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TOME I

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ANIMAL DOMESTICATION IN THE ZAGROS: AN UPDATE AND DIRECTIONS FOR FUTURE RESEARCH

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ABSTRACT

Early research on the origins of agriculture focused on the highland valleys and piedmont flanks of the Zagros Mountains as the likely heartland of both plant and animal domestication. This research demonstrated that animals were domesticated at least as early as plants in the Zagros, perhaps slightly earlier, and that both of these developments arose in the context of semi-sedentary communities centered on the intensive utilization of the wild plants and animals. After the late 1970s, the geographic focus of origins of agricultural research in the Near East shifted to the Southern and Northern Levant in western arm of the Fertile Crescent, where plant domestication seems to have preceded animal domestication by at least 1000 years. Most recent considerations of Near Eastern plant and animal domestication and agricultural origins, if they mention the Zagros at all, portray the region as a backwater sitting on the sidelines of the primary developments that drove the emergence of farming and herding. Recent research on curated collections of animal remains recovered in early excavations from Zagros sites is providing a much more detailed picture of the course, context, and causes of animal domestication in this region. This research has also resulted in a reconsideration of methods used to detect animal domestication in archaeological assemblages. In particular, this work calls into question the efficacy of body size reduction as a marker of initial animal domestication, while new techniques for reconstructing the age and sex of harvest populations show considerable promise for tracing the transition from hunting to herding. Using these techniques it is possible to detect shifting hunting strategies that foreshadow animal management at about 12,000 cal.ender years ago in the recently reanalyzed sheep assemblage from Zawi Chemi Shanidar. Morphologically unaltered but clearly managed goats are first seen at the site of Ganj Dareh in the central Zagros at about 10,000 years ago, moving into lowland areas outside the natural habitat of wild goats about 500 years later. Domesticated sheep do not arrive in the region until about 9,000 calendar years ago. It is hypothesized that initial domestication of sheep and goats occurred at about 11,000-10,500 years ago in the Eastern Taurus/Northwestern Zagros region within the context of sedentary communities that were also in the process of domesticating wild cereals and pulses. While herded goats spread quite quickly throughout the Fertile Crescent following initial domestication, the movement of domesticated sheep into both its eastern and western arms was quite delayed. This work points the way for future research, especially in the Central and Eastern Fertile Crescent, which will almost certainly reclaim this region's central position in the unfolding story of Near Eastern agricultural origins.

Keywords: Domestication, caprines, Zagros, demographic profiling, size reduction.

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RÉSUMÉ

Les premières recherches sur les origines de l'agriculture s'étaient concentrées sur les hautes vallées montagneuses et les piémonts des massifs du Zagros considérés comme le foyer probable de la domestication à la fois des plantes et des animaux. Ces recherches avaient démontré que, dans le Zagros, les animaux avaient été domestiqués au moins aussi tôt que les plantes, peut-être même légèrement plus tôt et que chacun de ces développements avait surgi dans un contexte de communautés semi-sédentaires centrées sur l'exploitation intensive des plantes et des animaux sauvages. Après la fin des années soixante-dix, la focalisation géographique de la recherche sur les origines de l'agriculture au Proche-Orient se déplaça vers le sud et le nord du Levant dans la branche occidentale du Croissant fertile, où la domestication des plantes semblait avoir précédé la domestication des animaux d'au moins 1000 ans. La plupart des considérations récentes sur la domestication des plantes et des animaux et sur l'origine de l'agriculture, si jamais elles mentionnent le Zagros, décrivent la région comme un trou perdu se trouvant à côté des premiers développements qui ont conduit à l'émergence de l'agriculture et de l'élevage. L'analyse récente des collections conservées de vestiges de faune récoltés lors des premières fouilles des sites du Zagros donne une vision bien plus détaillée du développement, du contexte et des causes de la domestication des animaux dans cette région. Cette recherche est le résultat d'une reconsidération des méthodes utilisées pour détecter la domestication animale dans un échantillon archéologique. En particulier, ce travail remet en question l'efficacité de la réduction de la taille comme marqueur des débuts de la domestication animale, alors que de nouvelles techniques de restitution de l'âge et du sexe des populations chassées offrent de sérieuses promesses pour retracer la transition entre chasse et élevage. En utilisant ces techniques, d'après l'échantillon de moutons récemment analysé de Zawi Chemi Shanidar, il est possible de détecter des changements dans les stratégies de chasse qui préfigurent le management des animaux il y a 12 000 ans. Des chèvres morphologiquement inchangées mais clairement contrôlées s'observent en premier sur le site de Ganj Dareh dans les monts du Zagros, il y a environ 10 000 ans ; elles quittent l'habitat naturel des chèvres sauvages pour les plaines près de 500 ans plus tard. Les moutons domestiques n'arrivent pas dans la région avant 9000 ans. On présume que la domestication initiale des moutons et des chèvres s'est produite, il y a environ 11 000-10 500 ans, dans la région du Taurus oriental et du Nord-Ouest du Zagros dans un contexte de communautés sédentaires qui étaient également en train de domestiquer les céréales sauvages et les légumineuses. Alors que les chèvres domestiques se répandent assez rapidement à travers le Croissant fertile à la suite de leur domestication initiale, le mouvement des moutons domestiques a été relativement tardif dans ses zones est et ouest. Ce travail montre des directions de recherche pour l'avenir, en particulier dans le Croissant fertile central et oriental, qui va probablement récupérer une position régionale capitale dans l'histoire en continué développement des origines proche-orientales de l'agriculture.

Mots-clés : Domestication, caprinés, Zagros, profils démographiques, réduction de taille.

INTRODUCTION

Early research on the origins of agriculture focused on the highland valleys and piedmont flanks of the Zagros Mountains as the likely heartland of both plant and animal domestication (fig 1; Braidwood, Howe 1960; Braidwood *et al.* 1983). A number of different archaeological projects were conducted in western Iran and northeastern Iraq during the 1950s, 60s, and 70s, which, together, provided a basic outline of human pre-history in this region from the Middle Paleolithic up through the Ceramic Neolithic—a period that encompasses the transition from hunting and gathering to farming and herding (Solecki R.S. 1965; Hole, Flannery 1967; Hole *et al.* 1969; Smith 1972; Mortensen 1975; Solecki R.L. 1981). These were the first interdisciplinary archaeological projects to include zoologists who pioneered now standard techniques for identifying domesticates among archaeological animal remains (Perkins 1964; Hole *et al.* 1969; Hesse 1978; Reed 1983). These early researchers demonstrated that animals were domesticated at least as early as plants in the Zagros, perhaps slightly earlier, and that both of these developments arose in the context of semi-sedentary communities centered on the intensive utilization of the wild plants and animals (see Hole 1996).

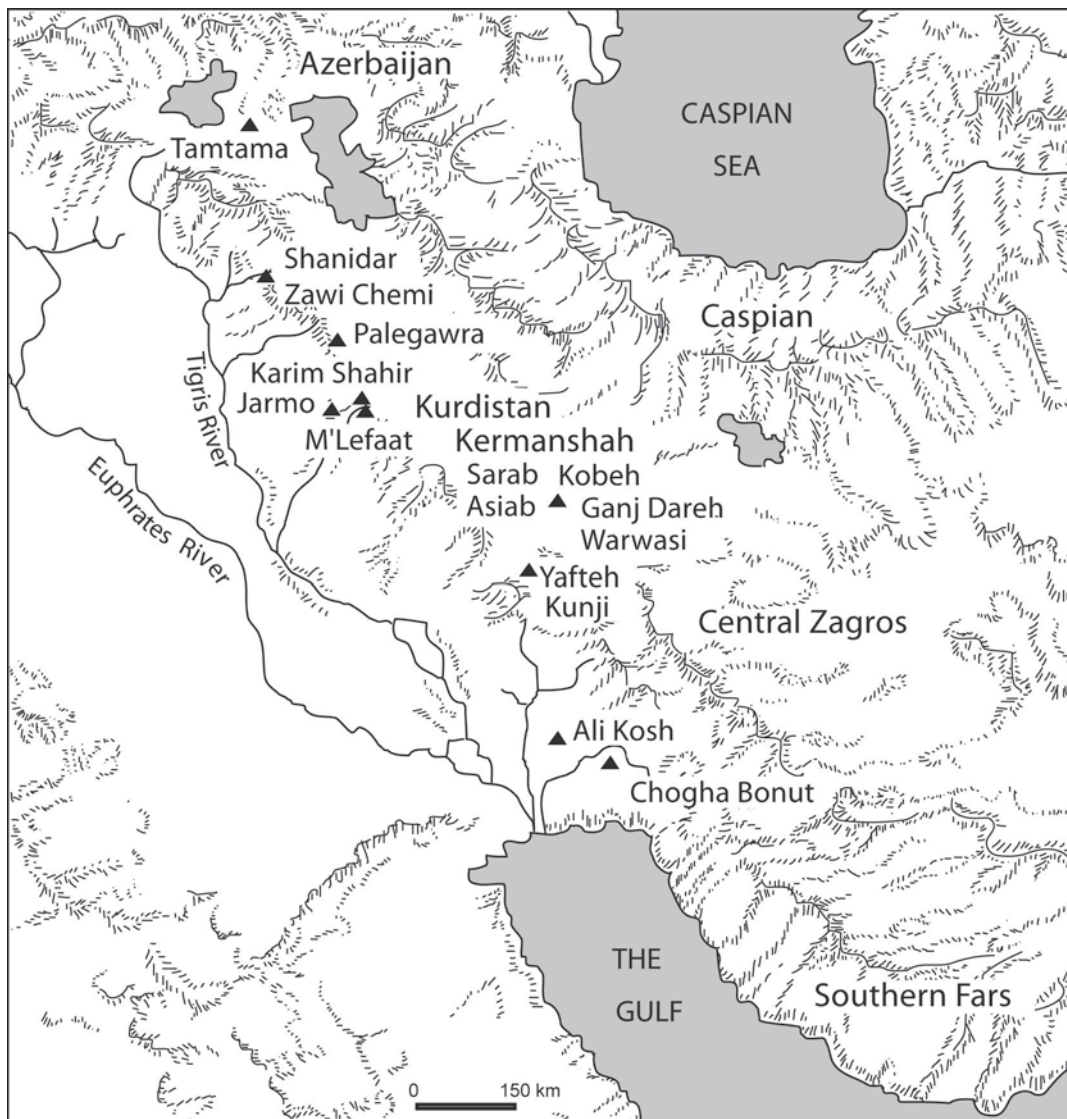


Fig. 1—Map of Iran and Iraq showing locations of modern and archaeological samples.

After the late 1970s, the geographic focus of origins of agricultural research in the Near East shifted to the Southern and Northern Levant in western arm of the Fertile Crescent. Plant domestication seems to have occurred here at least 1000 years earlier than in the Zagros (Bar Yosef, Meadow 1995). In contrast, animal domestication in the Levant seems to have been a much delayed and somewhat subsidiary development, with domestic animals first seen in the Levant more than 1000 years after initial plant domestication. There is still no consensus on where initial animal domestication took place. Various researchers have argued for both the Southern and Northern Levant, and more recently Southeastern Anatolia, as likely heartlands for the domestication of different livestock species (Legge 1996; Bar-Yosef 2000; Horwitz 2003; Peters *et al.* 2005). Most of recent considerations of Near Eastern plant and animal domestication and agricultural origins, if they mention the Zagros at all, portray the region as a backwater sitting on the sidelines of the primary developments that drove the emergence of farming and herding.

My own research over the last decade has returned to the Zagros and to the assemblages of animal remains recovered in early excavations there (Zeder 1999, 2001, 2003, 2005, 2006a; Zeder, Hesse 2000). This work brings new advances in documenting animal domestication to bear on these important assemblages in order to provide a much more detailed picture of the course, context, and causes of animal domestication in this region. While this work is still in progress, it has resulted in a number of new insights into the domestication of two primary livestock species—sheep and goats. In particular, my work has helped clarify the timing and the location of the initial appearance of both domestic sheep and goats in the Zagros. It has also resulted in a reconsideration, and refinement, of the methods used to detect animal domesticates in the archaeological record. This work points the way for future research, especially for future research in the Eastern Fertile Crescent that will almost certainly reclaim this region's central position in the unfolding story of Near Eastern agricultural origins.

PREVIOUS RESEARCH ON ANIMAL DOMESTICATION IN THE ZAGROS

Pioneering archaeozoologists working in Iran and Iraq in the mid-20th century developed essentially all the primary methods used today to trace the transition from hunting to herding. Markers of animal domestication employed by these researchers included changes in horn morphology, shifts in the age and sex of harvested animals, changes in species abundance, and reconstructions of the zoogeography of wild progenitor species. Early on Charles Reed (1959, 1961) found goat horn cores at the highland Iraqi village site of Jarmo that showed characteristic features of domestication (a pronounced medial flattening and reduction in size). At Epipaleolithic Zawi Chemi Shanidar Dexter Perkins (1964) used species abundance (a sharp increase in the representation of sheep), zoogeography (a proposed lack of suitable environmental conditions for sheep), and harvest profiles (an emphasis on young animals) to build an argument for sheep domestication at least 2000 years earlier than at Jarmo. Sandor Bökönyi (1977) pointed to more subtle changes in horn morphology and harvest strategies (in this case an emphasis on adult males) to make a case for an early phase of caprine domestication at the site of Asiab in the Kermanshah valley. At Ali Kosh, on the Deh Luran Plain, Kent Flannery (Hole *et al.* 1969) combined horn morphology (progressive changes in goat horn core size and shape and the presence of a hornless female sheep), species abundance and zoogeography (a high proportion of goats in a region outside the natural habitat for wild goats), and herd structure (an emphasis on young animals) to argue for initial sheep and goat domestication at this lowland site. A decade later Brian Hesse (1978, 1982, 1984) used both metric and demographic data to construct goat harvest profiles at the highland site of Ganj Dareh that showed an emphasis on harvesting young males and delayed female culling, patterns characteristic of management strategies used by sheep and goat herders today.

It was clear from this work that the Zagros saw the transition from hunting to herding caprines. However, it was less clear precisely when and where this transition took place. Radiocarbon dating was at its infancy when these sites were excavated and there was considerable confusion over the chronological placement of Zagros sites across this transition (see Hole 1987). For example, although signs of early goat domestication were seen at both highland Ganj Dareh and lowland Ali Kosh, available radiocarbon dates made it impossible to sort out which of these sites which was home to initial goat domestication. Very different developmental scenarios were needed to explain initial goat domestication in either highland Iran (within the natural habitat for wild goats) (Braidwood 1960) or in lowland Iran (well outside this natural habitat zone) (Hole, Flannery 1967; Binford 1971). During this early stage in the development of archaeozoology, there was also little agreement about the relative strengths of various methods for documenting domestication, nor was there any standardization in how these methods were applied. This made it difficult to evaluate and compare the different claims for early animal domestication made by different analysts.

In the late 1970s, Hans-Peter Uerpmann (1978, 1979) introduced a new method for documenting animal domestication. This method is based on the premise that newly domesticated animals experienced

a profound and essentially instantaneous reduction in body size that can be detected through the metrical analysis of archaeological animal bones. To compensate for the often small size of faunal assemblages from early sites, Uerpmann developed a method for normalizing metric data that allowed for the combination of measurements from different skeletal elements into a single size index. Applying this method to a wide range of curated collections from across the Fertile Crescent, including the Zagros sites, Uerpmann found indications of a shift in the size of sheep and goat bones that he attributed to domestication induced body size reduction. This osteometric technique (and related variants) has been widely adopted over the past 30 years. In fact, size reduction has become the primary analytical marker used to document animal domestication in all major livestock species (*e.g.* Meadow 1984; Helmer 1992; Legge 1996; Peters *et al.* 1999; Peters *et al.* 2005). Other methods, especially demographic profiling, have generally been treated as less reliable, secondary means of documenting animal domestication (Meadow 1989; Bar-Yosef, Meadow 1995; Peters *et al.* 2005).

RECENT WORK ON ANIMAL DOMESTICATION IN THE ZAGROS

My own work on animal domestication in the Zagros began when I noticed that the Baradostian age assemblage from Yafteh Cave, curated by the Smithsonian, contained not only the bones of very large sheep and goats that analysts using Uerpmann's technique would classify as wild animals, but also the bones of much smaller caprines that seemed quite similar in size to the domestic sheep and goats in the Bronze Age assemblages on which I was working at the time. Comparing these remains with those from the site of Ganj Dareh, also curated by the Smithsonian, I found a similar pattern of both large and small caprines. Although dubious of Hesse's demographic arguments, Uerpmann, and subsequent researchers, accepted the domestication status of the Ganj Dareh goats on the basis of apparent body size reduction (Uerpmann 1979; Helmer 1992; Bar Yosef, Meadow 1995; Legge 1996). And yet, when I compared Ganj Dareh goat bones to the bones of the much older Yafteh Cave goats, there was no clear evidence for reduction in the size of either the larger or the smaller goats from this site. The major difference between the goat remains from these two sites lay not in the size of the animals consumed there, but rather in the age of the animals consumed. The majority of the Yafteh goats were adult animals with fully fused bones, while the Ganj Dareh assemblage contained a large quantity of unfused bones of juvenile animals.

I decided it would be useful to reexamine the entire corpus of sheep and goat remains recovered from early excavations in the Zagros to look for markers of animal domestication in assemblages that spanned the period from the Middle Paleolithic through the Ceramic Neolithic (*ca* 50,000 BP to 7,000 BP)—a period which had already been demonstrated to include the transition from hunting to herding. In particular, I wanted to evaluate the efficacy of both body size reduction and demographic profiling in detecting initial domestication in sheep and goats. I also wanted to apply new methods for small volume AMS direct dating to these bones to help clarify the chronology of sites in the Zagros. The ultimate goal of the project was to reassess the transition from hunting to herding in the Zagros using improved methods for both detecting and dating animal domestication.

Modern Caprines from the Zagros

This on-going study also involves the analysis of a large corpus of modern sheep and goat skeletons from Iran and Iraq curated by the Field Museum of Natural History (FMNH) (Zeder 2001). This collection includes the remains of both wild and domestic sheep (61 individuals) and goats (41 individuals) from the region. The assemblage has a balanced representation of both males and females of various ages. It also represents a broad geographic area that stretches from the shores of the Caspian, through Azerbaijan, Iraqi Kurdistan, Kermanshah, the Central Zagros, and down to the Southern Zagros terminus at the Persian Gulf (*fig. 1*). This modern assemblage, then, offered a unique opportunity to directly assess the impact of factors

like age, sex, environment, and domestic status on the size of Zagros sheep and goats. Remarkably, my study of this modern collection represents the first empirical test of basic assumptions about the impact of these factors on body size in sheep and goat. This large collection also provided critical empirical data needed to improve the resolution of aging techniques (Zeder 2006b) and to refine methods for distinguishing between the bones of sheep and goats (Zeder, Lapham in preparation).

My analysis of the FMNH caprines study has shown that the single-most important factor affecting body size in both sheep and goats is sex, not domestic status. Although slightly less pronounced in sheep than in goats, in both species there is a clear and uniform separation between male and female animals in all measured dimensions (fig. 2, appendix 1-4). Environment plays the second-most important role in determining body size, with steady body size diminution in sheep and goats (both wild and domestic)

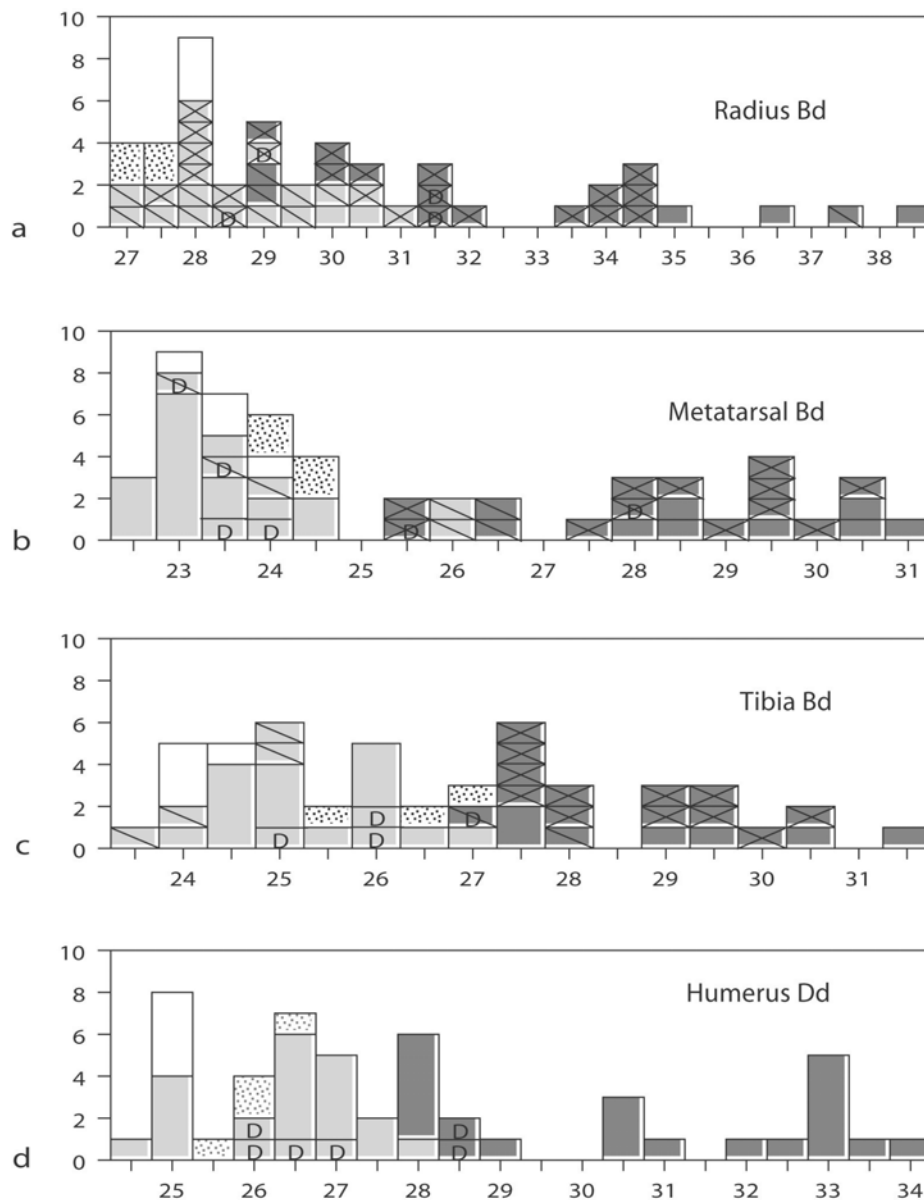


Fig. 2—Modern goat breadth and depth measurements of selected long bones. X axis shows dimension in mm. Y axis shows number of specimens. Dark gray shaded bars are males older than one year of age. Stippled bars are males one year of age or younger. Light gray shaded bars are females older than one year of age. White bars are females one year of age or younger. 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).

along a north to south gradient of increasing temperature and aridity (*fig. 3a-c, appendix 1-4*). Age plays a relatively small role in the size of the bones of these animals, especially in breadth and depth dimensions (*fig. 2*). After about one year of age, even the unfused bones of juvenile male sheep and goats are absolutely larger than those of fully fused adult females (*appendix 1-4*). Domestic status has the least impact on body size in these modern caprines. Among both female sheep goats, for example, the length, breadth, and depth measurements of the bones of domestic and wild animals are indistinguishable from one another (*fig. 2, appendix 1, 3*). The lengths of the bones of male domestic goats, on the other hand, are considerably shorter than wild males (Zeder 2005, p. 129). However, breadth and depth measurements of the bones of domestic males (which make up the vast majority of archaeological metric data) fall within the range of wild male bones (albeit within the range of smaller wild males) and are larger than both wild and domestic female breadth and depth measurements (*fig. 2, appendix 1*).

Goat Domestication in the Zagros

Metric data from 15 Zagros sites analyzed of this study (*fig. 1*) confirmed the original impression gained from my comparison of Yafteh Cave and Ganj Dareh caprines (*fig. 3, appendix 1, 2*). Despite earlier claims for size reduction in the goats from Ganj Dareh, there was no difference in the size of any of the measured skeletal elements of Ganj Dareh goats when directly compared to the bones of goats from earlier highland assemblages dating back as far back as the Middle Paleolithic (*fig. 3 f-i, appendix 1*). The goats from lowland Ali Kosh are significantly smaller than those from highland Ganj Dareh (*fig. 3e, appendix 2*), but the degree of body size difference between these two populations is similar to that seen in modern Zagros goats from comparable environments (*fig. 3a-b, compare Central Zagros wild goats to Southern Zagros wild goats in appendix 1, 2*). Thus the smaller size of the Ali Kosh goats may not be an artifact of domestication induced body size reduction, but rather a reflection a more general adaptation to the hotter more arid environment of the Deh Luran Plain.

Both the assemblages of goat remains from Ganj Dareh and Ali Kosh showed a strong bi-modality in all measured dimensions which closely resembles the bi-modal dimensions of male and female goats in the region today (*fig. 4, 5*). Given this similarity, it is highly likely that this pattern reflects sexual dimorphism in the size of ancient male and female goats. Moreover, in both assemblages, the larger bones were often unfused, meaning that these animals were slaughtered prior to reaching the age of fusion of the particular element. The smaller bones, in contrast, were more likely to be fused, meaning that they were slaughtered after the age of fusion.

Assuming, then, that the bimodal distribution in bone size is attributable to sexual dimorphism, it was possible to construct sex-specific harvest profiles for the goats from these sites. This was accomplished by using discriminate function analysis to identify the likely area of overlap between the male and female populations, and then calculating the percentage of fused, fusing, and unfused elements among bones that fuse at different ages for both the small-bodied (female) and large-bodied (male) sub-populations of goats that lay outside this overlap area (see Zeder 2001). When this was done a clear pattern of young male slaughter and prolonged female survivorship was seen at both Aceramic Neolithic Ali Kosh and Ganj Dareh (*fig. 6c-d, table 1*). A similar pattern is seen for the goats from Ceramic Neolithic levels at Jarmo (*fig. 6e, table 1*). This pattern is consistent with a herder's strategy that seeks to maximize off-take from the herd by harvesting young males, while preserving females and a few males as breeding stock to ensure the perpetuation of the herd.

It was also interesting to note that at both Ali Kosh and Ganj Dareh small (female) goats were much better represented than the larger (male) goats, especially among later fusing bones (*fig. 4-5, table 2*). This is because the unfused, friable bones of young males are more subject to post-depositional attrition than the fully fused bones of adult females. Unfused elements are also harder to both identify to species and to measure. These biases result in an under representation of the bones of young males in these assemblages compared to the hardier fused bones of females slaughtered as much older adult animals.

In contrast, sex-specific age profiles constructed for earlier sites, like Shanidar Cave (levels C and D) and Asiab, showed a much better representation of larger (male) animals (*table 2*) and a much greater

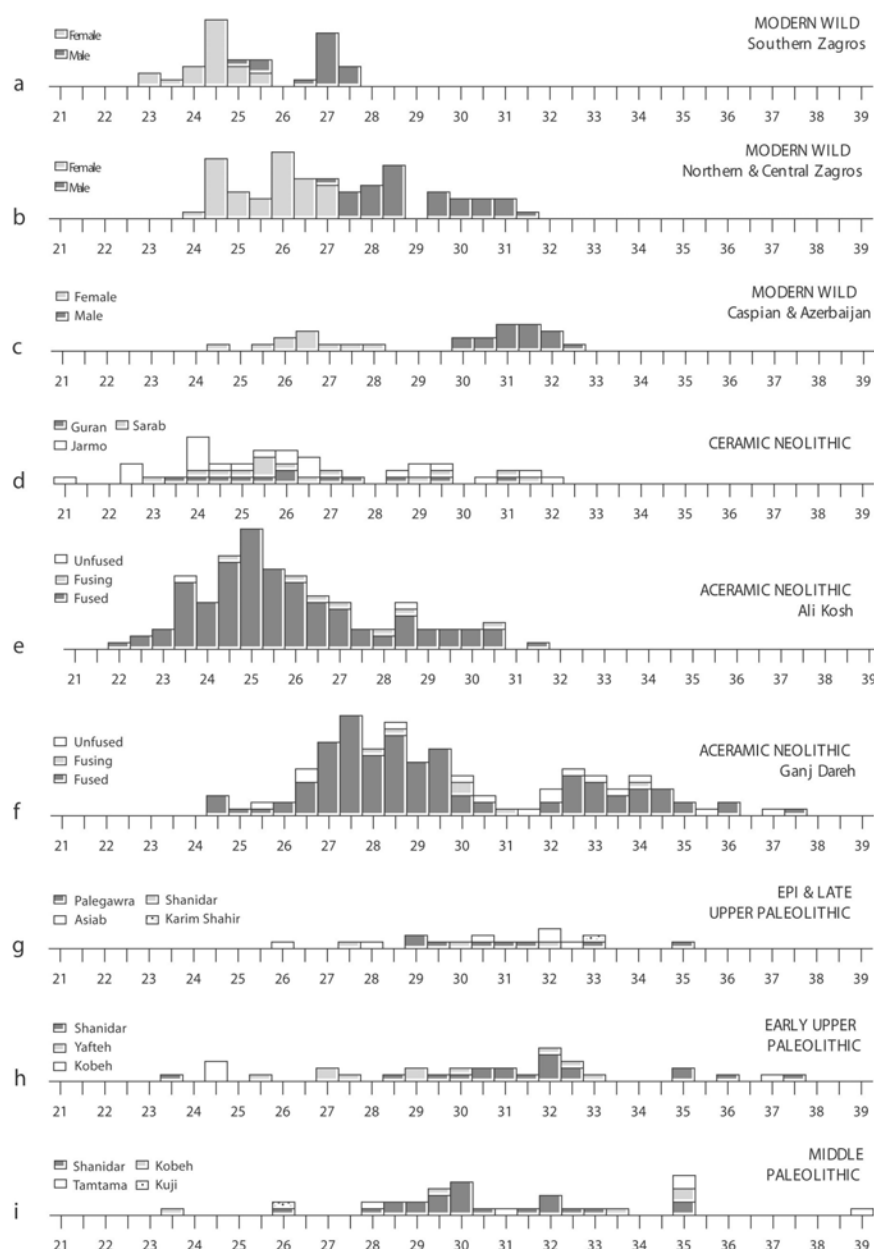


Fig. 3—Diachronic view of changes in the length of the second phalanx (GL) of goats from the Middle Paleolithic to the present day. X axis shows dimension in mm. Y axis shows number of specimens.

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 8,000-70,000 BP 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 (8,500-8,000 BP 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 (8,900 BP 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 BP 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 BP 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 BP 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 ($n = 34$).

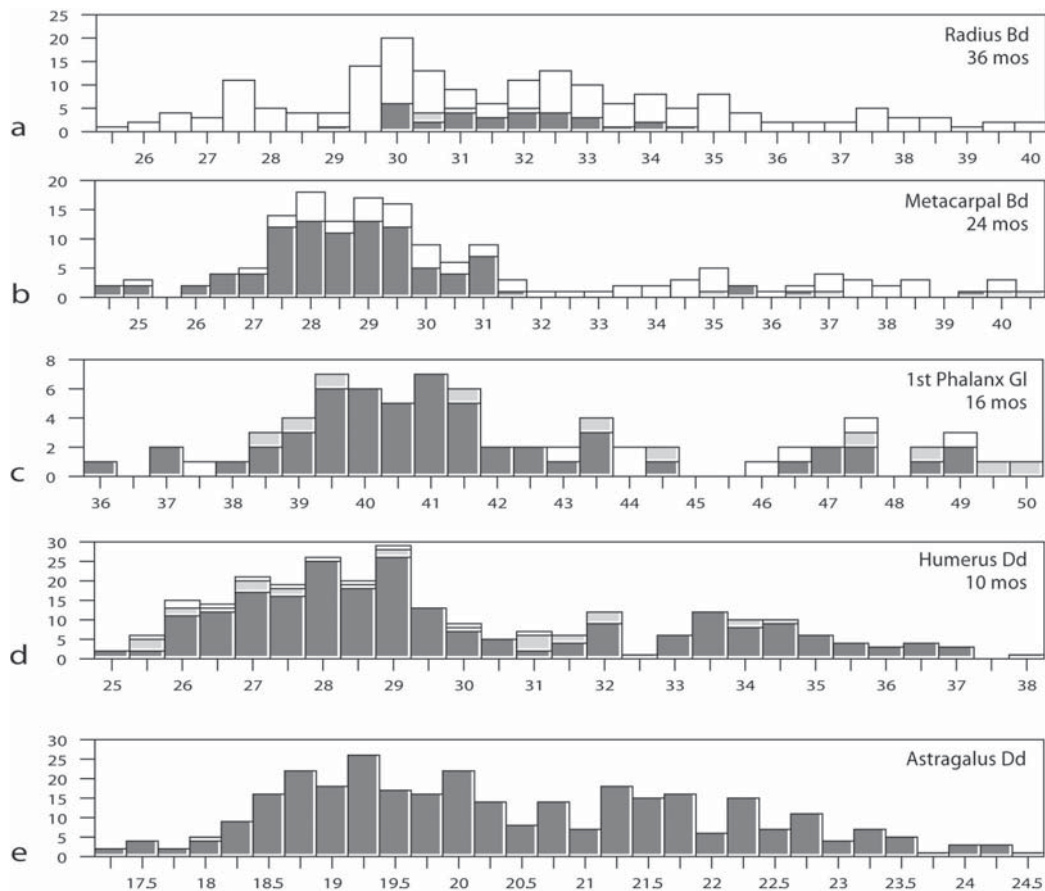


Fig. 4—Breadth and depth measurements of goat long bones from Ganj Dareh arranged by age at fusion. X axis shows dimension in mm. Y axis shows number of specimens. Dark gray bars are fused specimens. Light gray bars are fusing specimens. White bars are unfused specimens. a. Radius Bd-fusion at 36 months ($n = 187$); 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 ($n = 313$).

Age group	Shanidar C and D		Asiab		Ganj Dareh		Ali Kosh		Jarmo		Ali Kosh	
	Goats		Goats		Goats (total)		Goats		Goats		Gazelle	
	F	M	F	M	F	M	F	M	F	M	F	M
A	100	100	-	97	96	98	98	100	99	99	100	99
B	100	-	100	100	91	94	95	96	98	100	96	100
C	79	99	100	100	93	74	98	93	99	88	97	98
D	50	83	100	100	74	21	82	54	96	88	89	75
E	0	80	50	100	27	4	47	25	59	46	53	66
NISP	13	63	11	26	872	514	380	191	564	251	203	372

Table 1—Long Bone fusion scores# for goats and gazelle from archaeological sites (following Zeder 2001, 2006b). Fusion score computed using the formula $[(Fg \cdot 5) + Fd / (Uf + Fg + Fd)] \cdot 1000$ where Fg = number of fusing bones, Fd = number of fused bones, and Uf = number of unfused bones. A = proximal radius (ca 0-6 months); B = distal humerus (ca 6-12 months); C = proximal 2nd phalanx and proximal 1st phalanx (ca 12-18 months); D = distal tibia, distal metacarpal, distal metatarsal (ca 18-30 months); E = distal calcaneus, distal radius (ca 30-48 months); M = males; F = females.

Site	% Males	% Females	% Unfused and fusing males	% Unfused and fusing females	Total NISP
Shanidar C and D	83	17	6	23	76
Asiab	70	30	0	9	37
Ganj Dareh	37	63	54	34	1386
Ali Kosh	30	70	36	17	571
Jarmo	33	67	20	12	751
Ali Kosh-Gazelle	65	35	8	12	575

Table 2—Proportions of male and female goats, and gazelles, unfused and fusing bones in sites from the Zagros.

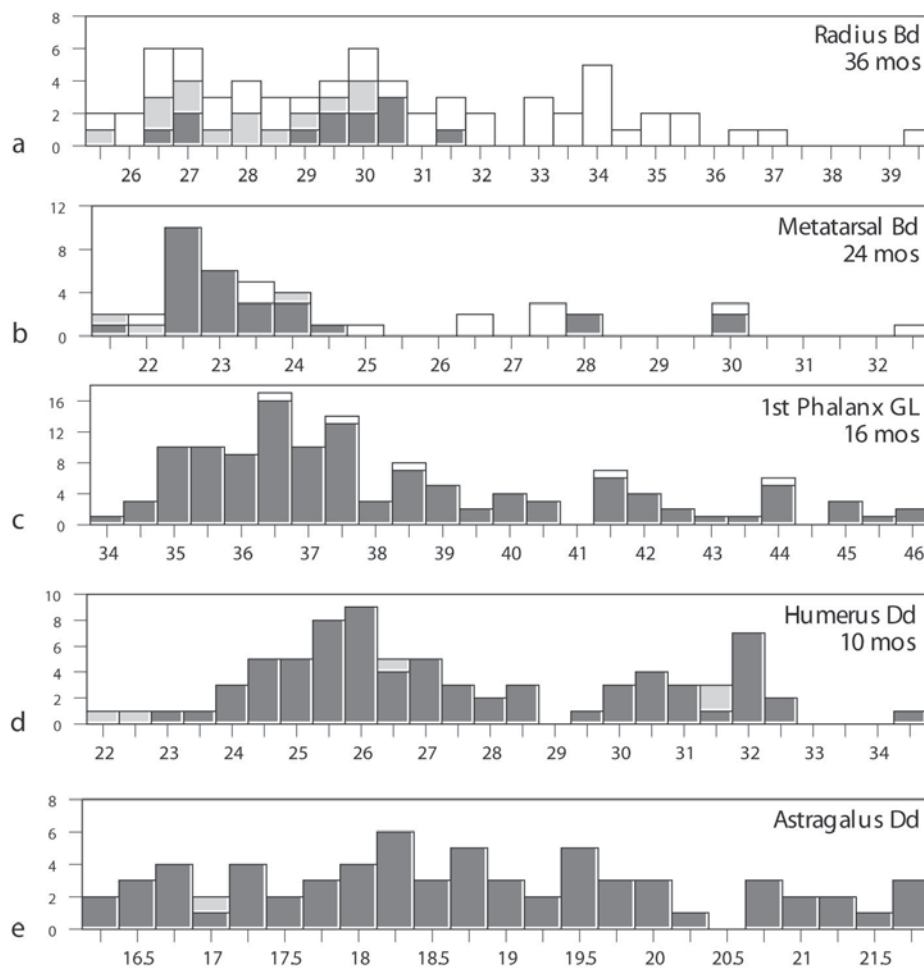


Fig. 5—Breadth and depth measurements of goat long bones from Ali Kosh arranged by age at fusion. X axis shows dimension in mm. Y axis shows number of specimens. Dark gray bars are fused specimens. Light gray bars are fusing specimens. White bars are unfused specimens. a. Radius Bd-fusion at 36 months, ($n = 183$); b. Metatarsal 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 ($n = 314$).

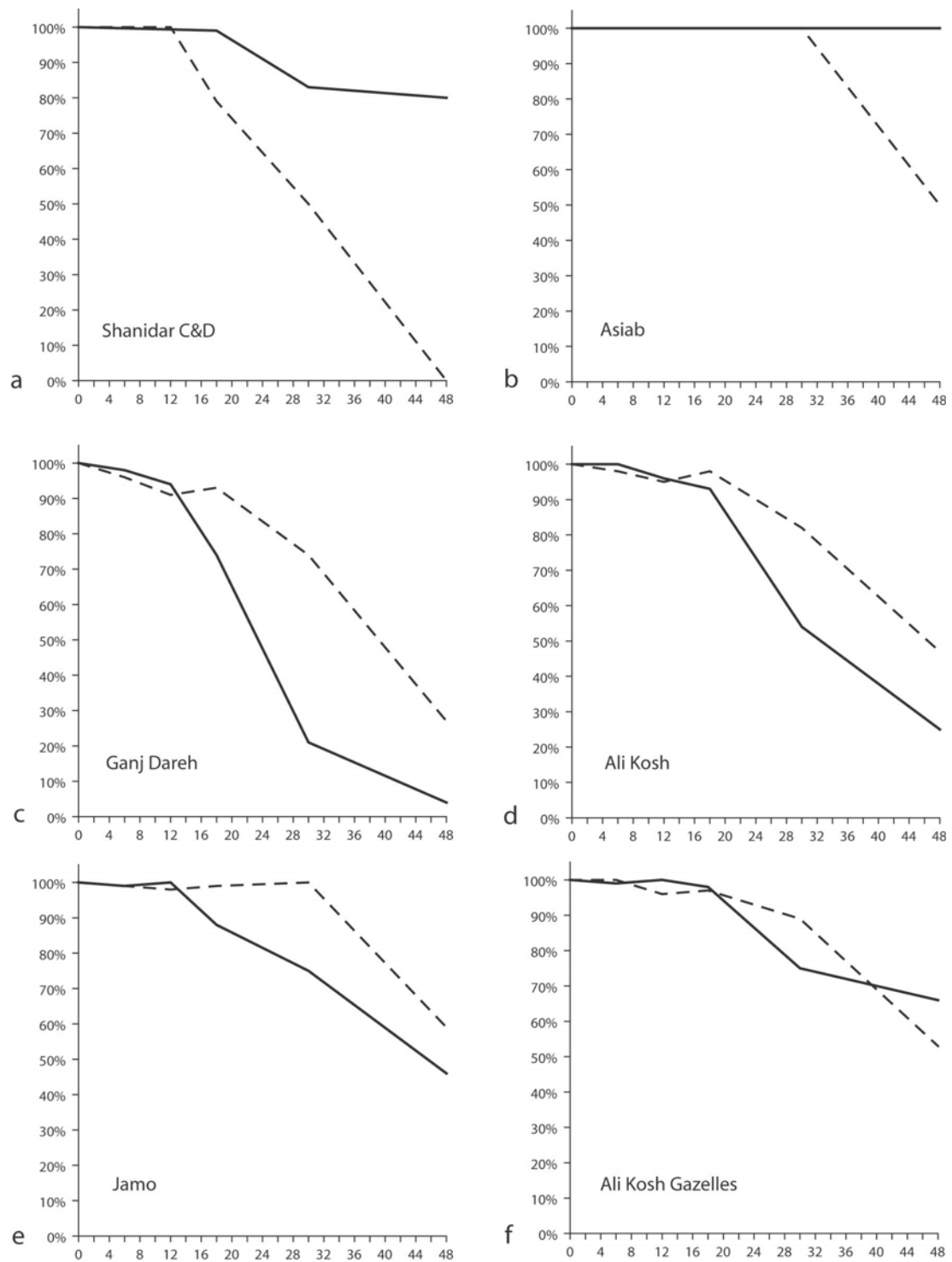


Fig. 6—Sex-specific harvest profiles of goats and gazelle from Zagros sites. X-axis represents age in months. Y-axis represents percentage surviving. Solid lines are males. Dotted lines are females.
 a. Goats from Shanidar levels C and D, females = 13 specimens, males = 63 specimens; b. Goats from Asiab, females = 26 specimens, males = 93 specimens; c. Goats from Ganj Dareh, females = 872 specimens, males = 514 specimens; d. Goats from Ali Kosh, females = 381 specimens, males = 162; e. Goats from Jarmo, females = 564 specimens, males = 251 specimens; f. Gazelle from Ali Kosh, females = 203 specimens, males = 371 specimens.

tendency for both large (male) and small (female) animals to survive beyond the 4-5 year limit of the long-bone fusion aging method (*fig. 6a-b, table 1*). A similar pattern is seen for hunted gazelle from Ali Kosh (*fig. 6f, table 1, 2*). This pattern is consistent with an emphasis on prime age large bodied males typical of a hunting strategy that seeks to maximize immediate return from the hunt.

I had, then, discovered a clear, unambiguous signal of herd management in the harvest profiles of goats at both Ganj Dareh and Ali Kosh that was distinctly different from the hunting harvest signal seen at sites like Shanidar Cave and Asiab. Questions remained, however, about the timing of the transition from hunting to herding in the Zagros and its geographic location. The AMS dating of bones from Zagros sites conducted as part of this study has largely resolved these questions (*table 3*). The dates obtained for Asiab, once thought to be roughly contemporary with basal levels at near-by Ganj Dareh, confirmed that this semi-sedentary encampment was occupied at about 10,700 cal. BP, considerably earlier than Ganj Dareh. Moreover, the new dates also showed that basal level E at Ganj-Dareh was not nearly a millennium older than levels A-D, as had been argued. Instead 13 AMS dates from Ganj Dareh showed that all five levels of this village site were occupied over the course of a relatively short span of time, from about 9,900 cal. BP to about 9,800 cal. BP. Lowland Ali Kosh seems to have been established several hundred years after the abandonment of Ganj Dareh. New AMS dates from Ali Kosh indicate that the Aceramic Bus Mordeh and Ali Kosh phase levels at the site were occupied from about 9,500 to about 9,000 cal. BP, while Ceramic Neolithic Mohammed Jaffar levels were occupied from about 9,000-8,000 cal. BP.

Thus it seems that goat management originated first in the highland habitat of wild goats, growing out of a long standing tradition of hunting wild caprines, and only later moved out of this heartland region onto the lowland Deh Luran Plain. And although the goats of Ganj Dareh were clearly being managed in the same way as modern domestic herds, they showed no evidence of the morphological changes in horn form or in body size usually held to be leading edge markers of domestication.

In fact, it now seems that what earlier researchers had interpreted as domestication induced body size reduction in the Ganj Dareh goats is instead attributable to a shift in the demographic composition of managed herds. Assemblages from managed herds (like those from Ganj Dareh, Ali Kosh and Jarmo) are dominated by smaller adult females, while those representing hunted prey populations (like those from Asiab and early levels at Shanidar Cave) are dominated by large adult males (*table 2*). Earlier comparisons of hunted, male dominated assemblages to herded, female dominated assemblage (that failed to take these demographic factors into account) had, then, led to the mistaken conclusion that body size reduction had occurred.

These biases were exacerbated by the routine practice of excluding unfused bones from the measured sample, thereby eliminating the majority of the males in assemblages from managed herds. Moreover, the normalization of individual measurements and their combination into multi-element size profiles served to further exaggerate the strong female bias in assemblages from managed herds, as well as the male bias in assemblages of hunted animals.

Biases introduced through the normalization of metric data are graphically demonstrated in figure 7, which presents the normalized size profiles for individual elements from the large Ganj Dareh goat assemblage. Normalization of the Ganj Dareh metric data, and that from other sites (shown in *fig. 8-11*) was performed using the size index (SI) method first described by Ducos (1969). This method was used instead of the more commonly employed Log-size index (LSI) method developed by Meadow (1984), since it is a more direct reflection of the actual raw measurements. A recent study by Meadow (1999) has shown that the SI method yields results that are directly comparable to those obtained using the LSI method.

A basic assumption behind all normalization techniques is that all dimensions of all elements will scale the same way when normalized. This means that, given a large enough sample, the normalized values for all elements should have roughly the same minimum and maximum values, means, and standard deviations. It has long been known that length measurements violate this principle (see Meadow 1999), as can be clearly seen when comparing the normalized values for the 1st and 2nd phalanges (*fig. 7e, f*) to the normalized breadth and depth measurements of other elements in the Ganj Dareh assemblage. However, it also appears that breadth and depth measurements scale differently from one another (compare *fig. 7h, g, c, b* to *fig. 7a, d*). Moreover, not all breadth elements scale the same way, as can be seen when comparing the normalized measurements of the metacarpal distal breadth to those of the metatarsal distal breadth

(fig. 7b, c). Comparing the normalized size profiles for individual elements with the unnormalized profiles shown in figure 4 makes it clear that the scaling differences seen in figure 7 is an artifact of normalization, not an inherent feature of the raw metric data. The cumulative impact of these scaling differences is

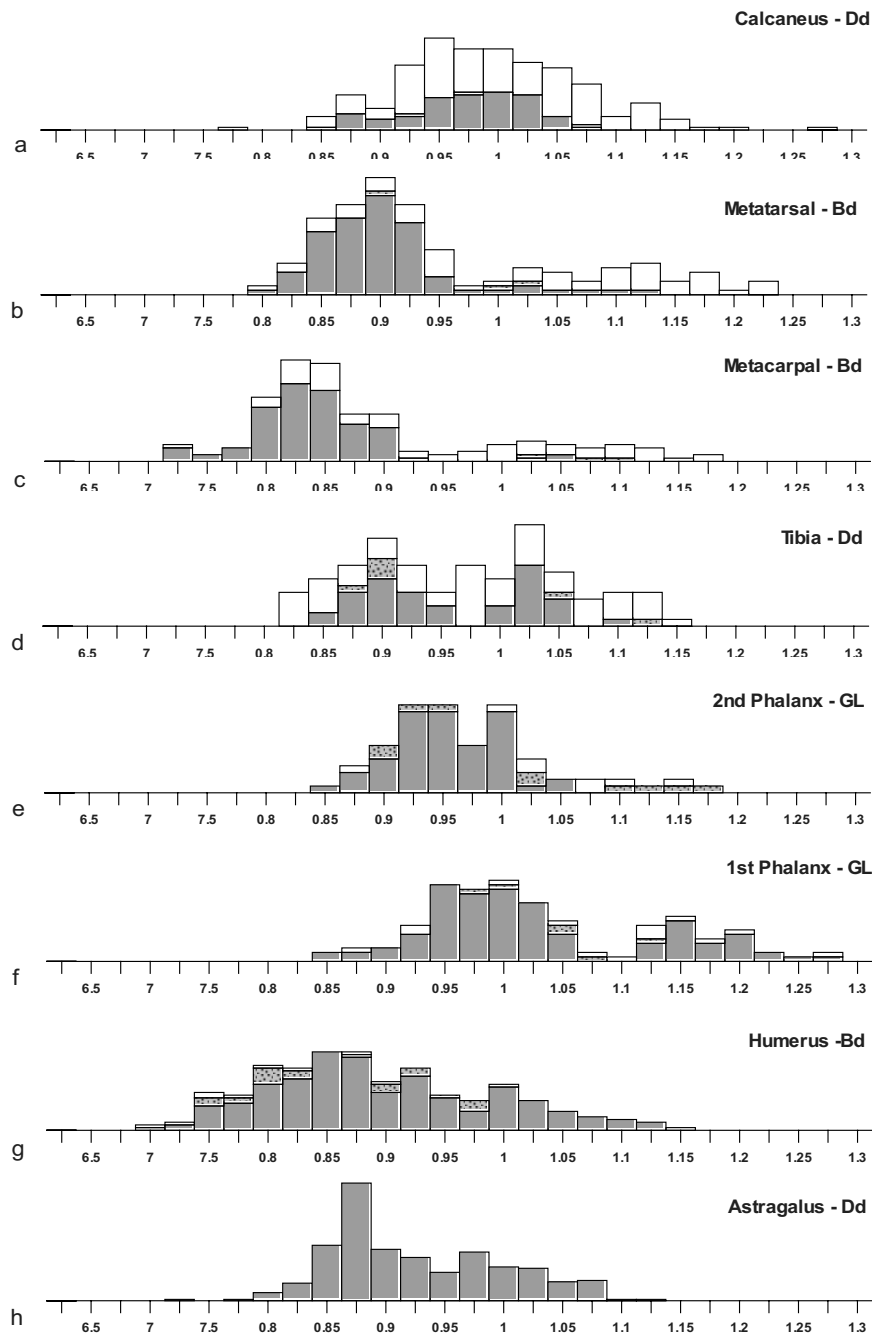


Fig. 7—Normalized size-profiles for individual skeletal elements of Ganj Dareh goats. Normalization was accomplished following the Size Index method developed by Ducos (1969) and using a modern wild male goat from the Baradost Mountains, Iraq (FMNH 44466).

Standard measurements used in figures 7, 8 and 9 are: Astragalus Bd = 21.73, Humerus Bd = 38.23, 1st Phalanx Gl = 42.57, 2nd Phalanx GL = 28.46, Tibia Dd = 22.82, Metacarpal Bd = 34.05, Metatarsal Bd = 28.95, Calcaneus Dd = 23.87, Radius Bp = 38.66, Radius Bd = 35.14. Dark gray bars are fused bones, light stippled gray bars are fusing bones, and white bars are unfused bones. a. Calcaneus Dd (n = 296); b. Metatarsal Bd (n = 148); c. Metacarpal Bd (n = 158); d. Tibia Dd (n = 104); e. 2nd Phalanx Gl (130); f. 1st Phalanx Gl (n = 73); g. Humerus Bd (n = 250); h. Astragalus Bd (n = 317).

the loss of the marked bimodality clearly apparent in both non-normalized and normalized data for individual measurements (see *fig. 8f*). This blended size profile also loses the age sensitive demographic patterns evident when bones that fuse at different ages are individually examined.

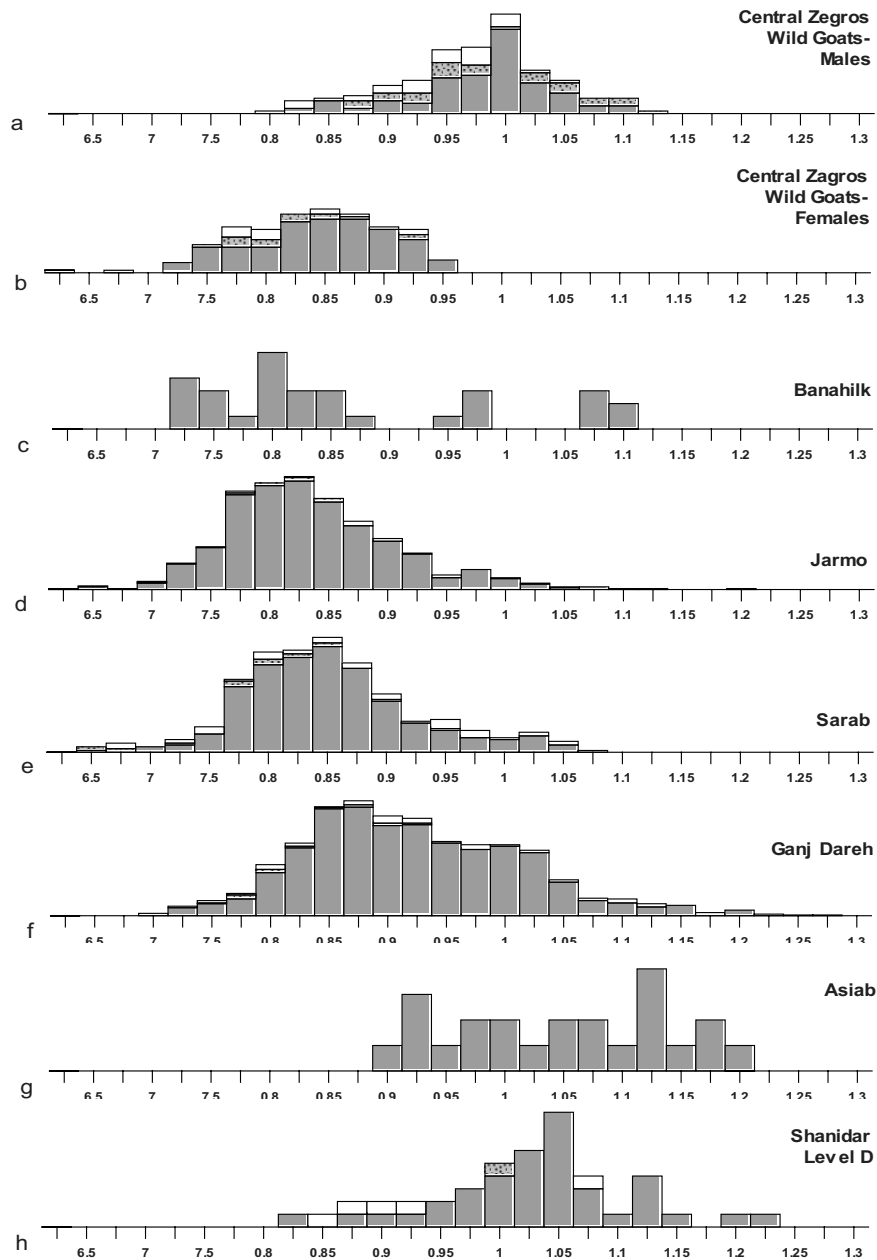


Fig. 8—Diachronic view of size-index profiles of goats from highland Zagros sites. Standard given in figure 7 caption. Dark gray bars are fused bones, light stippled gray bars are fusing bones, and white bars are unfused bones. a. Central Zagros Modern Wild Goats-Males (n = 105 from 4 individuals); b. Central Zagros Modern Wild Goats-Females (n = 95 from 4 individuals); c. Banahilk, ca 8,000-7,000 cal. BP, (n = 31); d. Jarmo, ca 9,000 cal. BP (n = 792); e. Sarab, ca 9,000 cal. BP (n = 410); f. Ganj Dareh, ca 10,000 cal. BP (n = 1,800); g. Asiab, ca 11,000 cal. BP (n = 41); h. Shanidar Cave Level D, ca 40,000 BP (n = 46).

Sites	Beta analytic number	Level	Depth (cm)	C14 BP#	C14 cal. BP!	2 s cal. BP@	1 s cal. BP^
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	11,110-10530	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	10000-9890	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	

Table 3—AMS dates on bones from Zagros sites. Notes:

#—Uncalibrated conventional ^{14}C age of specimens in ^{14}C BP ($\pm 1 \sigma$);

!—Intercept between the conventional ^{14}C age and the dendrocalibrated calendar time scale, in calendar yr BP (Pretoria calibration procedure program, Beta Analytic);

@— 2σ dendrocalibrated age range for specimens, in calendar yr BP;

^— 1σ dendrocalibrated age range for specimens, in calendar yr BP;

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

Sites	Beta analytic number	Level	Depth (cm)	C14 BP#	C14 cal. BP!	2 s cal. BP@	1 s cal. BP^
Ali Kosh	B-137020*	Moham. Jaffar	50-60	7100 ± 70	7940	8020-7775	7970-7845
	B-177122*	Moham. Jaffar	90-100	7550 ± 40	8370	8400-8300	8390-8350
	B-118719*	Moham. Jaffar	70-80	8130 ± 70	8995	9245-8940	9185-9110 9090-8970
	B-118720*	Moham. 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 8830-8790	9020-8990
	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	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

Table 3 (suite).

What is retained (and even exaggerated) in amalgamated normalized metric data for Ganj Dareh goats is the bias for older female animals—even when unfused and fusing bones are included in the normalized data set (*fig. 8f*). This bias is evident in the strong leftward skew of the Ganj Dareh normalized size profile with its long right directed tail. The left skewed, right tailed normalized profiles of herded goats from later sites in the highland Zagros (Sarab, Jarmo, and Banahilk, *fig. 8c, d, e*) also show the same female bias. The bias for adult male animals in assemblages of hunted goats, on the other hand, is evident in the normalized size profiles of goat metrics from the sites of Asiab and Middle Paleolithic levels at Shanidar Cave (*fig. 8g, h*), which both show a strong rightward skew and left directed tails.

It is especially interesting to compare these archaeological assemblages to the normalized site profiles of modern male and female wild goats from the highland Central Zagros region (*fig. 8a, b*). Despite the small downward shift in size of these modern animals when compared to assemblages older than 9,000 BP, the overlap between the size profile for modern wild females and those of ancient herded goats is striking. There is also a general correspondence between the modern wild males and the hunted animals in the assemblages from Asiab and Shanidar Cave.

A similar pattern is seen when one compares the normalized size profiles of goats from archaeological assemblages from lowland sites (*fig. 9*). All of these assemblages, beginning with the colonizing herded goats from basal levels at Ali Kosh (*fig. 9g*), show the same left skewed, right tailed pattern evidenced at Ganj Dareh and later highland sites. Moreover, the correspondence between these profiles and that of wild female goats from the Southern Zagros, lends further support to the conclusion that these are adult female dominated size profiles.

Unlike the early highland assemblages which show no signs of morphological change, the lowland Ali Kosh goats do exhibit domestication related morphological impacts in the form of progressive changes in horn size and shape over the course of 1500 year occupation of the site (Hole *et al.* 1969). These changes are likely the result of the relaxation of selective pressures for large horns in males coupled with reproductive isolation of colonizing managed goats from highland wild populations. However, the smaller body size of the lowland goats when compared to upland populations is less likely an artifact of domestication. The lack of corresponding changes in body size over the occupation of Ali Kosh (*fig. 9e, f, g*) argues instead that the smaller size of these goats is a reflection of the size of ancestral wild goats that came from more southerly parts of the Zagros range. This conclusion is further supported by the close correspondence between the size profiles of lowland archaeological assemblages (especially those from later sites) and the smaller bodied modern wild goats from the southern Zagros (*fig. 3a, e, fig. 9a, b*, see also *appendix 1, 2*).

Clear signs of body size reduction in later herded goat populations are evident, however, when one compares both raw and normalized metric data from Ceramic Neolithic highland sites of Sarab, Guran, and Jarmo (dated to about 9,000-8,500 cal. BP), and later Banahilk (*ca* 8,000-7,000 cal. BP), to Aceramic Neolithic goats from Ganj Dareh and earlier highland sites (*fig. 3d, f, fig. 8, appendix 1*). A similar, though perhaps less marked, downward shift in body size is evident in Ceramic Neolithic and Bronze Age assemblages from lowland sites (*fig. 9, appendix 2*). This downward shift in the body size of Zagros goats is difficult to attribute to domestication, however, since it occurs more than 1000 years after the first evidence of herd management in the highlands of Iran, and 500 years after the reproductive isolation of lowland managed goats from upland wild populations. Moreover, modern wild goats from both the Central and Southern Zagros also show signs of body size reduction when compared to their pre-9000 BP ancient counterparts, aligning more closely with the later assemblages from both highland and lowland Zagros sites (*fig. 3, 8, 9; appendix 1, 2*). This suggests that progressive body size reduction is a more general phenomena among Zagros goats, both domestic and wild.

Sheep Domestication in the Zagros

A different picture is emerging for the trajectory of sheep domestication in the Zagros. Back in the 1960s Dexter Perkins (1964) argued that a strong emphasis on sub-adult sheep at Epipaleolithic levels at Shanidar Cave (Level B1) and at the contemporary open air site of Zawi Chemi Shanidar (originally dated to about 11,700 cal. BP) was evidence for sheep domestication at least 2000 years earlier than seen

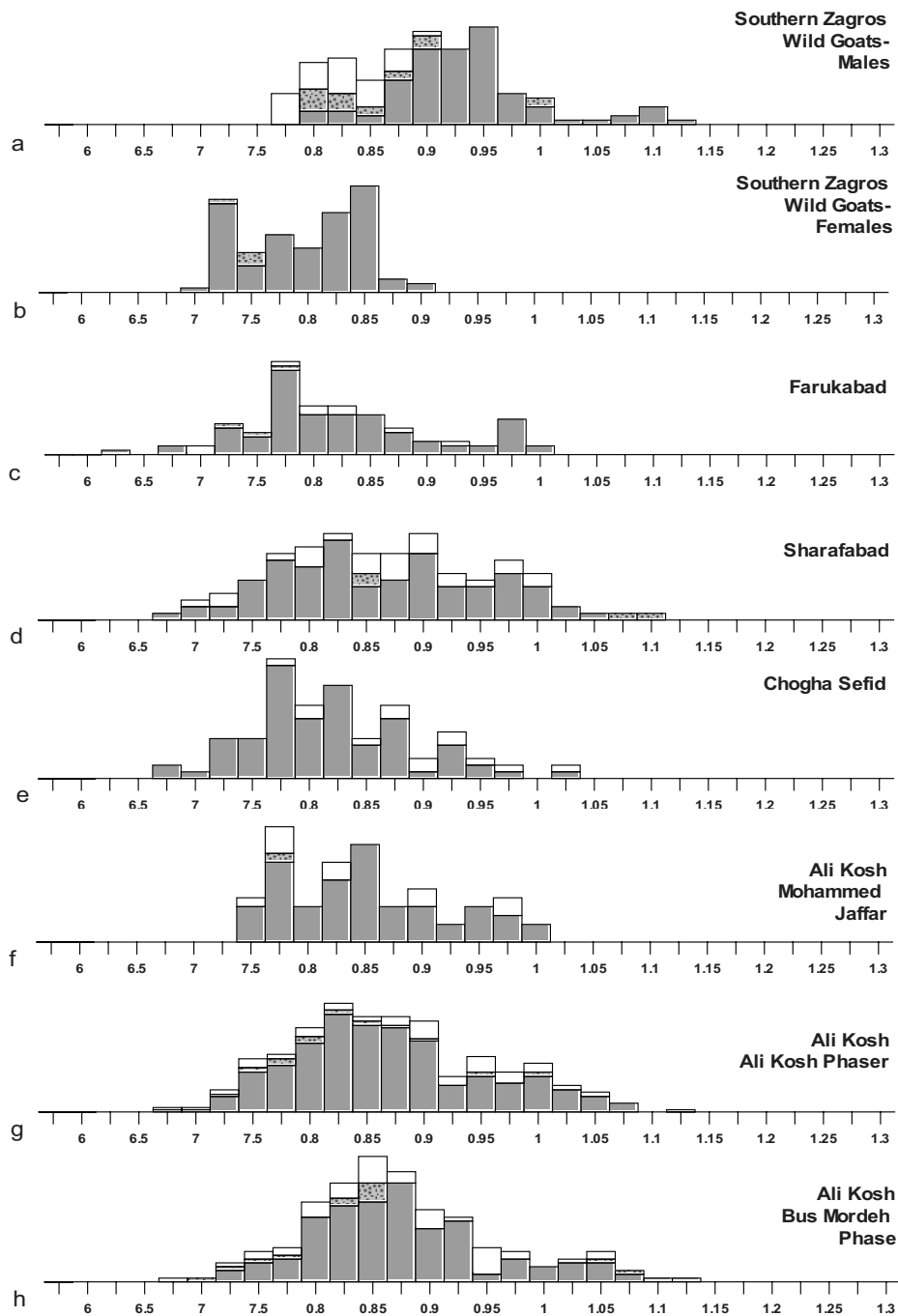


Fig. 9—Diachronic view of size-index profiles of goats from lowland Zagros sites. Standard given in figure 7 caption.

Dark gray bars are fused bones, light stippled gray bars are fusing bones, and white bars are unfused bones.

a. Southern Zagros Wild Goats-Males ($n = 149$ from 6 individuals); b. Southern Zagros Modern Wild Goats-Females ($n = 107$ from 4 individuals); c. Farukhabad, 4th millennium BC ($n = 96$); d. Sharafabad, 4th millennium BC ($n = 131$); e. Chogha Sefid, ca 9,000-7,000 cal. BP ($n = 98$); f. Ali Kosh, Mohammed Jaffar Phase, ca 9,000-8,000 cal. BP ($n = 68$); g. Ali Kosh, Ali Kosh Phaser, ca 9,400-9,000 cal. BP ($n = 402$); h. Ali Kosh, Bus Mordeh Phase, ca 9,500 cal. BP ($n = 237$).

elsewhere in the region. My reanalysis of the sheep and goat remains from these sites confirms Perkins' results. I too found a dramatic increase in the importance of sheep relative to earlier periods in the region. I also found an emphasis on younger animals. However, I do not think these data support his case for sheep domestication.

First, when put in the context of other roughly contemporary Zagros sites, the increase in sheep representation at Zawi Chemi and Shanidar Cave is seen as part of a region-wide increase in sheep exploitation that took place throughout the region beginning with the end of the Pleistocene and continuing through the period up to and through the Younger Dryas (*ca* 15,000-10,000 cal. BP) (*table 4*). This gradual increase in sheep utilization across the Zagros, especially in lower elevation sites, is more likely tied to changing environmental conditions and an associated expansion of grasslands areas suitable to sheep, rather than to sheep domestication. The almost complete absence of sheep in Aceramic Neolithic assemblages in the region suggests a general abandonment of hunting wild sheep once managed goats are introduced into the region.

Period	Site	Elev. (m.)	Sheep NISP	Goat NISP	Sheep/goat NISP	Gazelle NISP	Goat%	Sheep%	Gazelle%
Middle Paleolithic	Tamtama	?	6	22	5	-	79	21	-
	Kobeh	1300	2	27	16	-	93	7	-
	Kunji	1300	2	14	5	-	87	13	-
	Shanidar	725	7	173	102	-	96	4	-
Upper Paleolithic	Yafteh	1300	120	216	660	3	64	36	0,3
	Palegawra	990	36	22	31	4	38	62	4
	Shanidar	725	11	121	104	-	92	8	-
Epipaleolithic	M'lefaat	290	54	20	4	3	27	73	4
	Karim Shahir	850	45	3	8	6	6	94	10
	Shanidar	725	17	30	32	-	64	36	-
	Zawi Chemi	425	65	40	42	-	38	62	-
	Asiab	1000	97	112	104	4	54	46	1
Aceramic Neolithic	Ganj Dareh	1400	253	3649	4815	-	94	6	-
	Guran	950	14	81	49	22	85	15	13
	Ali Kosh	150	16	484	229	292	97	3	29
	Ali Kosh	150	50	774	232	305	94	6	22
Ceramic Neolithic	Ali Kosh	150	16	176	113	182	92	8	37
	Guran	950	33	63	100	153	67	33	44
	Jarmo	800	592	1324	980	161	69	31	5
	Sarab	1000	133	611	458	418	82	18	26
	Ch. Bonut	150	1	64	14	124	98	2	61
	Tepe Sabz	150	28	68	29	24	71	29	16
	Ch. Sefid	150	172	336	631	194	66	34	15
	Matarrah	220	5	10	7	3	67	33	12
Banahilk	675	60	43	27	-	42	58	-	
Chalcolithic/Bronze	Sharafabad	150	235	213	225	14	48	52	2
	Farukahbad	150	226	189	236	42	46	54	6

Table 4—Proportions of sheep, goats and gazelles in Zagros assemblages.

Moreover, while there is a clear emphasis on younger sheep at Zawi Chemi Shanidar, the pattern is not consistent with that seen for sheep and goats at later sites like Ganj Dareh and Ali Kosh. The sample of sheep from Zawi Chemi is too small to allow for the reconstruction of sex-specific harvest profiles like those constructed for goats from Zagros sites. However, a comparison of the age profile constructed using all relevant identified sheep remains from with those from other Zagros sites (*table 5*) suggests that the Zawi Chemi harvest profile is not consistent with either conventional hunted and herded harvest profiles. Harvest profiles of sheep and goats from both earlier and contemporary Zagros sites show an emphasis on fully adult animals expected in hunted assemblages. More than 60% of the animals in these assemblages were older than the limits of long bone fusion aging techniques (*i.e.* older than 4-5 years of age) when they were killed. In contrast the sheep from Zawi Chemi show a very strong emphasis on animals between two to three years of age. However, the Zawi Chemi sheep harvest profile also differs from the harvest profile of the managed goats from both Ganj Dareh and Ali Kosh. In both cases, goat harvest begins at about 6 months of age and continues steadily through the remaining age classes. In fact, 50% or more of the goats from Ganj Dareh and Ali Kosh were culled before they reached about 2 years of age, the point at which harvesting of sheep at Zawi Chemi begins in earnest.

Site	Taxa	Percentage Surviving of the age groups				Total NISP
		A + B	C	D	E	
Yafteh Cave	Sheep	-	85	88	100	35
	Goats	100	89	80	100	61
Palegawra	Sheep	90	93	75	67	79
Karim Shahir	Sheep	100	82	100	100	34
Zawi Chemi	Sheep	100	100	78	9	42
Asiab	Sheep	100	76	67	75	71
	Goats	100	62	57	67	65
Ganj Dareh	Sheep	94	87	75	59	197
	Goats	88	60	34	15	3118
Ali Kosh	Sheep	100	94	77	100	53
	Goats	97	87	55	31	1164

*Table 5—Age profiles for sheep and goat in Zagros assemblages (following Zeder 2006b, table 4).
A + B = 0-12 months; C = 12-18 months; D = 18-30 months; E = 30-48 months.*

In addition, normalized size profiles of the Zawi Chemi sheep (*fig. 10g*) do not show the strong adult female bias typically seen in the measurable bones from managed goat populations (*fig. 9 c-f*). Instead, the normalized metric data for Zawi Chemi sheep point to a heavy emphasis on male animals more consistent with a hunted assemblage. A similar male emphasis is seen for the sheep from both the Late Upper Paleolithic site of Palegawra (*fig. 10h*) and Aceramic Neolithic sheep from Ganj Dareh (*fig. 10f*). As with the goats, despite some body size reduction in modern animals, these apparently male dominated assemblages align relatively well with the size profiles of modern wild males in the region (*fig. 10a*). Once again, this heavy male emphasis is consistent with a hunter's strategy that seeks to maximize the returns of the hunt.

A similar prey profile (*i.e.* a focus on males between 2-3 years of age) has also been observed by Richard Redding among the sheep from the roughly contemporary site of Hallan Çemi in Southeastern Anatolia (Redding 2005). Redding interprets this pattern as indicative of a prime male hunting strategy under conditions of intensive pressure on local wild herds. He argues that the eradication of prime age

adult males in a region by semi-sedentary hunter-collectors created a kind of “male sink” that drew young males (with less established home territories) into the area, while preserving a local breeding stock of wild females. And while such a strategy can not be maintained indefinitely, it does set a kind of precedent for

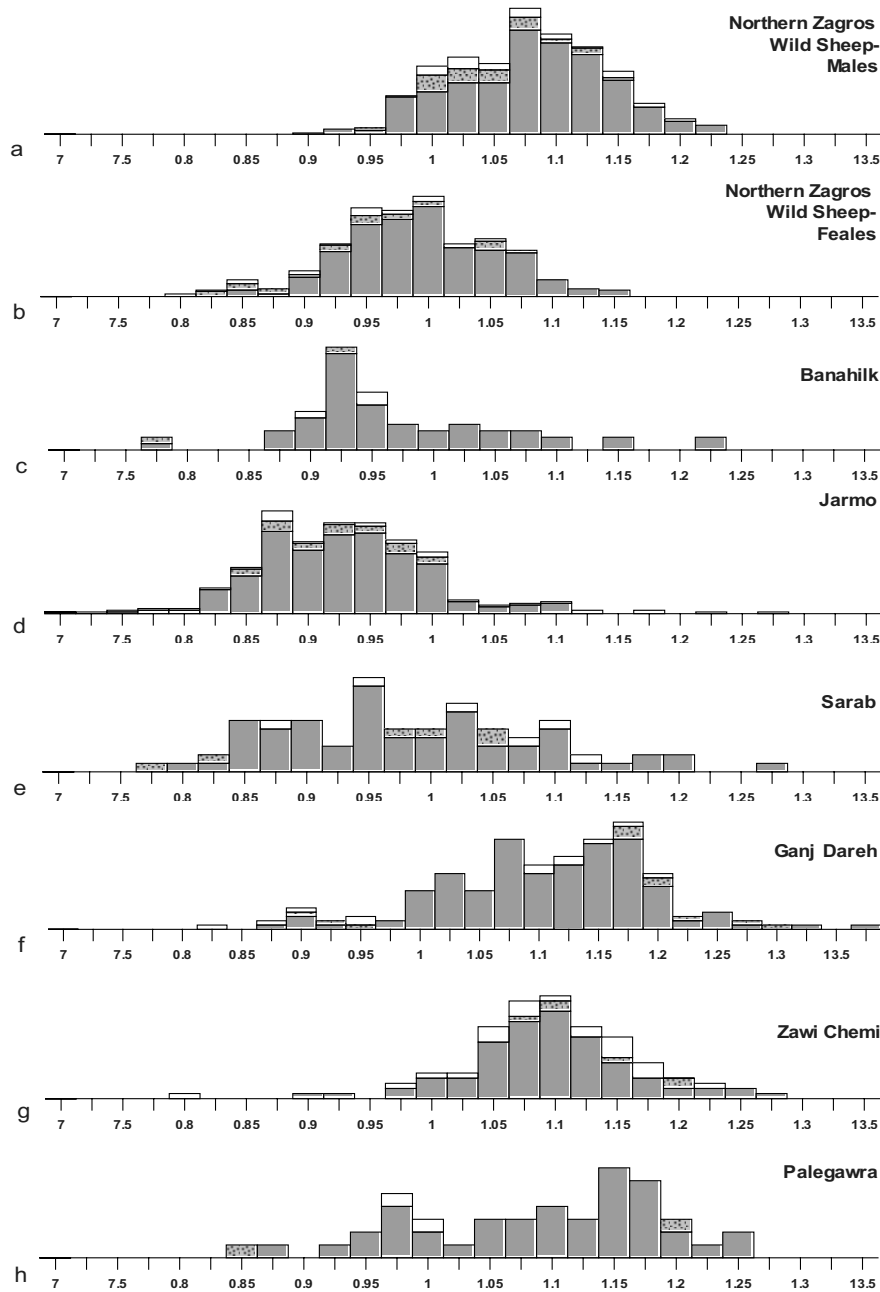


Fig. 10—Diachronic view of size-index profiles of sheep from highland Zagros sites. Normalization was accomplished following the Size Index method developed by Ducos (1969) and using a modern wild male from Kermanshah, Iran (FMNH 98162).

Standard measurements used in figures 10 and 11: Astragalus, Bd, 19.84; Humerus, Bd, 30.82; 1st Phalanx, GL, 42.08; 2nd Phalanx, GL, 24.2; Tibia, Bd, 26.08; Metacarpal, Bd, 22.42; Metatarsal, Bd, 25.24; Calcaneus, GH, 23.62; Radius, Bp, 31.14; Radius, Bd, 29.91. Dark gray bars are fused bones, light stippled gray bars are fusing bones, and white bars are unfused bones. a. Northern Zagros Wild Sheep-Males (n = 545 from 22 individuals); b. Northern Zagros Wild Sheep-females (n = 449 from 21 individuals); c. Banahilk, ca 8,000-7,000 cal. BP (n = 49); d. Jarmo, ca 9,000 cal. BP (n = 344); e. Sarab, ca 9,000 cal. BP (n = 80); f. Ganj Dareh, ca 10,000 cal. BP (n = 161); g. Zawi Chemi, ca 12,000 cal. BP (n = 108); h. Palegawra, ca 12,000 cal. BP (n = 82).

herd management by focusing on younger males while preserving female breeding stock. In particular, it shows how pressure on local wild herds by people increasingly dependent on the collection of territorially fixed plant resources might have resulted in the development of hunting strategies that paved the way for herd management.

Another early claim for sheep domestication was based on the presence of a single hornless female sheep in basal levels of Ali Kosh, which we now know dates to about 9,500 cal. BP (Hole *et al.* 1969). However, hornlessness is known to occur in modern wild female sheep (greater than 10% of the modern wild females in the FMNH collections had no horns) and so can not be taken as definitive proof of sheep domestication. The reanalysis of the Ali Kosh sheep, in fact, indicate an emphasis on prime age animals (*table 5*), most of which are males (*fig. 11*).

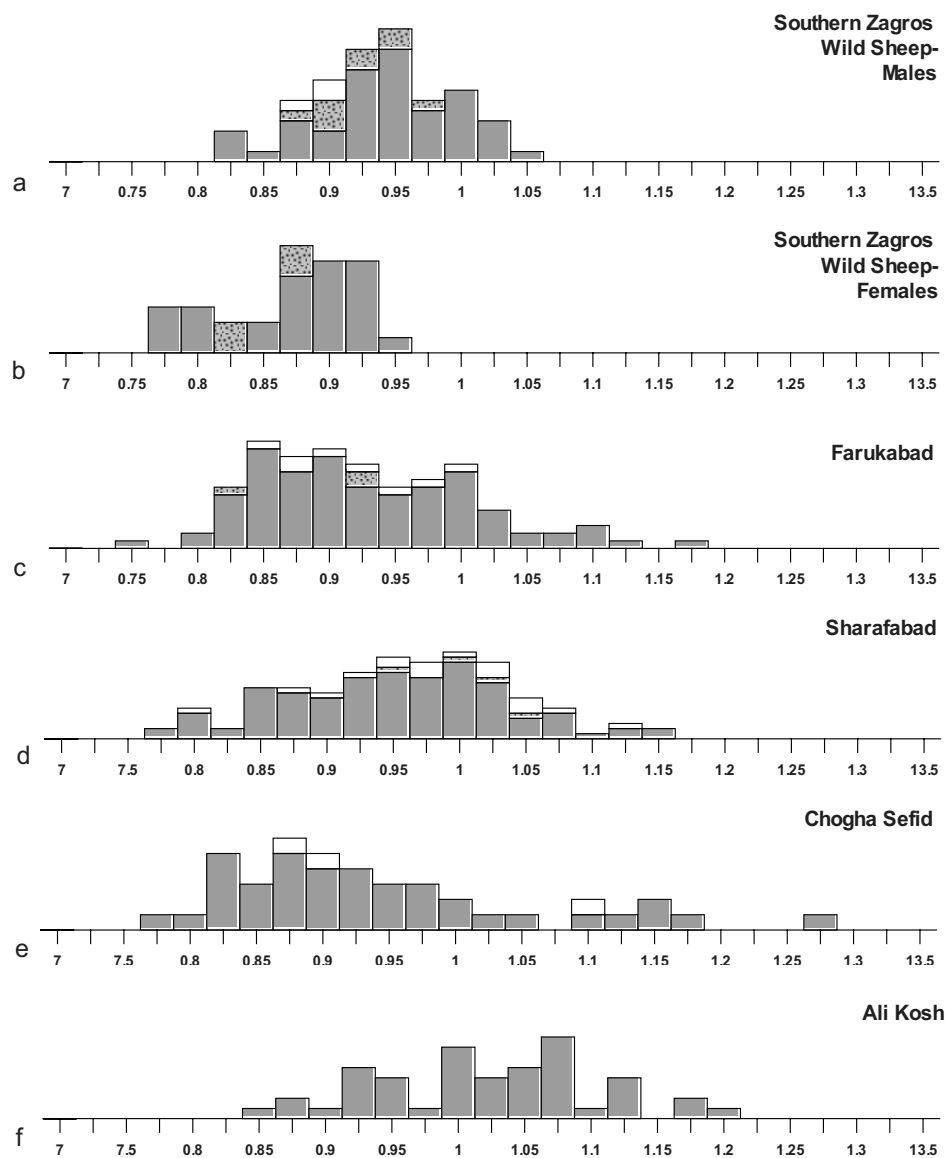


Fig. 11—A diachronic view of normalized measurements of sheep bones from lowland Zagros sites.

Standard given in figure 10 caption. Dark gray bars are fused bones,

light stippled gray bars are fusing bones, and white bars are unfused bones.

- a. Southern Zagros Modern Wild Sheep-Males ($n = 125$ from 4 individuals) b. Southern Zagros Modern Wild Sheep-Females ($n = 125$ from 4 individuals) c. Farukhabad, 4th millennium BC ($n = 105$); d. Sharafabad, 4th millennium BC ($n = 142$); e. Chogha Sefid, ca 9,000-7000 cal. BP ($n = 44$); f. Ali Kosh, ca 9,500-8,000 cal. BP ($n = 42$).

The shift toward demographic profiles consistent with herd management is not seen among Zagros sheep assemblages until the Ceramic Neolithic (*ca* 9,000 cal. BP) at sites like Tepe Guran, Sarab, and Jarmo (*fig. 10c-e*), which all display the left skewed, right tailed size profiles held here to be symptomatic of herded populations. As with the goats, the size profiles of these later sheep assemblages align with modern wild females from the Central Zagros. A similar shift is seen among sheep from lowland assemblages dating to the Ceramic Neolithic and later periods (*fig. 11c-e*). This demographic change in harvest populations coincides with a general increase in sheep exploitation across the region (*table 4*), the introduction of pottery, and, interestingly, a sharp increase in the importance of gazelle at sites in all elevations throughout the Zagros (*table 4*).

Like the goats, sheep in Ceramic Neolithic assemblages in the Zagros highlands also show some reduction in body size (*fig. 10c-e*). A more subtle downward shift in body size may also be detectable among the later lowland sheep (*fig. 11c-d*). However, as with the goats, modern wild sheep from both the Central and Southern Zagros are also smaller than sheep in archaeological assemblages predating 9,000 BP and align reasonably well with sheep from more recent archaeological sites (see also *appendix 1, 3*). Once again, the continued trend toward smaller body size through time in both managed and modern wild populations suggests more general causes for body size reduction in these animals that have nothing to do with domestication. It is possible that the marked climatic shift toward warmer more arid conditions across the entire Fertile Crescent region at about 9,000 BP (Bar Yosef, Meadow 1995, p. 45) served as a trigger for this downward shift toward smaller body size in caprines throughout the Near East. There is also evidence that Zagros gazelles have experienced even greater body size reduction over the course of the Holocene (Zeder 2005), although the timing of this downward shift in gazelle body size seems somewhat retarded compared to their caprine cousins.

Caprine Domestication in the Eastern Fertile Crescent

This new research indicates that the management of morphologically unaltered goats in the Eastern Fertile Crescent arose in the highland natural habitat of wild goats sometime between 10,700 and 9,900 cal. BP. The development of management strategies is best seen as an outgrowth of evolving hunting strategies developed to compensate for localized pressure on wild herds by semi-sedentary populations focusing on territorially restricted plant resources (cereals, pulses, nut trees) and associated wild herbivores. Precisely where in this natural habitat region goat domestication first arose is still hard to say. Recent evidence from the site of Nevalı Çori suggests the introduction of managed goats into in southeastern Anatolia at about 10,200-10,000 cal. BP (Peters *et al.* 2005), just slightly earlier than seen at Ganj Dareh in the Central Zagros at 9,900 cal. BP. Genetic data point to between three to five genetically independent instances of initial goat domestication (see Luikart *et al.* 2006). Emerging archaeological data strongly suggests that the earliest of these different domestication events took place somewhere in-between Nevalı Çori and Ganj Dareh in the Northwest Zagros/Eastern Taurus region.

The assemblage from Ali Kosh captures the continued movement of this new tradition out of the natural habitat of wild goats and onto the arid piedmont and steppe regions of southwestern Iran at about 9500 cal. BP. This movement resulted in an environmental and reproductive break with this initial zone of domestication and the subsequent development of morphological changes (*i.e.* changes in horn size and shape) that had once been thought to be leading edge markers of domestication.

The domestication of sheep seems to have followed a somewhat different trajectory. Recent evidence from southeastern Anatolia suggests that initial sheep domestication somewhere took place around the upper reaches of the Euphrates and Tigris valleys at about the same time as initial goat domestication (*i.e.* around 10,500-10,000 BP) (Peters *et al.* 2005). Domestic sheep do not appear in the Central Zagros, however, until at least 1000 years later, during the Ceramic Neolithic, when they are associated with significant socio-economic changes in the Zagros. Recent work on both older and more recently excavated assemblages from Marv Dasht Plain in Fars Province, also finds a significant delay in the introduction of domestic

sheep (*ca* 7,000 cal. BP) into the region compared to the first appearance of domestic goats in the region (*ca* 8,000 cal. BP) (Mashkour *et al.* 2006).

It is also interesting to note that the westward movement of sheep seems similarly retarded compared to goats. Initial signs of goat management are found in the Northern Levant at Abu Hureyra at about 9,500 cal. BP (Legge 1996; Moore *et al.* 2000), and quite probably in the Southern Levant about this time as well (Horwitz *et al.* 1999). Domestic sheep, on the other hand, are not evident in the Southern Levant until about 9,000 cal. BP (Horwitz, Ducos 1998), where they are also associated with smaller, morphologically altered domestic goats.

Recent archaeobotanical work in Southeastern Anatolia (Nesbitt 2002) suggests that emmer and einkorn wheat were domesticated here at about the same time as sheep and goat were domesticated. This puts the domestication of crops and livestock, once again, in the same temporal and spatial context and shifts focus to the apex and upper eastern arm of the Fertile Crescent as a key area in the emergence of both farming and herding in the Near East.

Directions for Future Work

This restudy of the early archaeozoological collections from Zagros sites (coupled with recent work in neighboring Southeastern Anatolia) highlights the exciting potential of future work in this region. It suggests that it is time for the Eastern Fertile Crescent to shed its underserved role as bit player in the origins of agriculture in the Near East and reclaim its place of central importance in this pivotal process. In particular, the search for the beginnings of animal and plant domestication should focus on the highland natural habitat zone of wild progenitor species, especially the far northwestern corner of Iran, neighboring Iraqi Kurdistan and the eastern reaches of southeast Anatolia, where animal herding and plant cultivation both seem to have grown out of the preceding intensive hunting and collecting strategies of increasingly sedentary peoples.

There are a number of powerful new analytical methods available for tracing and dating the initial stages in the domestication of both plants and animals (Zeder 2006c; Zeder *et al.* 2006a, b; Vigne *et al.* 2005; Smith 2006). This review has highlighted new techniques for detecting demographic shifts in animal harvest profiles that, I believe, show the greatest promise for tracking the evolution of intensive hunting strategies into herd management. At the same time, this analysis of modern and archaeological caprine assemblages from the Zagros raises serious questions about the utility the current normative paradigm for marking animal domestication—body-size reduction. Size does matter, but not as a marker of domestication induced morphological change. This longitudinal study of Zagros assemblages has unequivocally demonstrated that changes in caprine size profiles are almost entirely attributable to the changing demographic profiles of hunted and herded prey populations. And while there is some evidence of a shift toward smaller body size in managed sheep and goats in the Zagros over time, these relatively minor changes post-date initial herd management by at least 1000 years and are likely attributable to climate and environmental changes that also affected wild sheep and goats, as well as gazelles. The only impact of domestication on the size of caprines seems to be restricted to males and takes the form of a marked decrease in the length of long bones, and a much more subtle decrease in breadth and depth measurements. Since the occurrence of whole long bones is exceedingly rare in archaeological assemblages, this means that the only detectable domestication-induced change in caprine body-size may be a reduction in the degree of sexual dimorphism and a corresponding decrease in the strong bimodality in the size of males and females so evident in hunted and early herded populations (see Helmer *et al.* 2005). These subtle changes, however, will be hard to detect given the other, much more potent, factors that affect size profiles of archaeological assemblages (*i.e.* changing demographics, regional variations, and change over time, not to mention small sample sizes, sample taphonomy, and methodological distortions introduced by techniques like size indexing).

This means that archaeozoologists will have to wean themselves from the use of body-size reduction as a leading edge marker of domestication. Clinging to knee-jerk associations of “large = wild” and

“small = domestic” will not further our understanding of the process of animal domestication. Restricting the title of “domesticate” to morphologically altered animals, moreover, serves as a further impediment to understanding the critical initial stages of the transition from hunting to herding. Even unequivocal domestication-induced morphological changes (*i.e.* changes in the size and shape of horns in sheep, goats, and cattle) seem to happen long after the process of domestication is underway. Whether one wants to call morphologically unaltered, but clearly managed animals “domesticates” or “proto-domesticates” is essentially a semantic issue. Regardless of what one calls these animals, understanding changing nature of their interaction with humans is essential if we are to understand the when, where, and why of the process of domestication (Zeder 2006d).

Demographic profiling techniques capable of detecting the shifting age and sex composition of prey populations offer us the potential of actually tackling these intransigent problems. These techniques are best applied to large assemblages, like those from Ganj Dareh and Ali Kosh, where special attention has been paid to collecting and saving the full range of faunal remains needed for the construction of fine-grained sex-specific harvest profiles. However, as this study has shown, even less than optimally collected, smaller assemblages (and problematic techniques like size-index profiling) are capable of shedding considerable light on this process—once one acknowledges the importance of demographic factors in shaping these assemblages.

It will be especially exciting to see these same techniques applied to faunal assemblages recovered from the region by modern excavations, like those on-going in Southeastern Anatolia and, increasingly, in Northwestern Iran. We are clearly on the cusp of a new era in origins of agriculture research in the Near East. If archaeozoologists working in this region are willing to abandon, once and for all, the discredited size-reduction paradigm in favor of the powerful new techniques now available for studying animal domestication, the next few decades promise to significant advances in furthering our understanding of one of the most significant transitions in human history.

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Appendix 1—Summary statistics of highland goats metrics (measurements follow von den Driesch 1976).

Bone	Site	Fused bones							Unfused bones						
		NISP	Min	Max	Median	Mean	SD	CV	NISP	Min	Max	Median	Mean	SD	CV
1st Phalanx-GI	MN.F	23	37,01	42,32	38,49	39,22	1,88	3,52	0	-	-	-	-	-	-
	MN.M	23	43	49,52	45,77	45,94	1,61	2,59	8	45,77	48,37	47,29	47,12	1,07	-
	MC.F	46	26,34	39,17	37,68	37,01	2,03	4,13	0	-	-	-	-	-	-
	MC.M	21	40,96	45,32	43,07	43,01	1,13	1,28	22	40,18	47,94	42,18	43,33	2,71	7,34
	MCD.F	12	38,23	40,7	39,29	39,32	0,82	0,68	4	40,05	40,73	40,33	40,36	0,3	0,09
	MCD.M	0	-	-	-	-	-	-	8	39,4	40,61	39,8	39,95	0,45	0,2
	BH	2	40,78	42,03	41,41	41,41	0,88	0,02	0	-	-	-	-	-	-
	GU	8	34,67	45,84	40,22	40,46	4,3	0,11	0	-	-	-	-	-	-
	JM	38	32,99	42,22	37,2	37,09	1,9	3,95	3	35,86	40,67	39,24	38,59	2,47	0,06
	SA	29	35,1	46,4	38,06	38,51	2,89	0,08	0	-	-	-	-	-	-
	GD	55	36,48	49,25	41,01	41,79	3,05	9,3	18	37,5	50,57	44,49	44,62	4,05	16,38
	SC-B	2	43,08	44,7	43,89	43,89	1,15	1,31	0	-	-	-	-	-	-
	ZC	2	43,2	43,2	43,2	43,2	0	0	2	51,79	52,09	51,94	51,94	0,21	0
	PG	4	35,01	36,96	35,75	35,87	0,81	0,66	0	-	-	-	-	-	-
	KO-U	2	33,89	43,58	38,74	38,74	6,85	46,95	0	-	-	-	-	-	-
	SC-C	2	45,6	48,6	47,1	47,1	2,12	4,5	1	38,6	38,6	38,6	38,6	.	.
	YC	1	49,08	49,08	49,08	49,08	-	1	0	-	-	-	-	-	-
KU	3	35,64	39,68	35,92	37,08	2,26	5,09	1	32,71	32,71	32,71	32,71	.	.	
SC-D	3	39,12	45,73	44,9	43,25	3,6	12,97	0	-	-	-	-	-	-	
TT	3	45,04	54,03	52,43	50,5	4,8	23	0	-	-	-	-	-	-	
2nd Phalanx-GI	MN.F	10	24,97	28,1	26,86	26,65	0,95	0,9	0	-	-	-	-	-	-
	MN.M	15	30,07	32,82	31,34	31,42	0,82	0,67	0	-	-	-	-	-	-
	MC.F	37	24,33	27,36	26,07	25,89	0,93	0,86	0	-	-	-	-	-	-
	MC.M	31	27,34	31,73	28,84	29,24	1,26	1,58	8	29,28	30,49	29,79	29,85	0,46	0,21
	MCD.F	15	25,83	27,95	27,02	26,93	0,63	0,39	0	-	-	-	-	-	-
	MCD.M	8	25,93	27,71	26,68	26,78	0,61	0,38	0	-	-	-	-	-	-
	BH	3	23,17	24,23	23,76	23,72	0,53	0,02	0	-	-	-	-	-	-
	GU	11	23,98	31,09	26	26,63	2,32	0,09	1	27,71	27,71	27,71	27,71	.	1
	JM	23	21,04	32,2	25,88	26,31	3,06	0,12	2	26,8	29,81	28,31	28,31	2,13	0,08
	SA	14	23,19	31,59	26	26,84	2,61	0,1	0	-	-	-	-	-	-
	GD	110	24,59	36,38	28,79	29,59	2,79	7,8	20	25,6	35,92	31,04	30,87	2,78	7,73
	AS	6	26,48	32,67	31,53	30,47	2,57	0,08	0	-	-	-	-	-	-
	SC-B	5	28,37	35,29	30,94	31,75	2,93	8,57	0	-	-	-	-	-	-
	ZC	4	30,71	34,41	32,59	32,58	1,89	0,06	0	-	-	-	-	-	-
	PG	11	21,98	35,38	29,33	28,12	4,9	24,05	0	-	-	-	-	-	-
	KO-U	5	24,54	37,19	24,9	27,5	5,45	29,71	0	-	-	-	-	-	-
	SC-C	18	23,58	37,5	31,8	31,87	3,1	9,6	0	-	-	-	-	-	-
YC	9	25,99	33,15	29,44	29,7	2,66	0,09	0	-	-	-	-	-	-	
KU	1	26,45	26,45	26,45	26,45	-	-	0	-	-	-	-	-	-	
SC-D	19	28,1	35,43	30,08	30,62	1,83	3,34	1	30,55	30,55	30,55	30,55	.	.	
TT	3	35,15	39,53	35,89	36,86	2,35	5,5	0	-	-	-	-	-	-	
Astragalus-Bd	MN.F	8	16,75	20,04	18,32	18,34	1,22	1,48	0	-	-	-	-	-	-
	MN.M	8	20,9	22,45	22,09	21,89	0,59	0,34	0	-	-	-	-	-	-
	MC.F	10	17,18	19,77	18,52	18,55	0,79	0,62	0	-	-	-	-	-	-
	MC.M	12	19,53	22,73	21,11	20,98	0,93	0,86	0	-	-	-	-	-	-
	MCD.F	3	17,75	18,97	17,86	18,19	0,68	0,01	0	-	-	-	-	-	-
	BH	5	16,19	19,48	17,86	17,65	1,26	0,07	0	-	-	-	-	-	-
	GU	13	16,93	22,05	18,6	19,2	1,65	0,09	0	-	-	-	-	-	-
	JM	326	15,81	23,39	18,17	18,43	1,32	0,07	3	16,02	19,78	18,26	18,02	1,89	0,11
	SA	56	16,25	22,46	18,5	18,62	1,34	0,07	2	16,59	18,89	17,74	17,74	1,63	0,09
	GD	316	16,17	24,7	20,24	20,54	1,63	2,64	0	-	-	-	-	-	-
	AS	10	17,77	24,02	19,89	20,28	2,07	0,1	0	-	-	-	-	-	-
	ZC	6	20,03	27,16	23,3	23,75	2,99	0,13	0	-	-	-	-	-	-
	PG	3	18,77	20,62	20	19,8	0,94	0,89	0	-	-	-	-	-	-
	KO-U	3	16,89	20,45	17,39	18,24	1,93	3,72	0	-	-	-	-	-	-
	SC-C	3	22,74	24,01	23,55	23,43	0,64	0,41	0	-	-	-	-	-	-
	YC	3	20,13	20,56	20,15	20,28	0,24	0,01	0	-	-	-	-	-	-
	KU	3	16,41	18,64	17,92	17,66	1,14	1,3	0	-	-	-	-	-	-
KO-L	1	24,57	24,57	24,57	24,57	-	-	0	-	-	-	-	-	-	
SC-D	6	21,31	23,71	22,7	22,68	0,95	0,89	0	-	-	-	-	-	-	
TT	2	26,13	27,61	26,87	26,87	1,05	1,1	0	-	-	-	-	-	-	

Bone	Site	Fused bones							Unfused bones						
		NISP	Min	Max	Median	Mean	SD	CV	NISP	Min	Max	Median	Mean	SD	CV
Calcaneus-Dd	MN.F	4	21,12	22,95	21,87	21,95	0,77	0,59	4	21,28	23,32	22,15	22,22	1,06	1,12
	MN.M	1	26,06	26,06	26,06	26,06	-	-	6	24,14	26,97	24,76	25,31	1,21	1,47
	MC.F	4	20,2	23,08	21,6	21,62	1,37	1,89	9	20,57	22,61	22,19	21,86	0,79	0,63
	MC.M	3	23,87	26,03	24,11	24,67	1,18	1,4	9	22,61	25,92	24,52	24,26	1,18	1,39
	MCD.F	2	22,25	22,35	22,3	22,3	0,07	0,01	2	22,06	22,22	22,14	22,14	0,11	0,01
	MCD.M	0	-	-	-	-	-	-	2	23,05	23,05	23,05	23,05	0	0
	BH	3	19,64	20,72	20,54	20,3	0,58	0,03	0	-	-	-	-	-	-
	GU	3	19,22	21,11	19,94	20,09	0,95	0,05	7	20,29	26,34	22,43	22,62	1,95	0,09
	JM	13	18,83	24,58	21,39	21,72	1,61	0,07	16	18,99	25,26	21,65	21,38	1,5	0,07
	SA	30	19,46	24,75	21,26	21,39	1,3	0,06	14	19,21	25,19	22,53	22,21	1,68	0,08
	GD	74	20,71	26,18	23,67	23,57	1,22	1,48	159	18,87	31,01	24,01	24,24	1,94	3,76
	AS	2	23,71	27,97	25,84	25,84	3,01	0,12	0	-	-	-	-	-	-
	KO-U	2	19,76	20,32	20,04	20,04	0,4	0,16	0	-	-	-	-	-	-
SC-C	1	28,2	28,2	28,2	28,2	-	-	0	-	-	-	-	-	-	
Humerus-Bd	MN.F	7	28,38	34,63	31,66	31,95	2,1	4,4	0	-	-	-	-	-	-
	MN.M	8	35,47	40,22	37,33	37,72	1,8	3,23	0	-	-	-	-	-	-
	MC.F	10	28,67	32,46	29,45	30,32	1,58	2,48	2	30,07	30,74	30,41	30,41	0,47	0,22
	MC.M	13	32,79	39,49	36,61	36,11	2,39	5,71	0	-	-	-	-	-	-
	MCD.F	5	29,34	32,05	30,81	30,61	1,12	1,25	0	-	-	-	-	-	-
	MCD.M	2	33,45	33,53	33,49	33,49	0,06	-	0	-	-	-	-	-	-
	BH	6	28,2	42,16	30,74	33,82	6,52	0,19	0	-	-	-	-	-	-
	GU	16	28,17	36,16	30,29	31,25	2,43	0,08	4	29,11	35,68	32,17	32,28	2,69	0,08
	JM	119	25,34	45,95	31,26	32,08	3,35	0,11	3	26,9	31,76	27,5	28,72	2,65	0,09
	SA	50	28,77	41,06	31,68	32,41	2,7	0,08	9	25,38	32,46	29,91	29,07	2,74	0,09
	GD	214	27,69	44,03	34,1	34,85	3,59	12,86	36	27,19	39,06	31,77	32,72	3,21	10,31
	AS	8	31,7	43,43	34,7	35,9	4,25	0,12	0	-	-	-	-	-	-
	SC-B	1	31,18	31,18	31,18	31,18	-	-	0	-	-	-	-	-	-
	ZC	6	34,13	44,87	37,91	39,44	4,33	0,11	0	-	-	-	-	-	-
	PG	2	29,76	36,6	33,18	33,18	4,84	23,39	1	28,18	28,18	28,18	28,18	-	-
	KO-U	2	29,56	40,47	35,02	35,02	7,72	59,51	0	-	-	-	-	-	-
KO-L	1	44,89	44,89	44,89	44,89	-	-	0	-	-	-	-	-	-	
TT	1	45,88	45,88	45,88	45,88	-	-	0	-	-	-	-	-	-	
Metacarpal-Bd	MN.F	6	22,66	27,31	25,36	25,13	1,97	3,89	2	29,04	29,29	29,17	29,17	0,18	-
	MN.M	2	34,2	36,07	35,14	35,14	1,32	1,75	6	32,8	34,65	34,23	33,89	0,79	-
	MC.F	12	25,12	28,1	26,13	26,32	0,95	0,91	2	27,68	27,74	27,71	27,71	0,04	0
	MC.M	3	34,05	34,34	34,18	34,19	0,15	0,02	9	29,95	34,11	31,66	31,7	1,55	2,39
	MCD.F	2	27,41	27,64	27,53	27,53	0,16	0,03	2	26,45	26,85	26,65	26,65	0,28	0,08
	MCD.M	0	-	-	-	-	-	-	2	32,06	32,46	32,26	32,26	0,28	0,08
	BH	3	25,1	33,51	26,02	28,21	4,61	0,16	0	-	-	-	-	-	-
	GU	1	31,91	31,91	31,91	31,91	-	1	2	22,65	27,12	24,89	24,89	3,16	0,13
	JM	29	22,5	37,59	27,16	27,4	2,89	0,11	4	24,29	26,91	25,62	25,61	1,24	0,05
	SA	25	22,55	35,05	27,3	28,33	3,46	0,12	3	30,89	35,56	32,76	33,07	2,35	0,07
	GD	96	24,71	39,49	28,92	29,13	2,2	4,85	62	25,38	40,78	33,24	33,08	3,97	15,79
	AS	2	29,84	31,29	30,57	30,57	1,03	0,03	0	-	-	-	-	-	-
	ZC	1	26,42	26,42	26,42	26,42	-	-	2	30,86	33,78	32,32	32,32	2,07	0,06
	PG	1	26,29	26,29	26,29	26,29	-	-	0	-	-	-	-	-	-
KO-U	1	35,37	35,37	35,37	35,37	-	-	0	-	-	-	-	-	-	
SC-D	3	30,04	34,21	33,57	32,61	2,25	5,04	0	-	-	-	-	-	-	
Metatarsal-Bd	MN.F	3	22,99	23,43	23,21	23,21	0,22	0,05	4	23,16	26,27	24,71	24,71	1,66	2,76
	MN.M	2	30,76	31,47	31,12	31,12	0,5	0,25	4	29,78	30,98	30,02	30,2	0,53	0,29
	MC.F	12	22,97	24,83	23,2	23,56	0,66	0,44	2	23,96	24,18	24,07	24,07	0,16	0,02
	MC.M	5	28,38	30,71	28,95	29,26	0,93	0,87	7	25,73	29,92	27,56	27,72	1,52	2,31
	MCD.F	2	23,93	24,33	24,13	24,13	0,28	0,08	2	23,09	23,92	23,51	23,51	0,59	0,34
	MCD.M	0	-	-	-	-	-	-	3	25,94	28,76	28,31	27,67	1,52	2,3
	GU	2	25,26	33,62	29,44	29,44	5,91	0,2	3	23,53	30,86	24,34	26,24	4,02	0,15
	JM	36	19,65	28,56	23,5	23,75	1,62	0,07	3	22,84	24,61	23,81	23,75	0,89	0,04
	SA	16	23,12	30,58	25,05	25,92	2,06	0,08	0	-	-	-	-	-	-
	GD	88	16,84	32,63	26,24	26,39	1,97	3,89	60	23,49	35,88	30,99	30,19	3,5	12,26
	ZC	1	27,9	27,9	27,9	27,9	-	-	0	-	-	-	-	-	-
	SC-C	1	37,04	37,04	37,04	37,04	-	-	1	29,13	29,13	29,13	29,13	-	-
	KO-L	1	36,28	36,28	36,28	36,28	-	-	0	-	-	-	-	-	-
	SC-D	1	31,67	31,67	31,67	31,67	-	-	0	-	-	-	-	-	-
TT	1	39,97	39,97	39,97	39,97	-	-	0	-	-	-	-	-	-	

Bone	Site	Fused bones							Unfused bones						
		NISP	Min	Max	Median	Mean	SD	CV	NISP	Min	Max	Median	Mean	SD	CV
Radius-Bd	MN.F	2	30,4	30,73	30,57	30,57	0,23	0,05	6	26,14	31,12	28,71	28,6	2,15	4,61
	MN.M	0	-	-	-	-	-	-	7	29,29	37,58	34,34	33,3	3,01	9,07
	MC.F	0	-	-	-	-	-	-	12	27,02	30,45	28,1	28,27	0,98	0,96
	MC.M	3	35,14	38,92	36,56	36,87	1,91	3,65	9	29,42	34,83	31,85	32,09	2,14	4,58
	MCD.F	0	-	-	-	-	-	-	3	28,78	29,7	29,03	29,17	0,48	0,23
	MCD.M	0	-	-	-	-	-	-	2	31,74	31,81	31,78	31,78	0,05	0
	GU	0	-	-	-	-	-	-	8	27,58	38,05	28,25	29,9	3,6	0,12
	JM	25	23,69	35,11	28,96	28,63	2,19	0,08	28	26,5	37,08	29,52	29,68	2,69	0,09
	SA	23	27,05	31,57	29,85	29,9	1,25	0,04	15	23,86	36,92	28,21	29,12	4,28	0,15
	GD	31	29,18	34,72	31,91	31,89	1,44	2,08	151	25,93	42,2	31,38	32,08	3,51	12,29
	AS	2	31,78	41,4	36,59	36,59	6,8	0,19	0	-	-	-	-	-	-
	ZC	0	-	-	-	-	-	-	4	33,6	39,52	37,32	36,94	2,96	0,08
	PG	0	-	-	-	-	-	-	1	33,82	33,82	33,82	33,82	.	.
	KO-U	1	28,34	28,34	28,34	28,34	-	-	1	27,14	27,14	27,14	27,14	.	.
	KU	1	33,13	33,13	33,13	33,13	-	-	0	-	-	-	-	-	-
SC-D	1	36,72	36,72	36,72	36,72	.	13,31	4	30,06	38,02	31,52	32,78	3,65	.	
Radius-Bp	MN.F	8	28,65	33,13	31,53	31,21	1,94	3,78	0	-	-	-	-	-	-
	MN.M	8	36,95	39,46	38,19	38,26	0,87	0,75	0	-	-	-	-	-	-
	MC.F	4	26,99	30,66	29,81	29,32	1,61	2,6	0	-	-	-	-	-	-
	MC.M	13	32,23	40,88	35,55	35,9	2,72	7,42	0	-	-	-	-	-	-
	MCD.F	3	29,01	32,4	29,48	30,3	1,84	3,37	0	-	-	-	-	-	-
	MCD.M	2	32,37	32,49	32,43	32,43	0,09	0,01	0	-	-	-	-	-	-
	BH	4	28,74	41,67	30,84	33,02	5,88	0,18	0	-	-	-	-	-	-
	GU	10	28,67	36,93	30,44	31,56	2,81	0,09	0	-	-	-	-	-	-
	JM	46	21,82	37,42	30,22	30,72	3,26	0,11	1	25,44	25,44	25,44	25,44	.	1
	SA	51	27,84	38,98	31,56	32,32	2,71	0,08	1	25,17	25,17	25,17	25,17	.	1
	GD	114	28,05	43,94	33,35	34,87	3,11	9,68	27	27,25	36,43	31,45	31,72	2,77	7,65
	AS	8	32,52	44,62	38,2	38,53	3,86	0,1	0	-	-	-	-	-	-
	ZC	1	37,74	37,74	37,74	37,74	-	-	0	-	-	-	-	-	-
	PG	3	30,13	30,47	30,18	30,26	0,18	0,03	0	-	-	-	-	-	-
	KO-U	1	28,77	28,77	28,77	28,77	-	-	0	-	-	-	-	-	-
SC-D	3	32,85	37,52	36,55	35,64	2,46	6,07	0	-	-	-	-	-	-	
Tibia-Dd	MN.F	6	19,3	21,75	20,44	20,51	0,89	0,79	2	18,54	18,75	18,65	18,65	0,15	0,98
	MN.M	1	24,25	24,25	24,25	24,25	-	-	6	22,35	25,04	23,53	23,75	0,99	0,02
	MC.F	7	19,31	21,03	19,79	20,1	0,7	0,5	4	18,08	20,12	19,03	19,07	1,08	1,17
	MC.M	5	22,3	25,51	22,82	23,23	1,33	1,76	7	21,53	23,57	22,52	22,45	0,74	0,55
	MCD.F	4	19,42	20,23	19,6	19,71	0,36	0,13	0	-	-	-	-	-	-
	MCD.M	0	-	-	-	-	-	-	1	20,25	20,25	20,25	20,2	.	.
	BH	4	19,07	24,76	23,54	22,73	2,69	0,12	0	-	-	-	-	-	-
	GU	6	18,81	24,18	20,07	21,07	2,24	0,11	1	18,08	18,08	18,08	18,08	.	1
	JM	49	17,38	23,46	19,32	19,34	1,25	0,07	4	20,33	24,05	22,63	22,41	1,56	0,07
	SA	54	17,56	27,34	19,99	20,45	1,77	0,09	6	19,01	23,71	20,24	20,86	1,87	0,09
	GD	40	19,74	29,1	21,84	22,28	1,92	3,69	64	19,11	27,06	22,69	22,59	2,2	4,82
	AS	2	27,57	31,78	29,68	29,68	2,98	0,1	0	-	-	-	-	-	-
	ZC	1	28,65	28,65	28,65	28,65	-	-	0	-	-	-	-	-	-
	PG	1	24,04	24,04	24,04	24,04	-	-	1	21,97	21,97	21,97	21,97	.	.
	KU	1	22,74	22,74	22,74	22,74	-	-	0	-	-	-	-	-	-
SC-D	2	22,18	27,39	24,79	24,79	3,68	13,57	1	21,43	21,43	21,43	21,43	.	.	

Site abbreviations: MN.F: Modern Northern Zagros Females, MN.M: Modern Northern Zagros Males, MC.F: Modern Central Zagros Females, MC.M: Modern Central Zagros Males, MCD.F: Modern Central Zagros Domestic Females, MCD.M: Modern Central Zagros Males, BH: Banahilk, GU: Guran, JM: Jarmo, SA: Sarab, GD: Ganj Dareh, AS: Asiab, ZC: Zawi Chemi, PG: Palegawra, KO-U: Kobeh Upper Levels (Upper Paleolithic), KO-L: Kobeh Lower Levels (Middle Paleolithic), SC-B: Shanidar Level B (Late Upper Paleolithic/Epipaleolithic), SC-C: Shanidar Level C (Early Upper Paleolithic), SC-D: Shanidar Level D (Middle Paleolithic).

Appendix 2—Summary statistics of lowland goats metrics (measurements follow von den Driesch 1976).

Bone	Site	Fused bones							Unfused bones						
		NISP	Min	Max	Median	Mean	SD	CV	NISP	Min	Max	Median	Mean	SD	CV
1st Phal.-GI	MS.F	29	33,5	37,19	35,61	35,38	1,01	1,03	0	-	-	-	-	-	-
	MS.M	38	38,07	48,37	40,23	41,39	3,07	9,41	6	38,01	39	38,26	38,42	0,42	0,17
	FK	27	31,69	43,53	35,45	36,09	3,16	9,97	3	35,1	40,32	37,19	37,54	2,63	6,9
	SF	22	24,62	42,98	35,44	35,01	5,09	0,15	6	34,26	38,65	35,95	36,13	1,54	0,04
	CS	8	33,25	36,86	35,38	35,32	1,21	0,03	0	-	-	-	-	-	-
	AK	128	29,5	46,45	37,49	38,31	3,1	9,61	5	36,25	44,05	38,68	39,77	3,15	-
2nd Phal.-GI	MS.F	21	23,46	25,9	24,71	24,67	0,62	0,39	0	-	-	-	-	-	-
	MS.M	15	25,15	27,78	27,27	26,97	0,82	0,68	0	-	-	-	-	-	-
	FK	11	20,85	28,4	25,23	25,39	2,65	7	1	22,53	22,53	22,53	22,53	-	-
	SF	16	20,92	29,04	24,84	25,04	2,19	0,09	2	27,18	27,54	27,36	27,36	0,26	0,01
	CS	9	22,36	29,87	25	25,2	2,46	0,1	0	-	-	-	-	-	-
	AK	108	24,38	26,71	25,09	25,19	0,94	0,89	3	26,02	28,94	26,03	27	1,68	2,83
Astragalus-Bd	MS.F	8	17,04	18,19	17,3	17,48	0,43	0,19	0	-	-	-	-	-	-
	MS.M	12	18,33	22,07	19,46	19,7	1,19	1,43	0	-	-	-	-	-	-
	FK	12	13,66	19,5	17,28	17,34	1,54	2,36	0	-	-	-	-	-	-
	SF	20	16,37	21,4	17,94	18,24	1,47	0,08	0	-	-	-	-	-	-
	CS	35	15	21,05	17,22	17,62	1,4	0,08	0	-	-	-	-	-	-
	AK	66	14,36	19,82	16,83	17,24	1,85	3,4	0	-	-	-	-	-	-
Calcaneus-Dd	MS.F	7	19,91	20,81	20,52	20,46	0,28	0,08	0	-	-	-	-	-	-
	MS.M	4	23,4	26,65	25,03	25,03	1,6	2,57	8	20,44	22,14	21,43	21,32	0,7	0,49
	FK	4	19,26	23,5	19,84	20,61	2	4	0	-	-	-	-	-	-
	SF	3	20,05	20,8	20,37	20,41	0,38	0,02	14	17,31	23,94	21,46	21,31	1,95	3,79
	CS	4	19,81	23	20,51	20,96	1,51	0,07	4	18,95	22,08	21,34	20,93	1,39	0,07
	AK	25	19,15	25,48	21,28	21,74	1,69	2,85	22	18,87	25,18	22,05	22,07	1,49	2,22
Humerus-Bd	MS.F	6	27,82	29,52	28,37	28,61	0,7	0,5	0	-	-	-	-	-	-
	MS.M	8	31,4	38,27	34,8	34,53	2,64	6,96	2	31,28	31,5	31,39	31,39	0,16	0,02
	FK	5	29,18	38,64	37,36	35,1	4	16,01	1	28,3	28,3	28,3	28,3	-	-
	SF	6	27,66	38,81	31,09	32,28	4,06	0,13	0	-	-	-	-	-	-
	CS	9	28,64	35,94	29,91	30,66	2,15	0,07	0	-	-	-	-	-	-
	AK	67	32,44	38,56	32,7	34,57	3,46	11,98	0	-	-	-	-	-	-
Metacarpal-Bd	MS.F	7	23,85	24,93	24,75	24,48	0,45	0,2	0	-	-	-	-	-	-
	MS.M	4	30,3	32,68	31,41	31,45	1,29	1,66	8	27,56	29,1	28,11	28,19	0,52	0,27
	FK	6	23,31	28,02	25,39	25,51	1,91	3,65	0	-	-	-	-	-	-
	SF	9	24,26	31,83	26,01	26,37	2,22	0,08	1	27,06	27,06	27,06	27,06	-	1
	CS	3	23,87	25,15	24,8	24,61	0,66	0,03	0	-	-	-	-	-	-
	AK	27	28,04	28,04	28,04	28,04	-	-	4	26,32	33,39	29,71	29,78	3,63	-
Metatarsal-Bd	MS.F	8	21,08	22,35	21,45	21,67	0,55	0,3	0	-	-	-	-	-	-
	MS.M	4	26,77	28,31	27,52	27,53	0,82	0,68	8	23,22	26,14	24,39	24,65	1,01	1,03
	FK	5	21,44	24,73	22,67	22,83	1,19	1,41	0	-	-	-	-	-	-
	SF	4	21,39	23,19	22,32	22,3	0,82	0,04	0	-	-	-	-	-	-
	CS	1	22,27	22,27	22,27	22,27	-	1	0	-	-	-	-	-	-
	AK	31	23,25	24,14	24,02	23,8	0,48	0,23	1	22,71	22,71	22,71	22,71	-	-
Radius-Bd	MS.F	2	25,37	25,83	25,6	25,6	0,33	0,11	5	26,33	27,12	26,71	26,71	0,33	0,11
	MS.M	2	31,91	32,19	32,05	32,05	0,2	0,04	10	28,44	38,28	29,73	31,19	3,64	13,24
	FK	2	27,54	27,72	27,63	27,63	0,13	0,02	4	25,07	29,58	27,14	27,23	1,91	3,64
	SF	1	28,37	28,37	28,37	28,37	-	-	5	25,46	33,84	30,78	29,36	3,7	0,13
	CS	1	30,97	30,97	30,97	30,97	-	-	3	28,5	36,05	31,98	32,18	3,78	0,12
	AK	12	31,02	31,02	31,02	31,02	-	-	2	30,65	30,74	30,7	30,7	0,06	0
Radius-Bp	MS.F	6	28,02	28,97	28,4	28,46	0,36	0,13	0	-	-	-	-	-	-
	MS.M	6	31,56	38,64	34,7	34,9	3,06	9,33	0	-	-	-	-	-	-
	FK	2	30,45	35,66	33,06	33,06	3,68	13,57	0	-	-	-	-	-	-
	SF	8	26,81	36,42	30,23	30,59	3,01	0,1	0	-	-	-	-	-	-
	CS	6	30,14	36,54	33,19	33,38	2,63	0,08	0	-	-	-	-	-	-
	AK	26	30,46	32,63	31,55	31,55	1,53	2,35	0	-	-	-	-	-	-
Tibia-Dd	MS.F	8	17,05	18,79	17,72	17,82	0,6	0,36	0	-	-	-	-	-	-
	MS.M	4	20,98	23,69	21,85	22,09	1,26	1,58	8	18,91	20,98	20,11	20,13	0,66	0,44
	FK	7	17,69	20,51	19,36	19,2	1,04	1,08	3	16,3	19,07	18,33	17,9	1,43	2,06
	SF	7	18,48	23,39	19,47	20,09	1,69	0,08	2	19,64	21,49	20,57	20,57	1,31	0,06
	CS	4	19,2	22,29	20,02	20,38	1,39	0,07	6	18,73	22,69	20,92	20,8	1,53	0,07
	AK	49	18,49	19,73	19,11	19,11	0,88	0,77	0	-	-	-	-	-	-
			17,5	25,92	19,86	20,4	1,84	3,4	31	16,81	24,66	20,91	20,87	1,99	3,96

Site abbreviations: MS.F: Modern Southern Zagros Females, MS.M: Modern Southern Zagros Males, FK: Farukhabad, SF: Sharafabad, CS: Chogha Sefid, CB: Chogha Bonut, AK: Ali Kosh.

Appendix 3—Summary statistics of highland sheep metrics (measurements follow von den Driesh 1976).

Bone	Site	Fused bones							Unfused bones						
		NISP	Min	Max	Median	Mean	SD	CV	NISP	Min	Max	Median	Mean	SD	CV
1st Phalanx-GI	MN.F	135	38,66	46,4	42,13	42,38	2,01	4,02	12	35,29	42	36,16	37,64	2,69	7,23
	MN.M	154	41,13	49,51	45,78	45,72	1,91	3,63	15	42,08	45,54	43,78	43,85	1,08	1,16
	MCD.F	16	38,05	42,11	40,03	39,99	1,16	1,34	0	-	-	-	-	-	-
	BH	1	38,1	38,1	38,1	38,1	-	-	0	-	-	-	-	-	-
	GU	1	43,3	43,3	43,3	43,3	-	-	0	-	-	-	-	-	-
	JM	10	33,13	40,54	37,47	37,55	2,38	5,65	0	-	-	-	-	-	-
	GD	18	37,06	51,36	49,56	47,73	3,69	13,64	2	49,46	50,39	49,93	49,93	0,66	0,43
	KS	6	44,26	50,45	47,84	47,42	2,28	0,05	4	47,03	48,3	47,36	47,51	0,57	0,01
	ZC	18	42,2	49,54	45,92	45,96	2,16	4,67	8	42,94	50,73	45,93	46,89	2,96	8,73
	SC-B	3	32,25	46,46	37,43	38,71	7,19	51,72	0	-	-	-	-	-	-
	KO-U	1	35,01	35,01	35,01	35,01	-	-	1	37,87	37,87	37,87	37,87	-	-
YC	3	46,81	48,29	47,24	47,45	0,76	0,58	0	-	-	-	-	-	-	
TT	1	53,17	53,17	53,17	53,17	-	-	0	-	-	-	-	-	-	
2nd Phalanx-GI	MN.F	18	23,05	28,69	24,9	25,31	1,83	3,37	0	-	-	-	-	-	-
	MN.M	49	24,35	30,22	27,41	27,41	1,67	-	0	-	-	-	-	-	-
	BH	5	23,2	26,65	24,83	24,8	1,33	1,78	0	-	-	-	-	-	-
	GU	2	25,57	26,86	26,22	26,22	0,91	0,04	3	22,61	26,54	25,87	25,01	2,1	4,42
	JM	14	21,29	24,83	23,79	23,5	1,03	1,06	0	-	-	-	-	-	-
	SA	1	25,95	25,95	25,95	25,95	-	-	0	-	-	-	-	-	-
	GD	29	25,95	34,26	28,52	28,6	1,85	3,44	2	28,85	29,31	29,08	29,08	0,33	0,11
	AS	8	26,2	29,84	28,25	28,13	1,29	1,67	0	-	-	-	-	-	-
	KS	4	25,89	29,84	27,04	27,45	1,85	0,07	0	-	-	-	-	-	-
	ZC	30	23,37	29,68	27,58	27,42	1,16	1,33	6	27,09	28,76	27,35	27,72	0,76	0,58
	SC-B	5	20,94	33,96	28,2	28,49	4,89	25,47	0	-	-	-	-	-	-
	KO-U	1	23,66	23,66	23,66	23,66	-	-	0	-	-	-	-	-	-
	YC	8	25,36	33,83	27,88	28,2	2,67	7,1	0	-	-	-	-	-	-
	SC-CD	1	27,68	27,68	27,68	27,68	-	-	0	-	-	-	-	-	-
Astragalus-Bd	MN.F	37	17,15	21,21	19,56	19,66	0,93	0,87	0	-	-	-	-	-	-
	MN.M	42	19,07	22,99	20,97	20,92	0,92	0,85	0	-	-	-	-	-	-
	MCD.F	4	19,91	22,26	21,07	21,08	1,23	1,52	0	-	-	-	-	-	-
	BH	14	17,41	22,08	18,53	18,79	1,21	1,46	0	-	-	-	-	-	-
	GU	3	19,38	20,23	19,76	19,79	0,43	0,02	0	-	-	-	-	-	-
	JM	101	16,42	22,3	18,39	18,53	1,01	1,02	1	15,25	15,25	15,25	15,25	-	-
	SA	16	16,26	21,88	17,7	18,14	1,59	2,53	0	-	-	-	-	-	-
	GD	37	18,07	23,62	21	21,28	1,5	2,25	0	-	-	-	-	-	-
	AS	7	19,05	22,83	21,15	21,18	1,21	1,46	0	-	-	-	-	-	-
	KS	5	18,69	22,67	22,09	21,36	1,62	0,08	0	-	-	-	-	-	-
	ZC	18	18,02	24,58	21,32	21,54	1,53	2,34	0	-	-	-	-	-	-
	SC-B	1	19,25	19,25	19,25	19,25	-	-	0	-	-	-	-	-	-
	KO-U	6	17,8	25,2	18,41	20,11	3,05	9,33	0	-	-	-	-	-	-
	YC	8	25,36	33,83	27,88	28,2	2,67	7,1	0	-	-	-	-	-	-
SC-CD	2	18,17	23,68	20,93	20,93	3,9	15,18	0	-	-	-	-	-	-	
Calcaneus-Dd	MN.F	21	22,7	27,61	24,46	24,88	1,4	1,96	15	20,35	25,81	24,52	23,93	1,59	2,53
	MN.M	18	24,21	28,22	25,73	26,01	1,45	2,09	21	23,62	27,21	24,95	25,25	1,1	1,2
	MCD.F	1	26,28	26,28	26,28	26,28	-	-	2	24,95	25	24,98	24,98	0,04	-
	JM	11	20,43	23,97	23,07	22,81	1,1	1,2	11	21,23	26,3	23,61	23,66	1,35	1,82
	SA	5	22,26	23,81	22,62	22,88	0,62	0,39	2	23,25	23,86	23,56	23,56	0,43	0,19
	GD	4	26,47	28,27	27,19	27,28	0,81	0,66	4	22,58	27,11	24,38	24,61	2,35	5,53
	AS	3	25,34	29,51	26,25	27,03	2,19	4,81	0	-	-	-	-	-	-
	KS	2	25,99	26,87	26,43	26,43	0,62	0,02	0	-	-	-	-	-	-
	ZC	1	27,21	27,21	27,21	27,21	-	-	1	27,8	27,8	27,8	27,8	-	-
	SC-AB	1	21,56	21,56	21,56	21,56	-	-	0	-	-	-	-	-	-
Humerus-Bd	MN.F	35	26,75	34,98	31,74	31,65	2,08	4,34	0	-	-	-	-	-	-
	MN.M	42	30,65	38,19	35,31	35,06	2,05	4,2	0	-	-	-	-	-	-
	MCD.F	4	31,27	36,72	34,13	34,06	2,82	7,97	0	-	-	-	-	-	-
	BH	16	27,57	38,02	31,93	32,15	2,91	8,47	0	-	-	-	-	-	-
	GU	1	35,83	35,83	35,83	35,83	-	1	0	-	-	-	-	-	-
	JM	69	21,91	38,2	29,61	29,81	2,79	7,76	18	26,47	31,31	29,68	1,21	3,13	9,79
	SA	15	26,42	40,02	30,1	31,2	3,09	9,51	1	27,55	27,55	27,55	27,55	-	-
	GD	18	33,55	38,58	35,54	35,81	1,62	2,64	1	37,03	37,03	37,03	37,03	-	-
	AS	3	32,39	34,87	32,48	33,25	1,41	1,98	0	-	-	-	-	-	-
	KS	8	32,09	39,02	35,01	35,73	2,6	0,07	0	-	-	-	-	-	-
	ZC	6	33,12	39,23	34,47	35,43	2,71	7,34	0	-	-	-	-	-	-
	SC-AB	1	31,44	31,44	31,44	31,44	-	-	0	-	-	-	-	-	-
	KO-U	2	29,37	32,21	30,79	30,79	2,01	4,03	0	-	-	-	-	-	-
	KO-L	1	31,14	31,14	31,14	31,14	-	-	0	-	-	-	-	-	-
SC-CD	1	25,6	25,6	25,6	25,6	-	-	0	-	-	-	-	-	-	

Bone	Site	Fused bones							Unfused bones						
		NISP	Min	Max	Median	Mean	SD	CV	NISP	Min	Max	Median	Mean	SD	CV
Metacarpal-Bd	MN.F	26	23,56	27,45	25,32	25,5	1,25	1,57	9	24,79	28,28	25,24	26,24	1,38	1,91
	MN.M	29	25,56	30,64	29,46	28,91	1,49	2,22	14	26,08	32,41	28,52	28,86	2,06	4,24
	MCD.F	4	27,22	29,34	28,46	28,37	1,02	1,05	0	-	-	-	-	-	-
	SA	2	22,38	31,56	26,97	26,97	6,49	42,14	0	-	-	-	-	-	-
	GU	1	24,66	24,66	24,66	24,66	-	-	0	-	-	-	-	-	-
	JM	14	22,49	29,02	24,42	24,62	1,95	3,79	2	23,61	24,68	24,15	24,15	0,76	0,57
	GD	10	26,44	30,88	28,52	28,43	1,23	1,52	3	30,75	32,89	32,51	32,05	1,14	1,3
	AS	2	23,08	30,88	26,98	26,98	5,52	30,42	0	-	-	-	-	-	-
	KS	1	28,48	28,48	28,48	28,48	-	-	0	-	-	-	-	-	-
	ZC	4	27,94	31,13	29,98	29,76	1,39	1,94	3	28,14	30	29,39	29,18	0,95	0,9
	SC-AB	1	28,52	28,52	28,52	28,52	-	-	0	-	-	-	-	-	-
KO-U	1	27,72	27,72	27,72	27,72	-	-	0	-	-	-	-	-	-	
YC	1	26,09	26,09	26,09	26,09	-	-	0	-	-	-	-	-	-	
Metatarsal-Bd	MN.F	25	23,22	27,69	24,7	25,05	1,29	1,66	8	23,08	27,02	24,48	24,71	1,59	2,52
	MN.M	25	24,86	29,31	27,34	27,14	1,39	1,93	16	25,24	29,64	27,51	27,54	1,31	1,73
	MCD.F	4	25,22	27,5	26,15	26,25	1,09	1,18	0	-	-	-	-	-	-
	BH	1	24,13	24,13	24,13	24,13	-	-	0	-	-	-	-	-	-
	GU	1	27,9	27,9	27,9	27,9	-	-	1	26,64	26,64	26,64	26,64	.	1
	JM	24	20,44	32,06	22,61	23,02	2,26	5,11	2	23,49	24,41	23,95	23,95	0,65	0,42
	SA	4	22,12	27,42	22,66	23,72	2,49	6,18	0	-	-	-	-	-	-
	GD	9	26,16	32,6	28,41	28,68	1,99	3,94	2	32,38	32,83	32,61	32,61	0,32	0,1
	AS	1	27,11	27,11	27,11	27,11	-	-	0	-	-	-	-	-	-
	KS	3	28,55	30,1	29,16	29,27	0,78	0,03	0	-	-	-	-	-	-
	ZC	3	27,63	32,14	28,84	29,54	2,33	5,45	2	28,91	29,7	29,31	29,31	0,56	0,31
SC-AB	1	26,45	26,45	26,45	26,45	-	-	0	-	-	-	-	-	-	
YC	1	26,09	26,09	26,09	26,09	-	-	0	-	-	-	-	-	-	
Radius-Bd	MN.F	16	27,88	33,75	30,26	30,43	1,59	2,52	18	25,36	30,5	28,73	28,49	1,53	2,34
	MN.M	12	30,55	34,85	33,18	32,95	1,14	1,31	25	29,91	35,44	32,02	32,33	1,56	2,44
	MCD.F	2	34,05	34,53	34,29	34,29	0,34	0,12	1	33,32	33,32	33,32	33,32	.	.
	BH	3	27,17	30,93	29,31	29,14	1,89	3,56	0	-	-	-	-	-	-
	GU	3	28,98	33,21	30,38	30,86	2,16	0,07	0	-	-	-	-	-	-
	JM	18	25,78	33,87	28,19	28,43	1,78	3,79	10	25,02	27,37	26,54	26,44	0,65	0,43
	SA	2	26,95	27,39	27,17	27,17	0,31	0,1	1	31,29	31,29	31,29	31,29	.	.
	GD	6	30,53	36,42	33,59	33,09	2,24	5,02	2	33,37	33,98	33,68	33,68	0,43	0,19
	KS	1	30,89	30,89	30,89	30,89	-	1	0	-	-	-	-	-	-
	ZC	0	-	-	-	-	-	-	6	24,46	40,15	33,13	33,59	5,82	33,85
	YC	1	25,66	25,66	25,66	25,66	-	-	0	-	-	-	-	-	-
SC-CD	0	-	-	-	-	-	-	1	28,77	28,77	28,77	28,77	.	.	
Radius-Bp	MN.F	37	26,57	35,88	32,39	32,34	1,94	3,77	0	-	-	-	-	-	-
	MN.M	41	31,14	38,64	35,69	35,48	1,93	3,74	0	-	-	-	-	-	-
	MCD.F	4	32,94	37,75	35,39	35,37	2,75	7,54	0	-	-	-	-	-	-
	BH	3	29,12	38,31	33,44	33,62	4,6	21,14	0	-	-	-	-	-	-
	GU	5	26,76	34,36	31,1	31,06	2,82	0,09	0	-	-	-	-	-	-
	JM	30	27,7	36,53	30,12	30,9	2,18	4,75	3	26,93	27,85	27,13	27,3	0,48	0,23
	SA	8	27,97	37,32	31,2	31,52	2,83	7,98	1	30,08	30,08	30,08	30,08	.	.
	GD	11	32,57	39,26	37,55	36,7	2,2	4,82	2	28,84	38,12	33,48	33,48	6,56	43,06
	AS	2	33,18	34,8	33,99	33,99	1,15	1,31	0	-	-	-	-	-	-
	KS	1	40,56	40,56	40,56	40,56	-	-	0	-	-	-	-	-	-
	ZC	4	30,48	36,44	35,09	34,27	2,74	7,52	0	-	-	-	-	-	-
Tibia-Dd	MN.F	27	20,21	25,96	21,28	21,92	1,48	2,19	10	17,94	21,74	20,09	19,9	1,2	1,44
	MN.M	32	20,62	25,88	22,9	23,05	1,4	1,96	10	21,64	24,24	22,55	22,62	0,76	0,58
	MCD.F	2	22,76	23,8	23,28	23,28	0,74	0,54	2	22,34	22,42	22,38	22,38	0,06	2
	BH	4	17,91	24,03	22,15	21,56	2,61	6,81	2	17,66	21,48	19,57	19,57	2,7	7,3
	GD	2	20,26	22,79	21,53	21,53	1,79	3,2	5	18,96	21,47	20,23	20,21	0,89	0,8
	GU	7	18,89	24,72	20,7	21,45	2,16	0,1	0	-	-	-	-	-	-
	JM	23	17,7	24,38	20	20,32	1,66	2,77	5	17,56	20,85	19,19	19,14	1,39	1,92
	SA	13	22,59	27,2	24,75	24,7	1,33	1,77	5	23,65	25,47	24,41	24,39	0,75	.
	AS	2	23,83	25	24,42	24,42	0,83	0,68	0	-	-	-	-	-	-
	ZC	1	28,81	28,81	28,81	28,81	-	-	0	-	-	-	-	-	-
	SC-B	1	22,61	22,61	22,61	22,61	-	-	0	-	-	-	-	-	-
KO-U	1	20,21	20,21	20,21	20,21	-	-	0	-	-	-	-	-	-	
YC	1	24,49	24,49	24,49	24,49	-	-	0	-	-	-	-	-	-	

Site Abbreviations follow Appendix 1.

Appendix 4—Summary statistics of lowland sheep metrics (measurements follow von den Driesch 1976).

Bone	Site	Fused bones							Unfused bones						
		NISP	Min	Max	Median	Mean	SD	CV	NISP	Min	Max	Median	Mean	SD	CV
1st Phalanx-GI	MS-F	24	37,49	41,26	39,06	39,33	1,26	1,6	8	37,72	39,93	39,33	39,04	0,81	0,66
	MS-M	32	38,57	42,8	41,08	41,01	1,32	1,75	0	-	-	-	-	-	-
	FK	30	32	43,51	36,73	37,44	2,74	7,52	4	35,56	40,04	37,69	37,75	1,83	3,35
	SF	30	31,84	45,85	39,81	38,95	3,91	15,29	8	34,18	45,26	42,22	41,68	3,45	11,87
	CS	1	33,56	33,56	33,56	33,56	-	-	0	-	-	-	-	-	-
	AK	4	39,43	50,29	42,32	43,59	5,2	27,06	0	-	-	-	-	-	-
2nd Phalanx-GI	MS-F	23	22,37	25,1	23,33	23,56	0,89	0,79	8	22,8	24,31	23,67	23,65	0,54	0,29
	MS-M	31	22,61	26,52	23,78	23,97	1,02	1,04	0	-	-	-	-	-	-
	FK	19	21,35	29,19	22,91	23,66	2,03	4,13	2	22,26	23,42	22,84	22,84	0,82	0,67
	SF	37	21,14	28,85	24	24,1	1,91	3,66	2	26,12	26,5	26,31	26,31	0,27	0,07
	CS	7	22,34	31,68	28,13	26,97	3,42	0,13	0	-	-	-	-	-	-
	AK	19	22,86	29,85	26	26,08	2,01	4,04	0	-	-	-	-	-	-
Astragalus-Bd	MS-F	8	16,87	17,96	17,33	17,33	0,36	0,13	0	-	-	-	-	-	-
	MS-M	8	16,77	18,57	17,05	17,34	0,72	0,51	0	-	-	-	-	-	-
	FK	8	18,18	19,95	19,16	19,06	0,7	0,5	0	-	-	-	-	-	-
	SF	19	15,38	20,63	19,37	19	1,22	1,48	0	-	-	-	-	-	-
	CS	11	16,11	20,5	17,97	18,23	1,48	0,08	0	-	-	-	-	-	-
	AK	9	17,09	22,4	20,73	20,19	1,69	2,86	0	-	-	-	-	-	-
Calc.-Dd	MS-F	2	21,35	21,57	21,46	21,46	0,16	0,02	5	20,64	22,47	21,49	21,57	0,87	0,75
	FK	5	20,59	24,58	21,43	22,38	1,89	3,56	1	23,08	23,08	23,08	23,08	.	.
	SF	3	21,96	22,82	22,77	22,52	0,48	0,23	3	22,65	24,92	24,08	23,88	1,15	1,32
	CS	1	21,42	21,42	21,42	21,42	-	-	1	26,3	26,3	26,3	26,3	26,3	.
	AK	1	24,4	24,4	24,4	24,4	-	-	0	-	-	-	-	-	-
	MS-F	6	27,01	30,14	29,14	28,77	1,29	1,67	2	28,9	29,4	29,15	29,15	0,35	0,13
Humerus-Bd	MS-M	8	28,57	30,12	29,72	29,57	0,52	0,27	0	-	-	-	-	-	-
	FK	10	26,48	34,73	30,53	30,79	2,81	7,89	0	-	-	-	-	-	-
	SF	6	29,38	33,37	31,94	31,8	1,36	1,86	0	-	-	-	-	-	-
	CS	8	25,55	35,72	30,71	30,9	3,34	0,11	0	-	-	-	-	-	-
	AK	6	29,47	33,88	31,42	31,6	1,69	2,86	0	-	-	-	-	-	-
	MS-F	4	20,97	24,47	22,78	22,75	1,98	3,91	4	24,15	25,75	24,94	24,95	0,7	0,48
Metacarp.-Bd	MS-M	6	23,53	24,65	24,01	24,06	0,39	0,15	2	23,38	23,69	23,54	23,54	0,22	0,05
	FK	3	23,16	27,52	24,54	25,07	2,23	4,97	0	-	-	-	-	-	-
	SF	3	24,02	28,48	26,1	26,2	2,23	4,98	1	27,38	27,38	27,38	27,38	.	.
	AK	1	28,43	28,43	28,43	28,43	.	.	0	-	-	-	-	-	-
	MS-F	3	19,98	22,78	20,18	20,98	1,56	2,44	4	23,59	24,67	24,11	24,12	0,5	0,25
	Metatars.-Bd	MS-M	6	22,12	23,08	22,95	22,72	0,45	0,2	2	22,86	23,08	22,97	22,97	0,16
FK		4	21,19	23,65	22,48	22,45	1,14	1,3	0	-	-	-	-	-	-
SF		3	22,15	25,98	22,67	23,6	2,08	4,32	2	22,37	28,66	25,52	25,52	4,45	19,78
AK		3	24,06	27,53	25,24	25,61	1,76	3,11	0	-	-	-	-	-	-
MS-F		0	-	-	-	-	-	-	8	24,87	27,18	26,47	26,21	0,86	0,74
Radius-Bd		MS-M	2	26,54	26,57	26,56	26,56	0,02	0	5	26,84	28,09	27,83	27,64	0,51
	FK	2	29,58	29,98	29,78	29,78	0,28	0,08	2	27,71	29,93	28,82	28,82	1,57	2,46
	SF	5	27,98	34,39	32,57	31,78	2,55	6,52	3	28,41	31,1	28,77	29,43	1,46	.
	CS	3	26,07	28,45	26,19	26,9	1,34	0,05	2	26,85	27,64	27,25	27,25	0,56	0,02
	MS-F	6	28,1	30,17	29,49	29,35	0,8	0,65	2	28,71	28,89	28,8	28,8	0,13	0,02
	Radius-Bp	MS-M	8	29,54	32,3	30,64	30,74	1,07	1,14	0	-	-	-	-	-
FK		6	26,03	34,41	30,77	30,17	2,97	8,84	0	-	-	-	-	-	-
SF		5	27,42	32,09	29,24	29,61	2,22	4,93	0	-	-	-	-	-	-
CS		4	26,1	29,17	28,42	28,03	1,45	0,05	0	-	-	-	-	-	-
MS-F		6	17,75	20,54	20,13	19,49	1,27	1,6	2	20,74	20,88	20,81	20,81	0,1	0,01
Tibia-Dd		MS-M	6	18,74	19,78	19,15	19,24	0,4	0,16	2	20,37	21,06	20,72	20,72	0,49
	FK	4	22,23	24,75	23,55	23,52	1,36	1,84	1	19,25	19,25	19,25	19,25	.	.
	SF	6	18,35	24,22	20,21	20,69	2,11	4,45	2	22,1	23,15	22,63	22,63	0,74	0,55
	CS	4	18,59	20,38	19,56	19,52	0,88	0,05	0	-	-	-	-	-	-
	AK	1	19,77	19,77	19,77	19,77	-	-	0	-	-	-	-	-	-

Site Abbreviations follow Appendix 2.