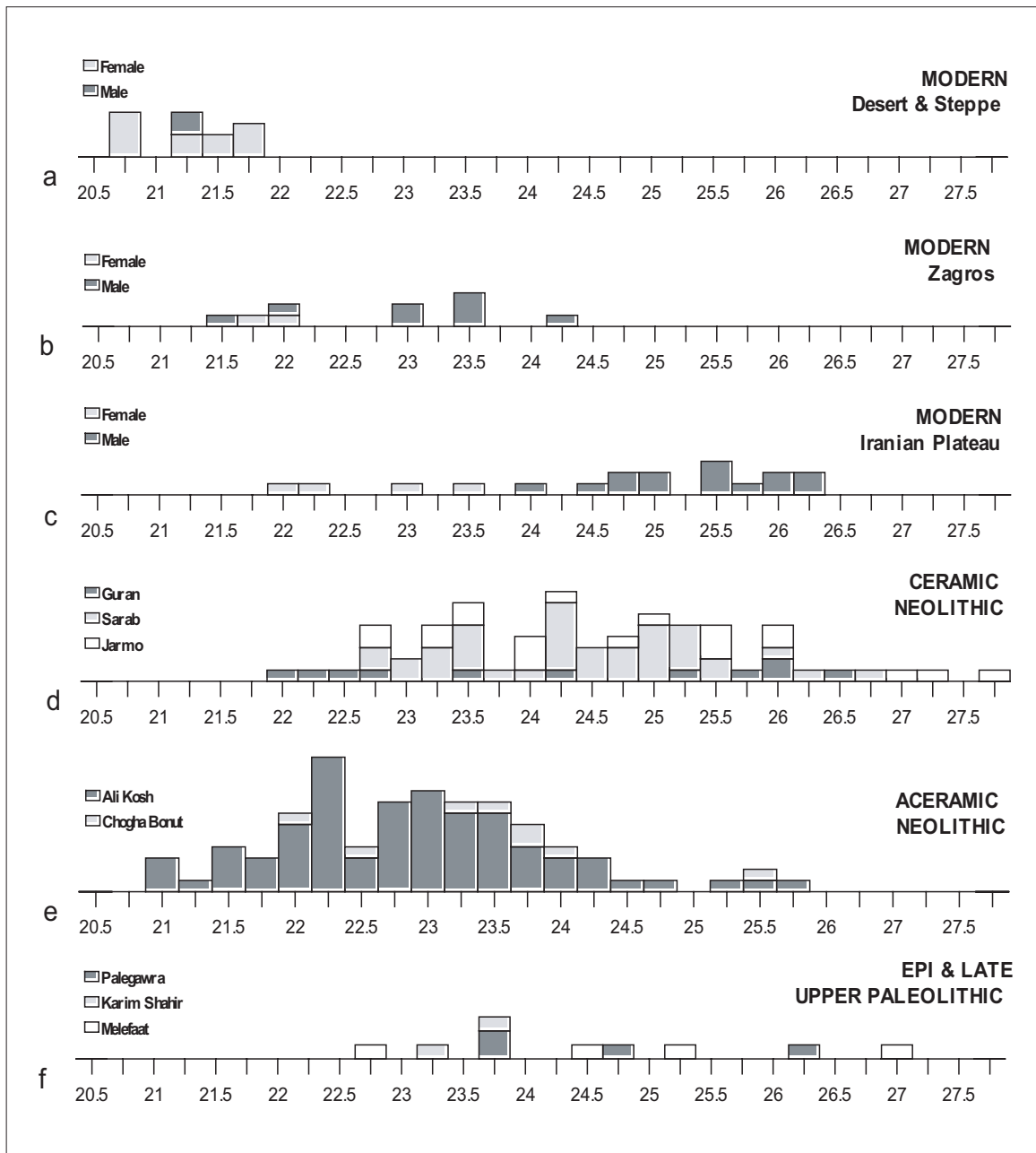


Figure 5. Diachronic view of changes in the depth of the distal humerus (*Dd*) of gazelle from the Epi- and late Paleolithic to the present day. X axis shows dimension in mm. Y axis shows number of specimens. a. Modern gazelle from desert and steppe regions of Iran and Iraq, dark gray bars are males, light gray bars are females, ($n=13$); b. Modern gazelles from the Zagros Mountains, dark gray bars are males, light gray bars are females, ($n=10$); c. Modern gazelles from the Iranian Plateau, dark gray bars are males, light gray bars are females, ($n=19$); d. Gazelles from Ceramic Neolithic sites (ca. 8000–7000 B.P. uncalibrated), dark gray bars are gazelle from Tepe Guran, light gray bars are gazelles from Tepe Sarab, white bars are gazelles from Jarmo, ($n=70$); e. Gazelles from Aceramic Neolithic lowland sites (8500–8000 B.P. uncalibrated), dark gray bars are gazelles from Ali Kosh, light gray bars are gazelles from Chogha Bonut, ($n=86$); f. Gazelles from Epi- and Late Upper Paleolithic sites, dark gray bars are gazelles from Palegawra, light gray bars are goats from Karim Shahir, white bars are gazelles from Melefaat, ($n=9$).

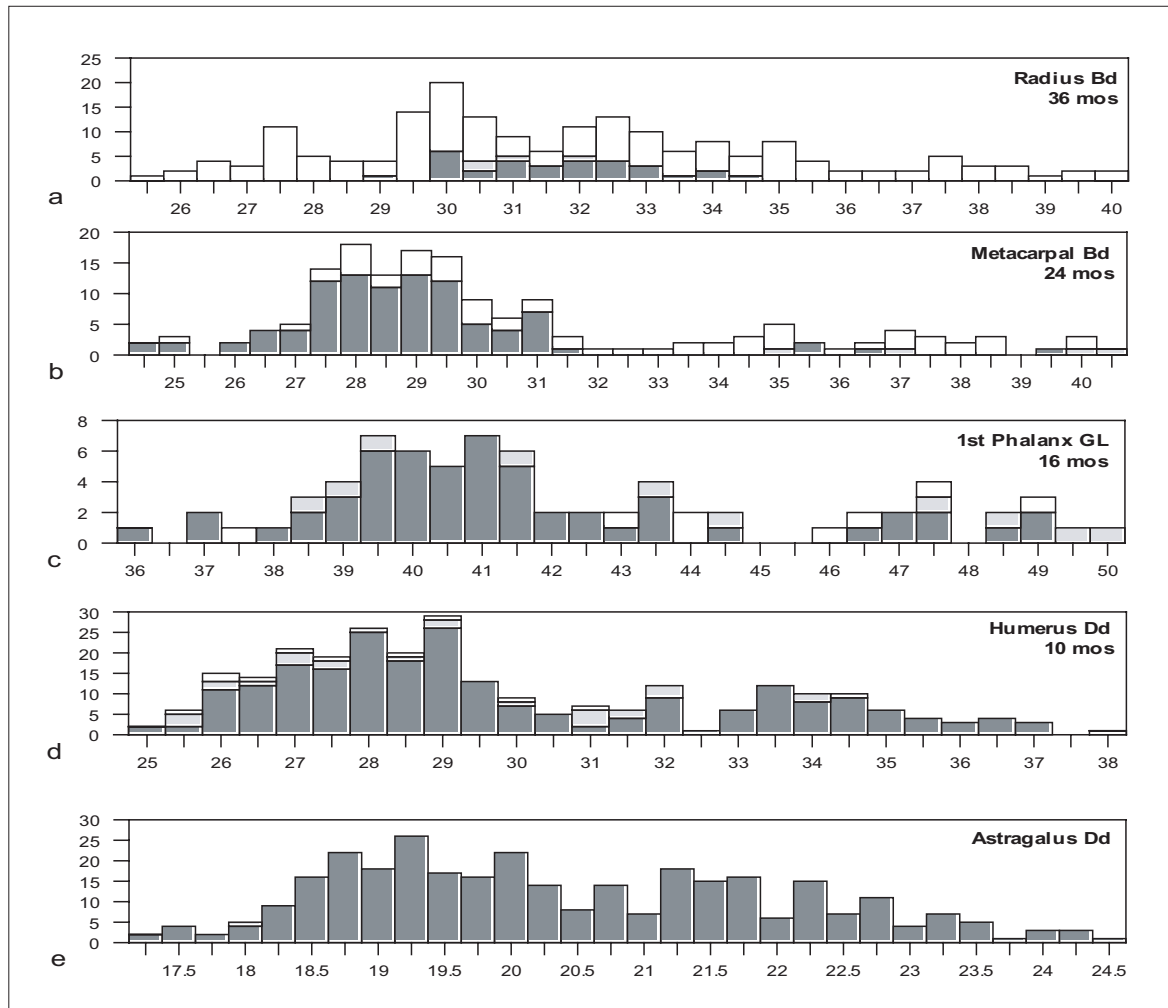


Figure 6. Breadth and depth measurements of goat long bones from Ganj Dareh arranged by age at fusion. X axis shows dimension in mm. Y axis shows number of specimens. Dark gray bars are fused specimens. Light gray bars are fusing specimens. White bars are unfused specimens. a. Radius Bd – fusion at 36 months, ($n=187$); b. Metacarpal Bd – fusion at 24 months, ($n=158$); c. First Phalanx GL – fusion at 16 months, ($n=73$); d. Humerus Dd – fusion at 10 months, ($n=263$); e. Astragalus Dd – fused at birth, ($n=313$).

the modern skeletal assemblages (Figs 4e and f, Fig. 6 and 7). Despite the smaller size of modern wild goats when compared to the goats from Ganj Dareh, these ancient assemblages show the same consistent bimodality in all measured bones, with the smaller animals making up about 40% of the total range of variation and the larger animals about 60% (Zeder 2001, 70–72). The inescapable conclusion is that the bimodality seen in these ancient assemblages reflects the same strongly marked sexual dimorphism found in modern goats, rather than the presence of both wild and domestic animals in the sample as is sometimes claimed.

Another notable feature of the Ganj Dareh and Ali Kosh assemblages is the high frequency of bones of larger animals that are unfused, a trend that is more evident in later fusing bones. This pattern was noted by Hesse in his

analysis of Ganj Dareh in the 1970s (Hesse 1978, 1982, 1984), but has been largely ignored by other researchers, who as a standard practice (see von den Driesch 1978, 4) exclude fusing and unfused bones from osteometric analysis. The poor representation of the bones of larger animals in the Ganj Dareh and Ali Kosh assemblages is undoubtedly attributable to the fact that so many of them are unfused. Unfused elements are more likely to be lost, discarded, or overlooked in recovery. It is also more difficult to identify these bones as either sheep or goat. They may also not be well enough preserved to allow measurement, even if an analyst were inclined to do so. Among early or non-fusing bones, like the astragalus (Figs 6e and 7e), the number of bones that fall into the larger size mode is approximately the same as those in the smaller modes, while the representation of larger

bones decreases in later fusing bone, like the distal metacarpal (Figs 6b and 7b) and distal radius (Figs 6a and 7a). This pattern points to taphonomic factors resulting in the differential loss of the larger bones of young males, rather than an uneven, female biased sex ratio in the ancient herd.

Following protocols discussed in Zeder (2001, 73), this consistent bimodality was used to separate ancient assemblages into probable male and female sub-samples, and sex-specific demographic profiles were computed using revised fusion sequence and calibration indices (Table 1, Zeder in press b). In the likely wild hunted populations from Middle and Upper Paleolithic levels C and D at Shanidar Cave and Epipaleolithic Asiab (Figs 8a and b), the resulting demographic profiles for male and female animals are quite similar to one another in all but the oldest fusing bones, where survivorship of female animals appears to drop significantly. In both cases a strong emphasis on older animals is indicated. Moreover, the predominance of bones that fall into the larger bodied, male portion of the assemblages from each site suggests an emphasis on the acquisition of older male animals (Table 3). This pattern is consistent with a hunting strategy that focuses on prime age adult animals, with a preference for large bodied males.

In contrast, the samples from both Ganj Dareh and Ali Kosh (Figs 8c and d) show divergent demographic profiles for males and females. In both cases males are slaughtered at younger ages, with few males surviving beyond about 2 years of age. Female slaughter is delayed. Also, unlike the demographic profiles for Shanidar and Asiab, females are much better represented than males at Ganj Dareh and Ali Kosh (Table 3). This pattern can be attributed to a focus on the slaughter of young males whose more friable bones are less likely to be recovered, identified to species, and measured. At both Ganj Dareh and Ali Kosh the sex-specific demographic profiles are consistent with herd management strategies that focus on the slaughter of young males, and the retaining of females and a few older males as breeding stock.

Closer consideration of the sex-specific demographic profiles from Ganj Dareh and Ali Kosh do, however, suggest some difference in herd management strategies at these two early sites. Herders at Ali Kosh seem to have slaughtered both young males and older females at slightly older ages than at Ganj Dareh. The difference between slaughter strategies at these two sites is even more striking when the demographic profiles are computed using all bones identifiable to at least the subfamily Caprinae (sheep or goat), both measurable and non-measurable – a sample that contains a higher proportion of the less identifiable unfused elements (Fig. 9). Since goats comprise more than 90% of the identifiable remains from both sites, the vast majority of less identifiable caprine bones from these sites can safely be assumed to be goats. The stronger emphasis on young animals at Ganj Dareh is quite clear. About half of the

goats at Ganj Dareh were slaughtered between one and two years of age, with 30% or less of the goats surviving beyond two years of age. In contrast, at Ali Kosh caprine slaughter intensifies only after 18 months, with more than half of the population surviving to an age of between two to three years.

Significantly, however, the Ganj Dareh pattern does not conform to the profile that would result from selective hunting of nursery herds of lactating females and young. Nor does it conform to the profile generated by off-take from a captive herd of females and young. The demographic profile in a faunal assemblage accumulated as the result of hunting a nursery herd would show a strong emphasis on both very young males and females (less than 6 months of age,) as well as on females in prime reproductive ages (Hesse 1978, 304). The “walking larder” scenario involving captive females and young would also likely to show an emphasis on very young animals beginning at less than a year of age, though there could be an emphasis on the selective slaughter of very young males. At Ganj Dareh, however, 80% of the sheep/goat sample survive beyond 12 months of age (Fig. 9). Serious off-take beings only after one year of age, with a strong selective focus on male animals older between one and two years of age and a delay in slaughter of females until after their third or fourth year (or older) (Fig. 8c). This pattern is indicative of a culling strategy consciously directed at promoting herd propagation, the ultimate goal of domestication. It is not consistent with short-term optimization goals aimed at maximizing immediate off-take that are characteristic of hunting strategies.

The measurable goat remains from Jarmo (Fig. 8e) also shows a difference in the harvest profiles of males and females that is consistent with herd management. Here the lack of systematic collection of material from this site, which is likely to have missed unfused bones of both male and female animals, may account for the apparent more prolonged survival of both male and female animals, when compared to either Ganj Dareh or Ali Kosh. Finally, and tellingly, the sex-specific demographic profiles for the gazelle from Ali Kosh (Fig. 8f) produces a distribution pattern similar to that seen in the goats from Shanidar and Asiab. Note the similarity in demographic profiles for male and female animals, the emphasis on older animals, and the greater number of adult males in the sample – all patterns consistent with a hunting strategy that focuses on adult animals, especially males.

Documenting goat domestication in the Zagros

It is clear that the earliest indication of domestic status in goats in the Zagros is to be found in demographic data, not in morphological change. Sex-specific profiles clearly show that the Ganj Dareh goats were managed in a fashion similar to that employed with domestic herds today. And yet there is no evidence of detectable morpho-

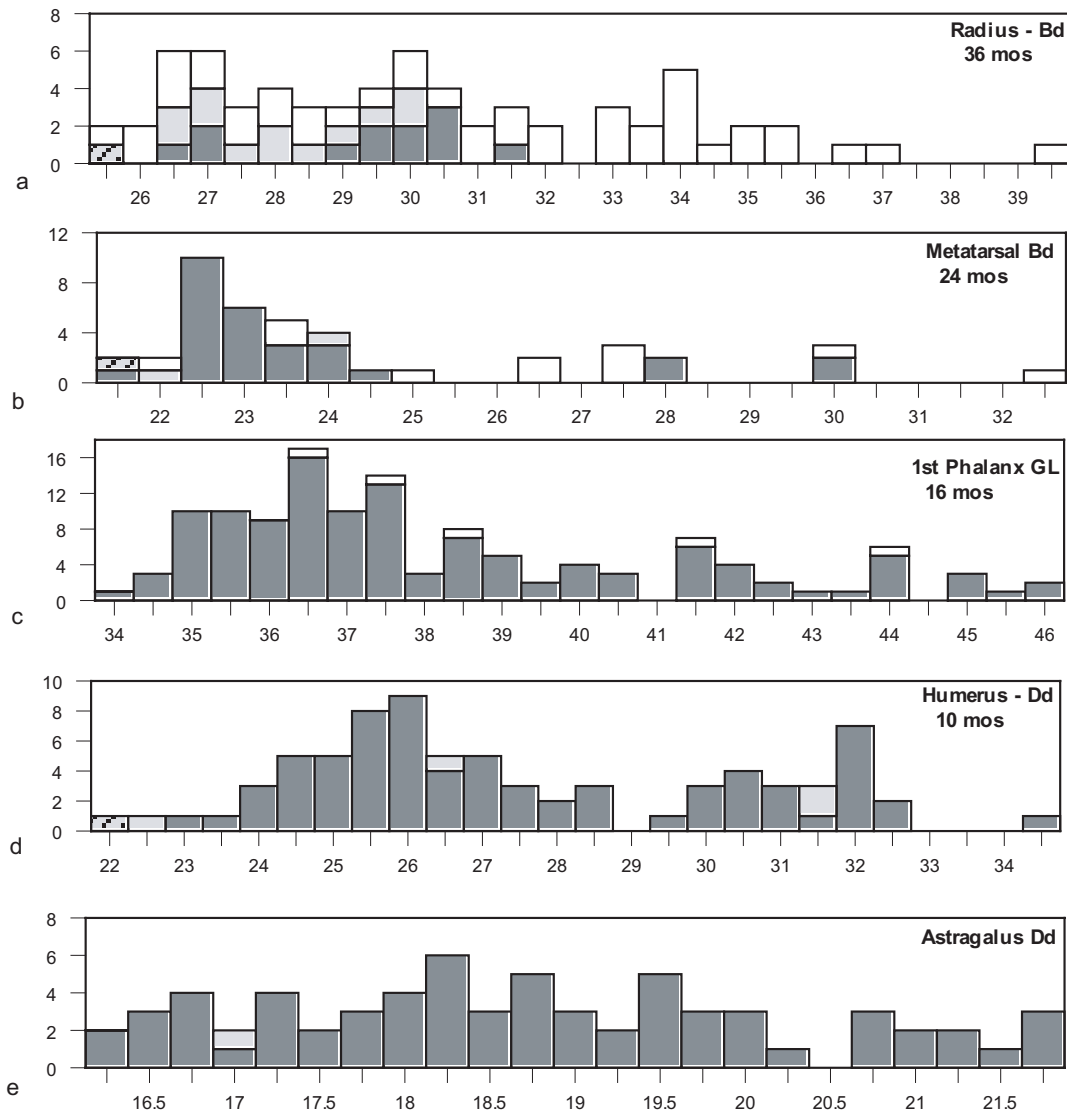


Figure 7. Breadth and depth measurements of goat long bones from Ali Kosh arranged by age at fusion. X axis shows dimension in mm. Y axis shows number of specimens. Dark gray bars are fused specimens. Light gray bars are fusing specimens. White bars are unfused specimens. a. Radius Bd – fusion at 36 months, ($n=183$); b. Metacarpal Bd – fusion at 24 months, ($n=158$); c. First Phalanx GL – fusion at 16 months, ($n=73$); d. Humerus Dd – fusion at 10 months, ($n=264$); e. Astragalus Dd – fused at birth, ($n=314$).

logical change in the Ganj Dareh goats as a result of their management. There are no clear changes in horn morphology in the Ganj Dareh goats similar to those reported by Flannery at Ali Kosh (Hesse 1978, 193–214). Moreover, the apparent reduction in size of the Ganj Dareh goats noted by earlier researchers is clearly the result of a demographic shift in which females dominate among the adult members of a managed herd. Bone assemblages generated by the hunting of a wild population, like those from Shanidar levels C and D and Asiab,

are more likely to be dominated by the bones of large adult males selected by hunters interested in maximizing meat yield. In contrast, the fused and more commonly preserved (and measured) bones of animals harvested from managed herds are dominated by the bones of smaller adult females kept as breeding stock following a herder's harvest strategy aimed at promoting herd propagation. The more friable bones of males harvested at young ages are not as likely to be preserved in as great a quantity, or if they are may not be as easily identified to

Table 3. Proportions of male and female goats in sites from the Zagros.

Site	% Males	% Females	Total NISP Measured Goats
Shanidar C & D	89	11	70
Asiab	78	22	36
Ganj Dareh	37	63	1374
Ali Kosh	26	74	512
Jarmo	33	67	751

species, or measured. Thus when a herded population, like Ganj Dareh, is compared to a hunted one, like Asiab, this demographic difference will make it seem, at a low level of resolution, as if the herded population is composed of smaller animals, lending weight to the erroneous conclusion that size reduction has occurred as a result of domestication.

The observed size difference between hunted and managed populations has also been inadvertently exaggerated by common analytical practices. In particular, the restriction of metric analysis to the fused bones of adult animals and the normalization and homogenization of metric data across the skeleton exacerbates the taphonomic bias for female specimens in an assemblage from a managed herd. The practice of comparing specimens from widely different regions also runs the risk of mistaking regional variation related to environmental variables for size differences resulting from domestication (Uerpmann 1979, and see Zeder 2001, 76–77).

The management of goats morphological indistinguishable from wild populations in the Zagros is, then, first seen in the highland natural habitat of goats, beginning sometime between the occupation of Asiab and Ganj Dareh (between 9500 and 8900 BP uncalibrated, 10,500–9900 BP calibrated). The Ali Kosh goats likely represent the movement of managed herds out of this natural habitat zone, perhaps as much 500 years after the occupation of Ganj Dareh, and into more marginal regions. Moving into the arid lowland plain was a dramatic break with the wild goat populations and their natural habitat, and it likely required some adjustment in management strategies. The more conservative harvest profile seen at Ali Kosh, which allows for somewhat more prolonged survivorship of young male and adult females, may be a response to the loss of easy access to wild animals for restocking managed herds. More complete genetic isolation from wild populations and the impact of new selective pressures imposed by tighter human control of breeding are signaled by the changes in horn morphology evident in later phases of occupation at Ali Kosh, and, possibly, by the smaller size of these animals. However, it is also possible that the founder population of the Ali Kosh goats was made up of smaller bodied wild animals located in more southern reaches of the natural habitat of wild goats.

Certainly by about 8000 years ago, based on assemblages from Ceramic Neolithic age sites, domestic goats in highland Iran were clearly reduced in body size compared to the managed goats from Ganj Dareh. However, the precise cause of this reduction in body size is not clear. It is possible that both the goats from Aceramic levels at Ali Kosh and the upland goats from Ceramic Neolithic sites have experienced size reduction as a result of domestication. This means that changes in horn morphology and overall body size reduction are delayed by as much as 500 to 1000 years after clear indications of herd management are first seen, and occur only after managed goats are moved out of their natural habitat breaking the genetic link to wild goats.

Alternatively, the reduction in body size in highland goat herds after 8000 BP could also signal the introduction and intermingling of smaller bodied goats with the original upland managed populations. The Ceramic Neolithic is not only marked by the introduction of ceramics into the Zagros. There is also a profound shift in faunal assemblages in the Zagros (Table 4, Zeder in press a). While goats dominate in the earlier aceramic assemblages from Ganj Dareh and Ali Kosh, there is a marked increase in the proportion of sheep in faunal assemblages from Zagros sites at all elevations after about 8000 BP uncalibrated. Samples are still too small to determine whether these sheep are wild or domestic, but given the appearance of domestic sheep in faunal assemblages from the southern Levant in the western arc of the Fertile Crescent (Horwitz and Ducos 1998), it is quite possible that these animals represent the movement of domestic sheep into the Zagros from the likely original hearth of sheep domestication in the central portion of the Fertile Crescent (see below). Interestingly, the increase in the representation of sheep in these Ceramic Neolithic age assemblages is accompanied by an even more marked increase in the hunting of gazelle at sites at all elevations in the Zagros region (Table 4). Taken together, these developments signal a dramatic restructuring of economy and perhaps cultural affiliation in this area. Certainly patterns of trade traced by exotic objects like obsidian, cowrie shells, turquoise, marble and alabaster, and bitumen throughout the Fertile Crescent (Mellart 1975, Blackman 1984, Bar Yosef and Meadow 1995) suggest that the dawn of the 8th millennium BP saw considerable movement of people, their goods, technology, and likely, their domestic animals.

So even today, it remains difficult to confidently pinpoint the cause of the reduction in size of goats seen at lowland Ali Kosh and at later Ceramic Neolithic age sites in the uplands. Some might interpret the smaller size of these goats as a response to new selective pressures stemming from human management. However, the size of these animals may instead be a reflection of regional variation and migration of managed animals and their human masters. Moreover, the smaller size of wild goats in the region today compared to ancient hunted and

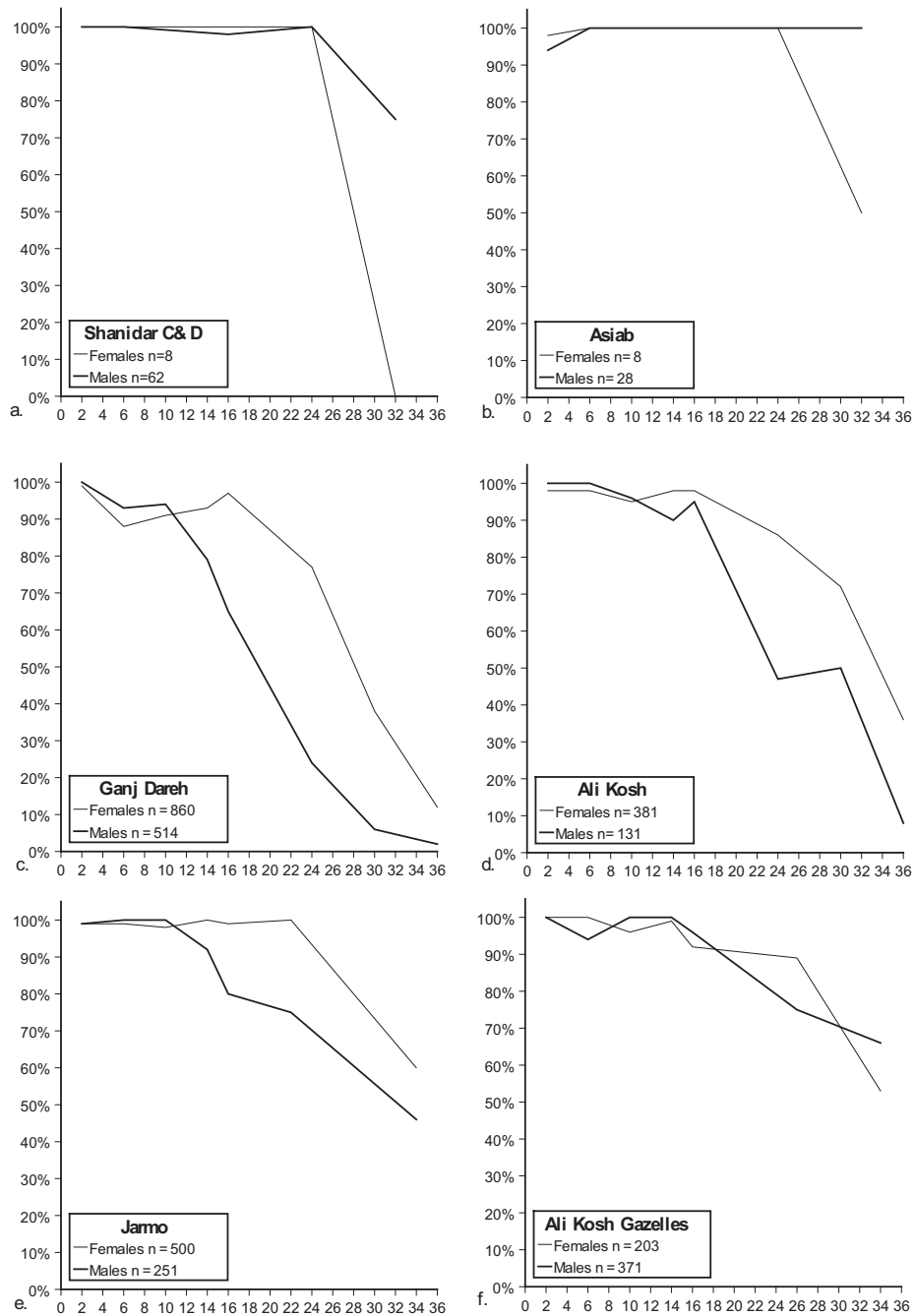


Figure 8. Sex-specific demographic profiles of goats and gazelle from Zagros sites: a. Goats from Shanidar levels C and D, females = 8 specimens, males = 62 specimens; b. Goats from Asiab, females = 8 specimens, males = 28 specimens; c. Goats from Ganj Dareh, females = 860 specimens, males = 514 specimens; d. Goats from Ali Kosh, females = 381 specimens, males = 131 specimens; e. Goats from Jarmo, females = 500 specimens, males = 251 specimens; f. Gazelle from Ali Kosh, females = 203 specimens, males = 371 specimens. X-axis represents age in months. Y-axis represents percentage surviving. Dark lines with diamonds are males. Light gray lines with sunburst symbols are females.

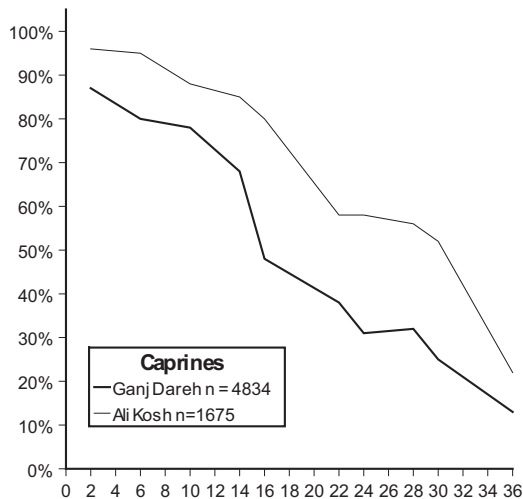


Figure 9. Demographic profile of caprinae from Aceramic Neolithic Sites. X-axis represents age in months; Y-axis represents percentage surviving; Dark lines with and diamond symbols are caprinae from Ganj Dareh ($n=4834$); Light gray lines with sunburst symbols are caprinae from Ali Kosh ($n=1675$).

managed goats, as well as the reduction in modern gazelles compared to their ancient counterparts, indicates that factors entirely unrelated to human management have caused reduction in body size of ungulate species in this region. Clearly there are a variety of factors that have affected the size of domestic and wild animals in the Zagros over time, making it difficult, if not irresponsible, to maintain that size change in early managed goats is a simple and incontrovertible artifact of domestication.

What can be said is that by 10,000 years ago at Ganj Dareh there are clear signs of manipulation of herd demographics of goats in a manner consistent with the goals of controlling herd propagation, the central feature of domestication. Moreover the unmistakable signal of herd management of goats as reflected in sex-specific demographic profiles precedes any evidence of morphological change by at least a half a millennium, and possibly a full 1000 years. This delay in the expression of morphological change in managed animals makes demographic profiling the optimal method for recognizing the initial stages of goat domestication, and likely the domestication of other primary livestock species (e.g., sheep, pigs, and cattle).

It is important to note that the lack of clear evidence of morphological change during the initial phases of herd management does not mean that these animals were genetically identical to wild goats. Unlike plants, selective factors involved in initial domestication of animals are more likely to operate on behavioral characteristics than on morphological traits. In particular, animal domestication likely involves selection for less aggressive, more tractable individuals more likely to yield to human control

over their movement and breeding. The presence of hoof impressions in the mud-bricks at Ganj Dareh (Hesse 1978, 314) suggests that goats were habituated to humans and human settlements and point to a shift toward more tractable, less wary behaviors in these early managed goats. While there may be a link between morphological characteristics and less aggressive behavior (i.e., reduced cranial capacity, juvenilized snouts, pie-bald pelage, lop ears, see Hemmer 1990), it is still not exactly clear what these morphological markers of reduced aggression are, how rapidly they manifest themselves after the domestic partnership between humans and animals began, or how readily detectable they will be in fragmentary skeletal remains.

Animal Domestication in the Fertile Crescent

The pattern of initial management occurring in the natural habitat of wild progenitors and delayed morphological response may not be unique to the eastern Fertile Crescent, but may instead be repeated with sheep, pigs, cattle, and perhaps more than once with goats in different parts of the broad arc that reaches from the Zagros Mountains in Iran and Iraq to the Jordan Valley of Israel and Jordan. The regional focus of initial sheep domestication seems to lie to the west of the Zagros in the central Fertile Crescent. Evidence from Hallan Çemi (Rosenberg *et al.* 1995), Çayönü (Lawrence 1982, Hongo and Meadow 1998, 2000), and most recently finds at Göbekli Tepe, Nevalı Çori (Peters *et al.* 1999) and sites in the upper reaches of the Euphrates River (Helmer 1992) point to the evolution of increasingly intensive hunting into management and domestication of sheep over a period stretching from about 10,000 to about 8500 BP uncalibrated. Demographic data from central Anatolia at Aşikli Höyük suggest management of morphologically unchanged sheep at about 9000 years ago (Vigne and Buitenhuis 1999). Similarly, age and sex profiles of sheep at the site of Shillourokambos on Cyprus have been interpreted as indicating the management of morphologically unchanged sheep (introduced to the island from somewhere in the northern Levant or coastal Anatolia) at about 9400–9000 BP uncalibrated (Vigne *et al.* 2000). Domestic sheep do not seem to arrive in the southern Levant, in the western arc of the Fertile Crescent, until about 8500–8000 BP (Horwitz and Ducos 1998), about the same time as the proportion of sheep increases in assemblages in the Zagros.

A parallel and roughly contemporary scenario is emerging for pig domestication in oak/pistachio forests of southeastern Anatolia at the apex of the Fertile Crescent. Mounting evidence points to the evolution of increasingly selective hunting of wild boar evolving into swine management over the period of time bracketed by the occupation of Hallan Çemi (Redding and Rosenberg 1998) and the many levels at Çayönü (Hongo and

Table 4. Representation of Sheep and Gazelle in assemblages from the Iranian Zagros based on the reanalysis of caprine and gazelle bones included in this study.

Phase	Site	Date*	Elevation	% Sheep vs Goat	Total NISP Sheep & Goat	% Gazelle vs Caprines	Total NISP Caprines & Gazelle
Aceramic	Ali Kosh	8500–8300 B.P.	200 m	6%	1299	24%	2398
	Guran	8100–8000 B.P.	950 m	15%	87	11%	144
	Ganj Dareh	8900–8800 B.P.	1350 m	7%	3859	0%	7941
Ceramic	Ali Kosh	8100–7100 B.P.	200 m	10%	156	44%	401
	Guran	7800–7000 B.P.	950 m	33%	101	42%	339
	Sarab	8000–7400 B.P.	1300 m	18%	739	25%	1561

* dates in uncalibrated years B.P.

Meadow, 1998, 2000, Ervnyck *et al.* 2001). Clear morphological markers of domestication are not seen until 500 to 1000 years after the first signs of swine management. Once again, the introduction of non-native pig to Cyprus seen in initial levels at Shillourokambos (ca 9400 BP uncalibrated) suggest an early date for pig management probably in either Eastern Anatolia or the Northern Levant (Vigne personal communication). The radiation of pigs throughout the arc of the Fertile Crescent follows a similar, though somewhat delayed, trajectory as that evident for sheep. Domestic pigs appear in the eastern arm of the Fertile Crescent about 7000 BP uncalibrated (Hole *et al.* 1969), and in the western arm at about 7500 BP (Horwitz *et al.* 1999).

A case could perhaps be made for an independent center of goat domestication in the far western arm of the Fertile Crescent in the Jordan Valley. Occuring sometime between 9000–8500 BP uncalibrated, when a long-standing emphasis on gazelle is abruptly replaced by a focus on morphologically unchanged goats (Horwitz *et al.* 1999). Unfortunately, sex-specific demographic profiles have not been computed for goats from this region. In fact, even basic caprine harvest patterns are not widely available for assemblages from the Southern Levant. Horwitz, however, believes that age data from some of these sites is consistent with a local domestication of indigenous wild goats (Horwitz *et al.* 1999, 69, Horwitz, 2003). Traditional morphological markers of domestication are not seen in goat remains from the southern Levant until about 8300–8000 BP uncalibrated.

Genetic data suggest three independent domestication events for goats, at least two of which were likely to have occurred in the Fertile Crescent (Luikart *et al.* 2001, Luikart *et al.* in press). So an independent domestication of goats in the southern Levant is certainly possible. However, it is also possible that the abrupt increase of goats in the Southern Levant at about 8600 BP uncalibrated marks the introduction of managed but morphologically unchanged goats from somewhere else. The first appearance of goats in the assemblage from Abu Hureyra in the northern Levant (most securely dated to about 8600 BP uncalibrated) is accompanied by demographic data that suggest a similar culling strategy to

that detected at Ganj Dareh (Legge 1996, Legge and Rowley-Conwy 2000). Goats dominate in the assemblage from the site after about 8300 BP uncalibrated, reversing a many millennia emphasis on hunted gazelle. Data from Cyprus suggest that morphologically unchanged goats were also being herded along with sheep at about 9400 to 9000 uncalibrated B.P (Vigne and Buitenhuis 1999, Vigne *et al.* 2000). Clearly better reporting of metric and age data, as well as more precise radiocarbon dating of material from across the entire region are needed (perhaps coupled with studies of ancient DNA), to both locate the center or centers of goat domestication in the Fertile Crescent, and to trace the direction and the pace of the subsequent movement of domestic goats throughout the region.

The outlines of the process of cattle domestication are somewhat less clear. Peters *et al.* (1999, 40) suggests a Middle Pre-pottery Neolithic B date for cattle domestication and points to the marshlands and gallery forests of the Middle Euphrates as a likely location for initial stages of cattle domestication. In this volume, Helmer places cattle domestication even earlier, in the Early PPNB, based on evidence from Dja'de. The appearance of morphologically unchanged cattle on Cyprus at about 9400 BP uncalibrated (Vigne and Buitenhuis 1999, Vigne *et al.* 2000), along with morphologically unchanged but possibly managed sheep, goats, and pigs, lends some support for this early date for initial attempts at cattle domestication. There is evidence of significant size reduction in cattle in the Late Pre-Pottery Neolithic and a shift in demographic profiles consistent with herding appearing first in the Middle and Upper Euphrates valley around 8300 B.P uncalibrated (Peters *et al.* 1999). Domestic cattle appear in the eastward and westward arcs of the Fertile Crescent at about the same time as pigs, between around 7500–7000 BP uncalibrated (Hole *et al.* 1969, Horwitz *et al.* 1999). Early claims for a center of cattle domestication at the site of Çatal Höyük in Central Anatolia (Perkins 1969) have been called into question in light of more recent work at the site (Martin and Russell in press), although Central Anatolia remains a possible contender as a site of initial cattle domestication. Recent genetic data point to both the Fertile

Crescent region and Central Anatolia as possible heartland areas for the domestication of taurine cattle (Troy *et al.* 2001, Bradley and Magee in press).

Conclusions

While the specific location and timing of the process varies, the domestication of all four cornerstone domesticates (sheep, goat, pig, and cattle) appears to have involved a process in which intensive exploitation of wild progenitor species evolved into the management of morphologically unchanged animals within their natural habitat. These developments took place within the context of an increasingly sedentary focus on the utilization of cereals, pulses, and nut resources that proliferated throughout the Fertile Crescent at the end of the last Ice Age (Hillman 1996). An emphasis on these newly more bountiful stationary resources, coupled with social forces that brought larger groups of people together into increasingly more sedentary communities (Kuijt 2000), may have resulted in localized pressure on the primary ungulates in the region. In the high valleys of the Zagros Mountains this was goats. In the rolling hills of the central Fertile Crescent and in the oak/pistachio forests of southeastern Anatolia it was sheep and pigs. In the Levant the primary target animal seems to have been gazelle. A corresponding effort to adjust hunting strategies toward to sustainable exploitation of these wild animals may have, in the case of certain behaviorally responsive species like sheep, goats, and pigs, led to herd management and domestication. The climatic shock of the Younger Dryas at about 11,000 years ago, and the subsequent amelioration of climate that marks the beginning of the Holocene, may also have played a role in the adoption of increasingly more “hands-on” strategies in manipulating reproductive cycles of animals with the goal of promoting more security and predictability in supply. Thus it is becoming increasingly clear that long transitional period over which intensive hunting of wild progenitor species gradually evolved into their management is central to the story of animal domestication in the Fertile Crescent. It is also increasingly evident that telling this story requires some fundamental changes in the conceptual approach to the problem of animal domestication and in the research methods used to study it.

Traditional approaches to the problem tend to equate domestication with the genetic isolation of managed herds from wild populations, as marked by morphological change and manifested by size reduction. An alternative and, I would argue, more useful approach unlinks the process of domestication from genetic isolation and subsequent morphological change. Domestication is instead defined as resulting from deliberate and systematic human intervention into the life cycle of a target species in order to control the supply of an desired resource – whether it be meat, fruit, seeds, or fiber. In

plants this involves deliberate planting of harvested seed stock. In animals it involves manipulating herd structure to promote herd propagation. Genetic isolation and related morphological change usually ensue, but these are largely follow-on outcomes of domestication. These follow-on outcomes are likely to happen more quickly in plants than in animals, because of the greater genetic plasticity in plants and their shorter generational cycles. Moreover, the new selective pressures involved in plant domestication are more likely to operate on morphological traits, either those relating to speed of germination (*e.g.*, seed size and coat thickness) or to dispersal mechanisms (*i.e.*, seed attachment). Selective pressures introduced by human management of animals, on the other hand, are more likely to act on behavioral characteristics, like degree of aggression, with subsequent morphological change a more ancillary follow-on result (see Zeder *et al.* in press, Zeder in press c). This proposed conceptual change in defining domestication requires a corresponding shift in methodological approaches for marking its initial appearance.

Archaeozoologists cannot monitor the formative processes involved in animal domestication if they cling to traditional morphological markers. The reexamination of the data on goat domestication from the Zagros, as well as tantalizing hints from other parts of the Fertile Crescent, indicate that morphological changes in early domesticates are more properly viewed as late markers of animal domestication, rather than hallmarks of the initial leading edge transition from hunting to herding. Moreover, the linkage between these observed changes and the causal human behavior patterns involved in process of domestication is not at all clear.

This is particularly true for changes in body size. While there is a marked reduction in the size of goats in upland Ceramic Neolithic age sites, this change is only evident more than 1000 years after incontrovertible evidence of management of morphologically unchanged goats is seen at Ganj Dareh. The smaller Ali Kosh goats might be an artifact of domestication, but Ali Kosh is founded half a millennium after herd management is detected at Ganj Dareh. Moreover, in both instances it is unclear whether the smaller size of these goats is directly attributable to new selective factors introduced by human management of goats, or other factors that select for smaller body size that are entirely unrelated to domestication. Based on analysis of modern goat specimens from the region, the impact of domestication on size seems to be limited to a reduction in the length of male long bones (seldom recovered intact in archaeological assemblages) and a slight reduction in breadth and depth measurements. These changes are consistent with Zohary *et al.* (1998), who maintain that removal of selective pressure for large dominant males in managed herds will result in a reduction of sexual dimorphism in domesticated animals. However, distinguishing such a relatively slight downward shift in the size of managed males within a larger

matrix of much more powerful factors that affect size in ungulates (both wild and domestic) is a daunting prospect. In fact, given the solid empirically grounded, time-depth data on the multiple factors that affect size in ungulate species, clinging to the use of size reduction as a definitive marker of domestication becomes an act of faith rather than scientifically sound methodological practice. Regional variation, demography, and change over time are all major causal factors that must be acknowledged in the consideration of osteometric data.

It is admittedly difficult to sort out the impact of this wide range of variables when confronted with the small number and size of faunal assemblages available for analysis. While metric normalization methods were initially developed to help sharpen the picture of size variation drawn using small samples, it is now clear that these methods do more to obscure patterns of size variability than they do to illuminate them. Comparing a normalized metric profile of goats from a managed herd with one from a wild hunted population, for example, gives the misleading appearance of body size reduction when it really is reflecting a shift in the sex ratio of adult animals. Moreover, a normalized profile of a managed herd that is comprised primarily of early or non-fusing bones, in which male and female animals are more evenly represented (*i.e.*, the astragalus, proximal radius, and distal humerus), would look very different from a profile constructed for the same site using later fusing bones, which are dominated by adult females (*i.e.*, metapodials distal radius, calcaneus). In addition, combining assemblages from within even a relatively small, but environmentally varied, area to obtain temporal benchmark metric profiles risks conflating what is largely environmentally controlled size variation with changes in size related to human management. If normalization of metric data is to be used at all, then it should only be employed with assemblages from the same or nearby, roughly contemporaneous sites from similar environmental contexts. An account of the skeletal elements used to compute the profile must also be provided.

Normalized metric profiles are also often presented without even summary statistics of the raw metric data on which they are based, nor are the standards used in the normalization process easily accessible, rendering them virtually useless for comparison to other data. This is simply bad science. At the very least tabular presentation of summary statistics of raw metric data (sample size, range, mean, standard deviation, coefficient of variation) must accompany presentations of normalized metric data, and the standard used must be either presented or clearly referenced. With today's vastly enhanced means of making data electronically available, the archaeozoological community should be working toward finding ways to enhance accessibility to raw metric data, not obscure it.

Rather than a means of monitoring size variability (which has only a tenuous connection, at best, to the

process of domestication), the real value of osteometric data lies in monitoring demographic shifts in harvesting strategies that mark the leading edge of the transition from hunting to herding. Coupled with refined methods for determining the sequence and age of long bone fusion, osteometric techniques are key in the computation of the sex-specific demographic profiles needed to detect the shift from hunting strategies that maximize off-take to herding strategies that promote propagation of domestic herds. Using these techniques requires measuring all bones, fused, fusing and unfused and it requires that metric data be presented in a manner that highlights rather than obscures demographic patterns.

Larger samples – collected with more rigorous attention to recovery than is commonly the case – are also needed. This should certainly be the goal of ongoing excavations in the Near East. However, as this study has shown, even older curated collections can be used effectively to this end. Here it is important for the archaeozoological community to recognize the need to locate and improve the research potential of the many older collections of animals remains stored in museums and laboratories around the world. Policies of proper curation and open access need to be established.

A shift in regional focus is also needed. Research has tended to center on the foothills and steppe areas where morphological change in early livestock domesticates is first apparent. It now seems that we need to look deeper into the mountain arc that serves as home to most progenitor species in order to find the initial phases of the domestication process.

A comprehensive program of direct AMS dating of specimens is the only way to securely establish the chronological sequence of the course of animal domestication and agricultural origins in the Fertile Crescent. Standard and consistent reporting of dates (especially making it clear if dates reported are BC or BP, calibrated or uncalibrated) is essential.

A co-ordinated effort by archaeologists, archaeozoologists, molecular biologists and biochemists is needed to maximize what can be learned through the application of exciting new tools of DNA and isotope analysis. Developing careful sampling protocols and cooperation among those holding collections is needed to make sure material is available for such study, while also working to minimize the loss of material in the application of destructive sampling techniques.

The last few years have seen important movements in these directions. An effort originating in France aims at coordinating the full range of work focusing on the domestication and diffusion of domestic bovids through the Near East and Europe is such one example. The establishment of the Archaeozoology and Genetics Working Group at the 2002 ICAZ meeting in Durham England is another. The session on animal domestication held at the Durham meetings on which this volume is based, and the follow-on discussions on the need to

develop analytical and collection protocols for the study of animal domestication will also help promote this kind of open exchange of information and the sharing of new perspectives.

The origin of animal domestication has been a key focus of archaeozoological study throughout the history of the discipline. I believe, however, that the most exciting discoveries in this field are still to come. What is needed now is for archaeozoologists to face up to the limitations of embedded methods and mind-sets. We need to “unpack” the process of domestication from its outcomes, and we need to reorient ourselves in terms of where and how we look for evidence of domestication. Realizing the potentials of this new era of investigation will also take a spirit of cooperation and open communication among the growing community of researchers drawn to this complex and richly rewarding topic.

Acknowledgments

This research was supported by funds from the National Museum of Natural History’s Research Initiative Fund and by a Smithsonian Scholarly Studies Grant. Many thanks are owed to Field Museum of Natural History staff in the Departments of Zoology and Geology for facilitating access to skeletal collections of modern and archaeological caprines. This research could not have been completed without the assistance of a number of people including Amy Aisen, Susan Arter, Naomi Cleghorn, Lesley Gregoricka, Margaret Heirs, Heather Lapham, Justin Lev-Tov, Sarah McClure, Coleen McLinn, DOuglas Park, Anastasia Poulos, Scott Rufolo, and Bruce Smith. Bruce Smith also offered many helpful comments on earlier drafts of this paper. Many thanks are owed the editors of this volume for their patience with missed deadlines and their comments which helped sharpen many of the points made in this paper.

Bibliography

- Bar-Yosef, O. and Meadow, R. (1995) The origins of agriculture in the Near East. In D. Price and A.-B. Gebauer (eds) *Last Hunters, First Farmers: New Perspectives on the Transition to Agriculture*, 39–94. School of American Research Advanced Seminar Series. Santa Fe, SAR Press.
- Binford (1971) Post-Pleistocene Adaptations. In S. Struever (ed.) *Prehistoric Agriculture*, 22–49. American Museum Sourcebooks in Anthropology. New York, The Natural History Press.
- Bradley, D. and Magee, D. (in press) Genetics and the origins of domestic cattle. In M. A. Zeder, D. Bradley, E. Emshwiller and B. D. Smith (eds) *Documenting Domestication: New Genetic and Archaeological Paradigms*. Berkeley, CA: University of California Press.
- Bradley, D. and Magee, D. (in press) Cattle. In M.A. Zeder, E. Emshwiller, B.D. Bradley, Smith and D. Decker-Walters (eds) *Documenting Domestication: New Genetic and Archaeological Paradigms*. Washington, D.C., Smithsonian Press.
- Braidwood (1960) The Agricultural Revolution. *Scientific American* 203, 130–48.
- Braidwood, R. J. and Howe, B. (1960) *Prehistoric Investigations in Iraqi Kurdistan*. The Oriental Institute of the University of Chicago Studies in Ancient Oriental Civilization, N°31. Chicago, University of Chicago Press.
- Bökönyi, S. (1969) Archaeological problems and methods of recognizing animal domestication. In P. J. Ucko and G. W. Dimbleby (eds) *Domestication and Exploitation of Plants and Animals*, 219–29. London, Duckworth.
- Bökönyi, S. (1977) *Animal Remains from the Kermanshah Valley, Iran*. BAR Supplementary Series, N°34. Oxford, BAR.
- Driesch, A. von den (1978) *A Guide to the Measurement of Animal Bones from Archaeological Sites*. Peabody Museum Bulletin, N°1. Cambridge, Peabody Museum.
- Evins, M. (1982) The fauna from Shanidar Cave: Mousterian wild goat exploitation in northeastern Iraq. *Paléorient* 8, 47–73.
- Ervynck, A., Dobney, K., Hongo, H., and Meadow, R. (2001) Born free? New evidence for the status of *Sus scrofa* at Neolithic Çayönü. *Paléorient* 27, 47–73.
- Helmer, D. (1989) Le développement de la domestication au Proche-Orient de 9 500 à 7 500 BP: les nouvelles données d’el Kowm et de Ras Shamra. *Paléorient* 15, 111–21.
- Helmer, D. (1992) *La Domestication des animaux par les hommes préhistoriques*. Paris, Masson.
- Hemmer, H. (1990) *Domestication: The Decline of Environmental Appreciation*. Cambridge, Cambridge University Press.
- Hesse, B. (1978) *Evidence for Husbandry from the Early Neolithic Sites of Ganj Dareh in Western Iran*. PhD Dissertation, Columbia University, Ann Arbor, University Microfilms.
- Hesse, B. (1982) Slaughter patterns and domestication: the beginnings of pastoralism in western Iran. *Man* 17, 403–17.
- Hesse, B. (1984) These are our goats: the origins of herding in West Central Iran. In J. Clutton-Brock and C. Grigson (eds) *Animals and Archaeology: 3. Early Herders and their Flocks*, 243–64. BAR International Series 202. Oxford, BAR.
- Hillman, G. C. (1996) Late Pleistocene changes in wild plant-food available to hunter-gatherers of the northern Fertile Crescent: possible preludes to cereal cultivation. In D.R. Harris (ed.) *The Origins and Spread of Agriculture and Pastoralism in Eurasia*, 159–203. Washington, Smithsonian Institution Press.
- Hole, F. (1987) Chronologies in the Iranian Neolithic. In O. Aurenche, J. Evin, and F. Hours (eds) *Chronologies in the Near East*, 353–79. BAR International Series 379. Oxford, BAR.
- Hole, F. and Flannery, K.V. (1967) The Prehistory of Southwestern Iran: A Preliminary Report. *Proceedings of the Prehistoric Society* 33, 147–206.
- Hole, F., Flannery, K.V. and Neely, J.A. (1969) *Prehistory and Human Ecology on the Deh Luran Plain*. Memoirs of the Museum of Anthropology, N°1. Ann Arbor, The University of Michigan Press.
- Hongo, H. and Meadow, R. (1998) Pig exploitation at Neolithic Çayönü Tepesi (southeastern Anatolia). In S. Nelson (ed.) *Ancestors for the Pigs: Pigs in Prehistory*, 77–98. MASCA Research Papers in Science and Archaeology, vol. 15. Philadelphia, Museum Applied Science Center in Archaeology, University of Pennsylvania Museum of Archaeology and Anthropology.
- Hongo, H. and Meadow, R. (2000) Faunal remains from prepottery Neolithic levels at Çayönü, Southeastern Turkey: a preliminary report focusing on pigs (*Sus* sp.). in M. Mashkour, A.M. Choyke, H. Buitenhuis and F. Poplin (eds) *Archaeozoology of the Near East, IVA.*, 121–40. ARC Publication N°32. Groningen, ARC.
- Horwitz, L. (2003) Temporal and spatial variation in Neolithic caprine exploitation strategies: a case study of fauna from the site of Yiftah’el (Israel). *Paléorient* 29, 19–58.
- Horwitz, L. K. and Ducos, P. (1998) An investigation into the origins of domestic sheep in the southern Levant. In H. Buitenhuis, L. Bartosiewicz, and A.M. Choyke (eds) *Archaeozoology of the Near East, III.*, 80–95. ARC Publications N°18. Groningen, ARC.

- Horwitz, L. K., Tchernov, E., Ducos, P., Becker, C., von den Driesch, A., Martin, L., and Garrard, A. (1999) Animal domestication in the southern Levant. *Paléorient* 25, 63–80.
- Jarman M. R. and P. F. Wilkinson. (1972) Criteria for animal domestication. In E.S. Higgs (ed.) *Papers in Economic Prehistory*, 83–93. Cambridge, Cambridge University Press.
- Kuijt, I. (2000) *Life in Neolithic Farming Communities: Social Organization, Identity, and Differentiation*. New York, Kluwer Academic/Plenum Press.
- Lawrence, B. (1982) The principal food animals at Çayönü. In L.S. Braidwood and R.J. Braidwood (eds) *Prehistoric Village Archaeology in South-Eastern Turkey*, 175–99. BAR International Series N°138. Oxford, BAR.
- Legge, A. (1996) The beginning of caprine domestication in south-west Asia. In Harris, D. R. (ed.) *The Origins and Spread of Agriculture and Pastoralism in Eurasia*, 238–63. Washington, Smithsonian Institution Press.
- Legge, A. J. and Rowley-Conwy, P. A. (2000) The exploitation of animals. In A. M. T. Moore, G. C. Hillman and A. J. Legge (eds) *Village on the Euphrates: From Foraging to Farming at Abu, 423–74*. Hureyra. Oxford, Oxford University Press.
- Luikart, G., Ludovic, G., Excoffier, L., Vigne, J.-D., Bouvet, J., and Taberlet, P. (2001) Multiple maternal origins and weak phylogeographic structure in domestic goats. *Proceedings of the National Academy of Sciences* 98, 5927–5932.
- Luikart, G., Fernandez, H., Mashkour, M., England, P. R. and Taberlet, P. (in press) Origins and diffusion of domestic goats inferred from DNA markers: example analyses of mtDNA, Y-chromosome and microsatellites. In M. A. Zeder, D. Bradley, E. Emshwiller and B. D. Smith (eds) *Documenting Domestication: New Genetic and Archaeological Paradigms*. Berkeley, CA: University of California Press.
- Martin, L. and Russell, N. (in press) The Çatalhöyük faunal remains. In I. Hodder (ed.) *Çatalhöyük 1995–1999: Subsistence and Ecology*. McDonald Institute Monographs. Cambridge, McDonald Institute for Archaeological Research.
- Meadow, R. (1989) Osteological evidence for the process of animal domestication. In J. Clutton-Brock (ed.) *The Walking Larder: Patterns of Domestication, Pastoralism, and Predation*, 80–90. London, Unwin Hyman.
- Meadow, R. (1999) The use of size index scaling techniques for research on archaeozoological collections from the Middle East. In C. Becker, H. Manhart, J. Peters and J. Schibler (eds.) *Historia Animalium ex Ossibus, Festschrift für Angela von den Driesch. Beiträge zur Paläoanatomie, Archäologie, Ägyptologie, Ethnologie und Geschichte der Tiermedizin*, 285–300. Rahden/Westf., Verlag Maire leidorf GmbH.
- Mellart, J. (1975) *The Neolithic of the Near East*. New York, Charles Scribner's and Sons.
- Perkins, D. (1964) Prehistoric fauna from Shanidar, Iraq. *Science* 144, 1565–66.
- Perkins, D. J. (1969) Fauna of Çatal Hüyük: Evidence for early cattle domestication in Anatolia. *Science* 164, 177–8.
- Peters, J., Helmer, D., von den Driesch, A., and Segui, S. (1999) Animal husbandry in the northern Levant. *Paléorient* 25, 27–48.
- Redding, R.W. and Rosenberg, M. (1998) Ancestral pigs: a New (Guinea) model for pig domestication in the Middle East. In S. Nelson (ed.) *Ancestors for the Pigs: Pigs in Prehistory*, 65–76. MASCA Research Papers in Science and Archaeology, vol. 15. Philadelphia, Museum Applied Science Center in Archaeology, University of Pennsylvania Museum of Archaeology and Anthropology.
- Reed, C. A. (1959) Animal Domestication in the Prehistoric Near East. *Science* 130, 1629–1639.
- Reed, C. A. (1960) A Review of the osteological evidence on animal domestication in the prehistoric Near East. In R.J. Braidwood and B. Howe (eds) *Prehistoric Investigations in Iraqi Kurdistan*, 119–145. The Oriental Institute of the University of Chicago Studies in Ancient Oriental Civilization, N°31. Chicago, University of Chicago Press.
- Reed, C. A. (1983) Archaeozoological studies in the Near East: a short history (1960–1980). In L. Braidwood, R.J., Braidwood, B. Howe, C. A. Reed and P. J. Watson (eds) *Prehistoric Archaeology*, J.-D., Carrère, I., Saliège, J.-F., Person, A., Bocherens, H., Guilaine, J., and Briois, F. (2000) Predomestic cattle, sheep, goat, and pig during the late 9th and the 8th millennium cal. BC on Cyprus: preliminary results of Shillourokambos (Parekklisha, Limassol). In M. Mashkour, A.M. Choyke, H. Buitenhuis, and F. Poplin (eds) *Archaeozoology of the Near East, IVA.*, 83–106. ARC Publication N°32. Groningen, ARC.
- Zeder M. A. (1999) Animal domestication in the Zagros: a review of past and current research. *Paléorient* 25, 11–25.
- Zeder M. A. (2001) A metrical analysis of a collection of modern goats (*Capra hircus aegargus* and *Capra hircus hircus*) from Iran and Iraq: implications for the study of caprine domestication. *Journal of Archaeological Science* 28, 61–79.
- Zeder M. A. (2003) Hiding in plain sight: the value of museum collections in the study of the origins of animal domestication. In G. Grupe and J. Peters (eds), *Documenta Archaeobiologiae I: Deciphering Ancient Bones. The Research Potential of Bioarchaeological Collections, Yearbook of the State Collection of Palaeoanatomy. München, Germany*, 125–138. Rahden/Westf.: Verlag M. Leidorf GmbH.
- Zeder M. A. (in press a.) A critical examination of markers of initial domestication in goats (*Capra hircus*). In M. A. Zeder, D. Bradley, E. Emshwiller and B. D. Smith (eds) *Documenting Domestication: New Genetic and Archaeological Paradigms*. Berkeley, CA: University of California Press.
- Zeder M. A. (in press b.) Reconciling rates of long bone fusion and tooth eruption and wear in sheep (*Ovis*) and goat (*Capra*). In D. Ruscillo (ed.), *Ageing and Sexing Animals from Archaeological Sites*. Oxford, Oxbow Press.
- Zeder M. A. and Hesse B. (2000) The Initial Domestication of Goats (*Capra hircus*) in the Zagros Mountains 10,000 Years Ago. *Science* 287, 2254–2257
- Zeder, M. A. (in press c) Archaeological Approaches to Documenting Animal Domestication. In M. A. Zeder, D. Bradley, E. Emshwiller and B. D. Smith (eds) *Documenting Domestication: New Genetic and Archaeological Paradigms*. Berkeley, CA: University of California Press.
- Zeder, M. A., Bradley, D., Emshwiller, E. and Smith, B. D. (in press) Documenting domestication: bringing together plants, animals, archaeology and genetics. In M. A. Zeder, D. Bradley, Emshwiller and B. D. Smith (eds) *Documenting Domestication: New Genetic and Archaeological Paradigms*. Berkeley, CA: University of California Press.
- Zeder, M. A. and Lapham, H. A. (in prep.) Morphological criteria for distinguishing between the bones of sheep (*Ovis aries*) and goats (*Capra hircus*).
- Zohary, D., Tchernov, E., and Horwitz, L. K. (1998) The role of unconscious selection in the domestication of sheep and goats. *Journal of Zoology* 245, 129–135.

Melinda A. Zeder

Old World Archaeology and Zooarchaeology

Department of Anthropology

MRC 112

National Museum of Natural History

Smithsonian Institution

PO Box 37102

Washington D.C. 20013–7012

U.S.A.

E-mail: zeder.melinda@nsmnh.si.edu.