Chapter 5
New Opportunities for Previously Excavated Sites: Paleoeconomy as a Human Evolutionary Indicator at Tabun Cave (Israel)

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Introduction

In terms of human evolution, the Near East is an exceptional region. It was the only area where Neanderthals and Anatomically Modern Humans (AMH) were known to have inhabited the same geographical territory during the Middle Paleolithic (~250–40 ka), sharing also the same lithic technology, known as the "Levantine Mousterian." This interesting scenario took place during Marine Isotope Stages (MIS) 7-3, a period involving several abrupt climatic changes that threatened the survival of both human species, thus provoking two subsequent replacements, AMH by Neanderthals and these later in turn by *Homo sapiens* (Bar-Yosef 2000; Shea 2003b) although probably with no direct confrontation. This makes the Levant a unique place to assess the adaptive skills of Neanderthals and AMH independently, without the disturbing effect of distinctive culture, as is the case during the Middle to Upper Paleolithic transition. In this sense, the paleoeconomic differences found between them can reasonably be related both to biological or cognitive dissimilarities or environmental conditions, the latter being known by means of paleoclimatic reconstructions.

Thanks to the large number of Mousterian assemblages found in the region, the archaeozoological record of the period is well known. However, many of the existing sites were excavated in the first half of the twentieth century (Turville-Petre 1932; Garrod and Bate 1937; McCown and Keith 1939; Neuville 1951) with old-fashioned analytical techniques, the aim of which was principally to recover human fossils, to document the succession of lithic industries and to reconstruct the paleoenvironment as a way to understand the available food resources. However, little attention was paid to characterizing human subsistence strategies or to understanding the accumulative agents of the bone assemblages (de la Torre and Domínguez-Rodrigo 2000). Nonetheless, this limitation was progressively overcome with new projects starting in the 1970–1980s (including the sites of Tabun, Kebara, Hayonim, Qafzeh and Amud), where not only excavation procedures and dating techniques were radically improved, but also where a wide range of multidisciplinary approaches were applied in order to better understand the way each site was formed and preserved and to accurately reconstruct the behavior of the human groups who lived there (see for example Rabinovich and Tchernov 1995; Speth and Tchernov 2001 or Stiner 2005).

Based on this new information, there is now a wide consensus on the importance that large-game hunting had during the Levantine Middle Paleolithic (Shea 2003a), the residual significance of scavenging as represented in preferences for certain anatomical parts and taphonomic alterations (Speth and Tchernov 1998) and the influence of climate change on human dispersal and replacement in the region (Frumkin et al. 2011; Shea 2008). However, data regarding comparative hunting skills between AMH and archaic populations are still scarce, probably due to the fact that both human species inhabited similar topographic areas but very different ecological scenarios (Bar-Yosef 2000) although the lack of well preserved faunal assemblages associated with anatomically modern humans in the region, limited only to Qafzeh and Skhul, is also a constraint. The resulting variations in the type and abundance of available ungulate species due to climatic oscillations (Tchernov 1998) might have then concealed any particular pattern in human behavior.

Given this background, detailed new studies are clearly needed to boost our understanding of human economic evolution, as relates to both environmental and biological changes, leading thus to a better evaluation of the reasons behind the final success of *Homo sapiens* during the Middle to Upper Paleolithic transition. Until new sites are discovered

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and analyzed, an interesting option to expand our paleoeconomic knowledge is to pay new attention to classic sites, but with a modern methodological approach that can overcome the existing biases of old excavation procedures. One of these classic sites is Tabun Cave, located in the foothills of Mount Carmel (Israel), in a cliff-line overlooking the nearby coastal plain. The importance of Tabun in the cultural sequencing of the Near East, through the characterisation of its industrial phases, is well-established (Bar-Yosef 1998; Copeland 1975; Jelinek 1982b) as is its key place in paleoanthropological studies due to the fact that it holds human remains of both AMH (Quam and Smith 1998; Rak 1998) and Neanderthals (Coppa et al. 2005; McCown and Keith 1939) dated to the Middle Paleolithic. In addition, Tabun Level D is one of the few known Early Middle Paleolithic sites of the region, thus providing a unique chronological and evolutionary sequence throughout MIS 7-MIS 5 that can reveal relevant information about economic differences between AMH and archaic populations.

However, the long-available faunal assemblage has only been studied from a paleontological point of view (Bate 1937; Garrard 1981, 1982), usually without any taphonomic considerations. Not surprisingly, the lack of adequate excavation procedures during the 1930s, with a marked preference for the more diagnostic elements (i.e. epiphyses and teeth) and the almost total neglect of the shafts of long bones and axial remains, has discouraged a deeper analysis. Despite this, with the necessary precautions, the deposit might still provide new insights into subsistence strategies, if exhaustive taphonomic techniques to maximize the information that can be extracted are used. In this sense, the differential collection of faunal remains that occurred during the excavations may make the study more difficult, but does not prevent it. On one hand, it is possible that the biases were not as significant as previously thought, as the results of the skeletal profile study will show later. On the other hand, being aware of this problem, there are still useful comparative techniques that can be applied.

Consequently, the objective of the study presented here is to reappraise the faunal material of Garrod's excavation at Tabun Cave from a new paleoeconomic perspective, and to contextualize the obtained data with other well-known Levantine Middle Paleolithic sites. This has allowed the identification of behavioral differences between the two human species that occupied the site. As a result, a new hypothesis of human mobility and hunting preferences has been formulated, which is in agreement with biological and cognitive changes. Bearing this information in mind, the reasons behind the replacement of AMH at the end of MIS 5 by Neanderthals have been evaluated.

Materials and Methods

Tabun Cave is located on Mount Carmel (northern Israel) 45 m above present sea level in the Wadi el-Mughara valley (see Fig. 5.1). The entrance faces northwest, overlooking the Mediterranean coastal plain. The site contained a very long stratigraphic sequence from Lower Paleolithic to historical times. Dorothy Garrod first excavated Tabun between 1929 and 1934 (Garrod and Bate 1937), with rather expedited procedures, although this did not prevent her from recovering one of the richest Middle Paleolithic assemblages in the Levant. Garrod designated the Levantine Mousterian levels as B, C and D based mainly on differences in lithic industries. Between 1967 and 1972, Jelinek carried out a new excavation of the site, but unfortunately neither human nor faunal remains were recovered (Jelinek et al. 1973; Jelinek 1982a). There have been different

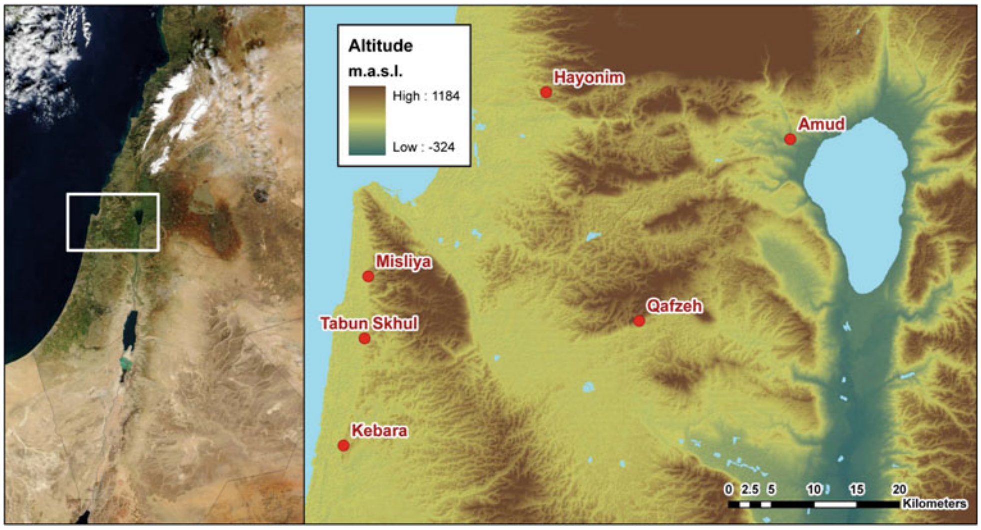

Fig. 5.1 Location of Tabun Cave and other sites cited in the text. Sea level at its present position

estimates of the age of the various levels at Tabun over time. At present, thermoluminescence, electron spin resonance and U-series absolute dates are available for Tabun (Grün and Stringer 2000: 602; Mercier and Valladas 2003), placing Level D, attributed to archaic human species, at the end of MIS 8 or second half of MIS 7, Level C, with AMH fossils, in the first part of MIS 5, and Level B at the end of MIS 5, with Neanderthal remains present (Shea 2003a, b, 2008). I have followed Bar-Yosef and Callander's (1999) assumption that the Neanderthal skeleton C1 is better placed within Level B and Rak's (1998) study when he attributes specimen C2 to an AMH jaw.

The current analysis was conducted in the Department of Paleontology at the Natural History Museum in London (NHM), where the material is currently curated. Only macromammalian remains were considered. Starting with the taxonomic and anatomical identification made by Garrard (1981), newly found specimens that were previously ignored, together with remains a priori unidentified but now successfully recognized using the large comparative collection of the NHM, were added to the study. The following indices were applied in terms of quantification: Number of Identified Specimens (NISP) (Payne 1975), Minimum Number of Individuals (MNI; Klein and Cruz-Uribe 1984), Minimum Number of Skeletal Elements (MNE; Marín-Arroyo 2009a) and Minimum Animal Units (MAU; Binford 1978). Biomass calculation was made by multiplying values of useable meat given by Garrard (1998: 63) by the MNI. This might be representative of human diet regardless of the differential transport that each prey might have undergone, because most edible parts would have been consumed should primary access to carcasses have occurred. In order to favor comparative analysis, different taxa were grouped together according to their size into large (*Rhinoceros/Hippopotamus/Bos/Equus/Camelids*), medium (*Cervus/Dama/Capra/Sus*) and small (*Gazella/Capreolus*) ungulate groups. Mountain gazelle and ibex are considered mountain species whereas the remaining ones are better suited to plains environments. The latter classification will allow the identification of trends in hunting preferences as a function of topographic relief, as this variable is not altered by climate change, unlike vegetation cover, which, on the other hand, can not be utilized due to a lack of adequate paleoenvironmental reconstructions in space and time.

Every element was examined under a 40× binocular microscope in order to detect any anthropogenic bone surface modifications, such as cut marks [identified as evisceration, skinning, dismembering and defleshing marks following Binford (1981) and Pérez Ripoll (1992)], hammerstone percussion marks [including conchoidal notches (Bunn 1981; Capaldo and Blumenschine 1994; Pickering and Egeland 2006), type and angle of fracturing (fresh-green versus old-dry), thermal alterations and trampling (Behrensmeyer et al. 1986). Carnivore and rodent gnawing marks and traces of digestion were also identified (Binford 1981; Stiner 1994) as well as other biological and physico-chemical alterations, such as weathering (Behrensmeyer 1978), root etching, carbonate deposits (Shipman 1981; Fisher 1995), dissolution or mineral coatings (mainly manganese, see Marín-Arroyo et al. 2008).

The ungulate mortality patterns (i.e. juvenile, prime or old adult) was assessed by both dental eruption and wear stage of dp4, P4 and M3, following Stiner (1991, 2005), and fusion of the bone epiphyses. For gazelle, the work of Munro et al. (2009) was used. The diet breadth and the degree of anthropogenic use of the environment has been evaluated with the Inverse of Simpson's Index (1949), whose maximum value equals the number of consumed species only when they are in the same proportion.

Differential transport of carcasses and the related functionality of the site was investigated using bivariable correlations of %MAU with utility (in terms of %MGUI following Binford 1978) and bone survivorship (represented by bone density following Lam et al. 1999). Pielou's evenness index (1966) was used to assess skeletal completeness for each size-class.

Finally, the relationship between the consumed fauna and the environment was investigated by estimating the catchment areas associated with several contemporaneous sites (Tabun, Misliya, Hayonim, Amud, Kebara, Skhul and Qafzeh) and characterizing the local relief, following the methodology described by Marín-Arroyo (2009b). This approach is based on the hypothesis that more carcass processing at the kill-site would arise when animals are hunted far from the base camp, implying thus non-desirable larger transport costs of low-yield anatomical parts. The Central Place Prey Foraging Model (Cannon 2003) predicts that small animals will likely be transported complete but that there is also a threshold of distance from the base camp beyond which the energetic yield of hunting this size of animals will diminish, favoring the exploitation of large game. Encounter rates will also affect these decisions, so that the shortage of a type of prey should prevent their usual consumption, above all when longer travel times are needed. Biotope abundance has been used as a proxy for encounter rates and so, the higher the biotope surface at a certain distance from the base camp, the larger the likelihood of hunting animals related to that kind of environment compared with other animals located at the same distance. From a practical point of view, a digital model of the terrain around the sites has been produced including the continental shelf (ASTER GLOBAL DEM and ETOPO1 data). An average sea level height of −80 and −40 m has been estimated for glacial and interglacial periods respectively (Siddall et al. 2006). Traveling times across the territory have been estimated with empirical formulae depending on distance, slope angles, movement direction (uphill or downhill) and the existence of insurmountable barriers (Marín-Arroyo 2008). In addition, to define the preferred biotopes or habitats for plains and mountain species within the boundaries determined by the catchment area, a threshold value of 10 % slope has been fixed to differentiate areas related to one or the other group of taxa. Beyond that value, grazing suitability is depleted (Holechek et al. 1998).

Results

Quantification of the Faunal Assemblage

The faunal assemblage is mainly dominated by complete bones. As previously mentioned, shaft fragments are rare and usually associated with epiphyses. A total of 3,402 specimens were accounted for, with roughly two-thirds belonging to Tabun B. 46 new bone remains were added to Garrard's total by means of a thorough evaluation of previously unidentified fragments. As a result of the recovery bias during Garrod's excavation, almost 99 % of the assemblage was identifiable taxonomically and anatomically. Table 5.1 shows the final figures for NISP, MNE and MNI together with biomass estimations. As can be seen, the NISP/MNE ratio (1.4 in Tabun D, 1.1 in Tabun C and 1.07 in Tabun B) is extremely low due to the same recovery problem.

Species Representation

A total of 25 mammal species were identified through the Tabun sequence; the carnivore frequency is low and ungulates clearly dominate the assemblage. In terms of NISP, *Dama mesopotamica* and *Gazella gazella* stand out, followed by a relatively large number of *Bos primigenius* (see Table 5.2). Taxonomic representation based on MNI values do not differ significantly. However, there are variations between levels in NISP. Thus, Tabun B shows a high presence of fallow deer (78.5 % NISP) in comparison with Tabun C (8.9 %) and Tabun D (31.3 %) while the percentage of gazelle decreases through time between 41.5 % in Tabun D to 15.1 % in Tabun B.

The significant difference in faunal composition of Tabun B was explained by Bate (1937) as being a result of climatic change, assuming then that the animal remains were introduced into the cave by humans, although she also considered that some of the Layer B fauna had been washed into the cave (1931: 150). However, as will be explained later, the origin of the accumulation of Tabun B was in fact mainly natural, and therefore the data from this level must not be interpreted economically. Other ungulates, such as *Cervus elaphus*, *Capreolus capreolus*, *Sus scrofa*, *Capra* sp. and *Equus* sp., are also represented in the deposit, although in small quantities, while large mammals such as *Dicerorhinus mercki* and *Hippopotamus amphibius* appear only in Levels D and C.

The percentage of large game, represented by rhinoceros, hippopotamus, horse, aurochs and camel, is highest in Tabun C (see Fig. 5.2). This is also the case with other Middle Paleolithic sites with known AMH accumulations, such as Skhul B (Marín-Arroyo 2011) and Qafzeh (Rabinovich and Tchernov 1995). In contrast, occupations by archaic hominins during the Early and Late Middle Paleolithic, such as Misliya (Yeshurun et al. 2007), Hayonim E (Stiner 2005), Amud B (Rabinovich and Hovers 2004) and Kebara VI-XIII (Speth and Tchernov 1998; Speth and Clark 2006), show a higher preference for the consumption of small ungulates, in these cases mountain gazelle. A similar comparison regarding the percentage of bone remains (NISP) belonging to taxa related to plains or mountain environments shows evidence of a greater use of rough terrain by archaic populations (see Fig. 5.2), which is not clearly related to the topographic relief around each settlement (see the heterogeneity of relative abundance of plains against mountains in Table 5.6). The diet breadth represented by the inverse of Simpson's Index notably reflects a more diverse use of the available resources during AMH occupations, with the inclusion of a larger proportion of high-ranked prey species typical of plains environments.

When biomass is calculated, the role of large fauna in all levels is more emphasized, as it comprises the most important caloric input in the diet, leaving gazelle as of secondary importance. This clearly shows the need to reconsider the role of each taxon in the subsistence strategies, based on the quantification of NISP (Marín-Arroyo and González Morales 2009), and opens new interpretative possibilities, as it would imply a more selective hunting strategy based on high-ranked species during the Middle Paleolithic, especially with regards to AMH. It is important to point out, however, that biomass calculations will establish the upper contribution of a species in the diet while NISP will define the lower. The real contribution will depend on both transport strategies and the role of scavenging in the paleoeconomy.

Bone Surface Modifications

Table 5.3 shows the abundance of different types of bone surface alterations in the assemblage. Due to the almost complete absence of bone shafts, cut marks were found mostly on epiphyses and near-epiphyses. In Tabun D (3.7 %) and especially Tabun C (9.2 %), the frequency of

Table 5.1 Assemblage quantification of Tabun Cave

	Tabun D				Tabun C				Tabun B			
	NISP	MNE	MNI	Biomass	NISP	MNE	MNI	Biomass	NISP	MNE	MNI	Biomass
Dicerorhinus mercki	12	11	2	2,084	26	26	2	2,500				
Hippopotamus amphibius	7	5	1	1,250	35	31	3	2,918				
Bos primigenius	31	31	3	934	100	97	3	1,200	49	45	3	1,200
Equus hydruntinus									39	39	3	600
Equus hemionus	3	3	1	150	4	4	2	300	4	4	1	150
Equus ferus					11	11	2	300				
Camellus sp.					1	1	1	150				
Cervus elaphus	46	37	3	200	21	17	2	150	17	17	2	150
Dama mesopotamica	141	115	11	696	43	38	3	174	1,729	1,599	78	4,022
Capreolus capreolus	5	5	1	8					3	3	1	8
Capra sp.	6	6	1	29	15	14	2	86	21	21	5	215
Gazella gazella	187	162	11	106	187	174	8	77	332	318	23	242
Sus scrofa	13	13	2	88	38	36	3	141	9	9	1	35
Lepus capensis					2	2	1					
Procavia capensis					3	2	2		1	1	1	
Hystrix indica	25	25	1						13	13	1	
Hyaena hyaena	1	1	1						9	9	2	
Crocuta crocuta	5	5	2		2	2	1					
Panthera pardus					2	2	1		48	46	4	
Felis cf. silvestris	1	1	1						2	2	1	
Canis aureus	2	2	1						4	4	1	
Canis lupus	27	27	2						2	2	1	
Vulpes vulpes					6	6	1		42	42	6	
Ursus arctos	2	2	1		15	15	1					
Martes foina									3	3	1	
Megafauna size					17	6						
Large mammal size					13	10						
Medium mammal size					3	2			3	3		
Small mammal size					10	8						
Indeterminate					1	1			3	3		
Total Ungulates	432	372	33		420	392	26		2,203	2,055	117	
Total Carnivores	38	38	8		25	25	4		110	108	16	
% Ungulates	84	82	73		76	78	68		94	94	87	
Total biomass				5,545				7,996				6,622
Total	**514**	**451**	**45**	**5,545**	**555**	**505**	**38**	**7,996**	**2,333**	**2,183**	**135**	**6,622**

tool-marked bones is high enough to confirm a human origin of the faunal deposit, whereas in Tabun B (1.1 %) the accumulating agent is unclear. The abundance of burnt bones and anthropogenic fractures confirms this assumption, with values of 20.7 and 10.6 % in Tabun C respectively. This is undoubtedly the level where more carcass processing occurred, perhaps due to a more permanent occupation (see some examples in Fig. 5.3). This is coherent with the abundant thin layers (red, white and black) resulting from repeated fires found at this level (Jelinek et al. 1973: 158; Albert et al. 1999). In addition, out of the 29 cut marks identified on the main ungulate remains from Level C, one corresponds to skinning, 24 to dismembering and five to defleshing (Marín-Arroyo 2011). They are located on meat-bearing skeletal elements such as the pelvis, ribs, radius and vertebrae, suggesting primary access to carcasses.

Carnivore activity was very scarce. Only 0.4 % of the assemblage shows gnawing marks, indicating that, at least in Tabun D and C, humans were the primary accumulating

Table 5.2 Taxonomic representation of Tabun Cave

	% NISP											
	Tabun D				Tabun C				Tabun B			
	NISP	MNE	MNI	Biomass	NISP	MNE	MNI	Biomass	NISP	MNE	MNI	Biomass
Dicerorhinus mercki	2.7	2.8	5.6	37.6	5.4	5.8	6.5	31.3	–	–	–	–
Hippopotamus amphibius	1.6	1.3	2.8	22.5	7.3	6.9	9.7	36.5	–	–	–	–
Bos primigenius	6.9	8.0	8.3	16.8	20.8	21.6	9.7	15.0	2.2	2.2	2.6	18.1
Equus hydruntinus	–	–	–	–	–	–	–	–	1.8	1.9	2.6	9.1
Equus hemionus	0.7	0.8	2.8	2.7	0.8	0.9	6.5	3.8	0.2	0.2	0.9	2.3
Equus ferus	–	–	–	–	2.3	2.4	6.5	3.8	–	–	–	–
Camellus sp.	–	–	–	–	0.2	0.2	3.2	1.9	–	–	–	–
Cervus elaphus	10.2	9.5	8.3	3.6	4.4	3.8	6.5	1.9	0.8	0.8	1.7	2.3
Dama mesopotamica	31.3	29.6	30.6	12.6	8.9	8.5	9.7	2.2	78.5	77.8	66.7	60.7
Capreolus capreolus	1.1	1.3	2.8	0.1	–	–	–	–	0.1	0.1	0.9	0.1
Capra sp.	1.3	1.5	2.8	0.5	3.1	3.1	6.5	1.1	1.0	1.0	4.3	3.2
Gazella gazella	41.5	41.8	30.6	1.9	38.9	38.8	25.8	1.0	15.1	15.5	19.7	3.7
Sus scrofa	2.9	3.4	5.6	1.6	7.9	8.0	9.7	1.8	0.4	0.4	0.9	0.5

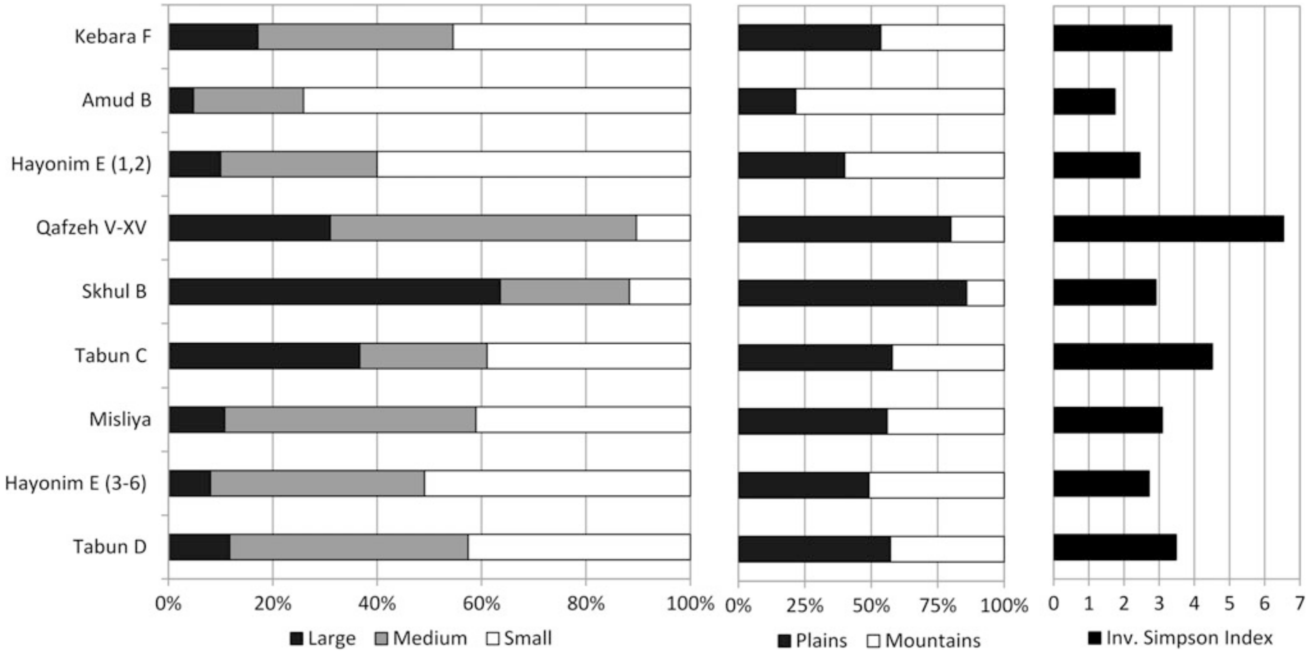

Fig. 5.2 Diet comparison of Levantine Middle Paleolithic in terms of NISP

agent with carnivores having a secondary and less important role (see results from actualistic studies in Marean 1998: 129; Marean and Spencer 1991; Marean et al. 1992).

The case with Tabun B is rather different. In addition to a low, although not negligible, level of human activity, the overall appearance of the bone assemblage is different throughout. On the one hand, bones show a white colouring with some manganese dendrites, related to a likely period of ponding in the cave, contrasting clearly with the general brown colouring of the bones in Tabun C and D (high presence of organic material in the sediment as a result of intense human occupation, see Marín-Arroyo et al. 2008). The action of water is also evidenced by the larger amount of dissolution and subaerial weathering. On the other hand, some bones appear in anatomical articulation and predominantly complete. The breakage pattern is typical of mechanical destruction produced by pressure applied by stones/bones within the sediment (Fisher 1995). Bearing this in mind, a natural accumulation of carcasses caused by animals falling through the hole in the cave roof can be

Table 5.3 Assemblage taphonomy of Tabun Cave

Bone modifications	%			
	Tabun B	Tabun C	Tabun D	Total
Cut marks	1.1	9.2	3.7	2.7
Impact scar	0.1	0.4	0.4	0.2
Green-bone fracture	2.3	10.6	2.9	3.6
Burnt	1.6	20.7	3.3	4.7
Gnaw-marks	0.2	1.6	0.4	0.4
Rodent-marks	0.0	0.4	0.2	0.1
Weathering	4.9	0.8	1.6	3.7
Trampling	3.5	0.6	0.4	2.5
Insect/fungus	0.0	1.4	0.0	0.2
Root etching	0.7	1.8	0.2	0.8
Carbonate	10.5	15.5	16.7	12.0
Coating (mineral)	12.6	10.6	11.9	12.0
Dissolution	9.7	2.2	2.3	7.3
Polishing	0.2	0.2	0.0	0.1

Fig. 5.3 Examples of tool-marked bones identified in Tabun Cave. **a** Lumbar vertebra of aurochs from Tabun C. **b** Metapodial of fallow deer from Tabun C with cut marks in the caudal proximal meta-diaphysis to cut tendons. **c** Shaft of gazelle femur from Tabun C with defleshing marks. **d** Tibia of fallow deer from Tabun B with dismembering marks. **e** Close-up of D. **f** Metacarpal of fallow deer from Tabun B

confirmed (Bate 1937: 150). However, this does not imply that the Tabun B assemblage is completely paleontological. The presence of cut marks on some fallow deer remains, as well as thermally alterated bones (identified on 1.6 % of the remains), seems to suggest an occasional human consumption of ungulates, possibly those accumulated naturally and found later by humans who knew the potential of the cave as a natural trap.

Apart from the cut marks found on ungulate remains, there are also some tool-marked carnivore bones, such as a metatarsal of *Panthera pardus* in Tabun B, probably related to skinning, and a radius of *Ursus* sp. in Tabun C that shows fresh breakage, burn traces and several dismembering marks, which could mean meat and marrow exploitation as well as skin use.

Skeletal Element Profiles

The MNE values for each skeletal element and class-size are presented in Table 5.4. Tabun B, which was not quantified anatomically by Garrard (1981), is also shown. The vast majority of skeletal elements in the assemblage are teeth (61 %), followed by feet (metapodial + phalanx) (24 %). The representation of long bones is only 6 % and it is mainly characterized by epiphyses of small-medium sized taxa, mostly with shafts attached. The axial skeleton is only represented by a proportion of 1 %.

The study of skeletal profiles at Tabun is problematic due to the excavation bias. There is now a wide consensus on the importance of recovering and quantifying long bone shafts in order not to hinder the economic interpretation (Marean and Frey 1997). However, taking into account the limitations of the available information, there is still room for drawing relevant conclusions if comparative analyses are applied, hence playing down individual absolute results. In this way, the effect of the bias in the collection can be side-stepped to a certain extent, as its influence would have been similar in the whole assemblage.

Figure 5.4 shows the skeletal profiles in terms of MAU. In general, small ungulates are more evenly represented than larger game, whereas long bones are less abundant in medium-size game. These results are consistent with a mostly whole transport of mountain gazelle and roe deer carcasses, whose smaller weight does not require the processing of the prey at the kill site (Cannon 2003), and with an intense defleshing of large fauna before transport, in order to maximize the energetic contribution to the base camp, particularly if the animal was hunted a long distance away (O'Connell et al. 1988, 1989). Taking into account

Table 5.4 Skeletal representation of large, medium and small ungulates in Tabun Cave

MNE w isolated teeth/tarsals	Tabun B			Tabun C			Tabun D		
	LU	MU	SU	LU	MU	SU	LU	MU	SU
Antler	–	2	–	–	2	4	–	1	11
Maxilar	22	61	7	1	1	4	–	10	4
Mandible	–	82	10	3	16	10	2	11	14
Teeth	50	976	234	124	29	82	31	114	91
Atlas	–	–	–	–	–	–	–	–	–
Axis	–	2	–	–	1	–	–	1	–
Cervical vert	–	2	–	–	1	–	–	–	–
Thoracic vertebrae	–	3	1	–	–	–	–	–	2
Lumbar vertebrae	–	4	–	1	–	1	–	–	–
Ribs	–	2	–	1	–	2	–	–	–
Sternum	–	10	–	–	–	–	–	–	–
Scapula	–	2	–	–	–	6	1	1	1
Humerus	–	11	4	–	2	4	1	1	5
Radius	–	14	4	1	2	2	3	1	4
Carpals	–	112	1	3	–	–	1	–	–
Metacarpal	1	26	10	1	7	4	3	5	7
Pelvis	–	1	–	–	1	3	–	–	–
Sacrum	–	1	–	–	–	–	–	–	–
Femur	–	13	6	–	2	3	3	–	–
Tibia	–	10	5	1	1	2	1	2	3
Astragalus	1	30	6	3	8	12	–	4	2
Calcaneus	–	3	2	1	1	5	–	–	1
Metatarsal	1	13	4	–	5	–	–	4	–
Tarsals	3	31	1	–	–	2	–	–	–
Proximal phalanx	4	107	14	6	6	9	2	10	11
Medial phalanx	6	70	6	2	7	11	–	2	7
Distal phalanx	–	50	3	1	8	7	1	4	3
Totals	**88**	**1,638**	**318**	**149**	**100**	**173**	**49**	**171**	**167**

LU Large Ungulates (rhinoceros, hippopotamus, horse, aurochs and camel), *MU* Medium Ungulates (red deer, capra, fallow deer and wild boar), *SU* Small Ungulates (gazella, roe deer)

that there are 24 different anatomical elements, Pileou's evenness index has been also calculated for each body-size class and level using MAU values. The higher values correspond to small ungulates in each level (average value of 0.76) followed by medium and large prey (average values of 0.74 and 0.53 respectively). Spearman's correlations between large, medium and small ungulates have been calculated for each level in order to better evaluate dissimilarities. As a result, significant positive correlations have been found between species in Tabun B ($\rho_s = 0.80$, $p = 0$ between medium and small ungulates, and $\rho_s = 0.62$, $p = 0.002$ between large and medium ungulates), thus corroborating the probable natural origin of this assemblage. In Tabun D, there is also a significant positive correlation between medium and small ungulates ($\rho_s = 0.46$, $p = 0.05$) and higher similarities between body-size skeletal profiles than in Tabun C, which can be interpreted as a greater importance of prey weight in transport decisions within AMH groups, probably due to longer travel times.

To better assess this assumption, correlations between %MAU and %MGUI, as well as between %MAU and maximum bone density, have been calculated (see Table 5.5). Correlations with bone survivorship are always positive (in three cases significantly), which could be related to the existence of moderate attrition. Not surprisingly, correlations with utility are low or negative (even significantly in two cases) as a result of bone attrition and the known bias in the assemblage recovery methods against long bone shafts and axial elements, the most meat-bearing parts of the skeleton. However, as regards medium and small ungulates, Tabun D shows more negative values compared with Tabun C, which could indicate less

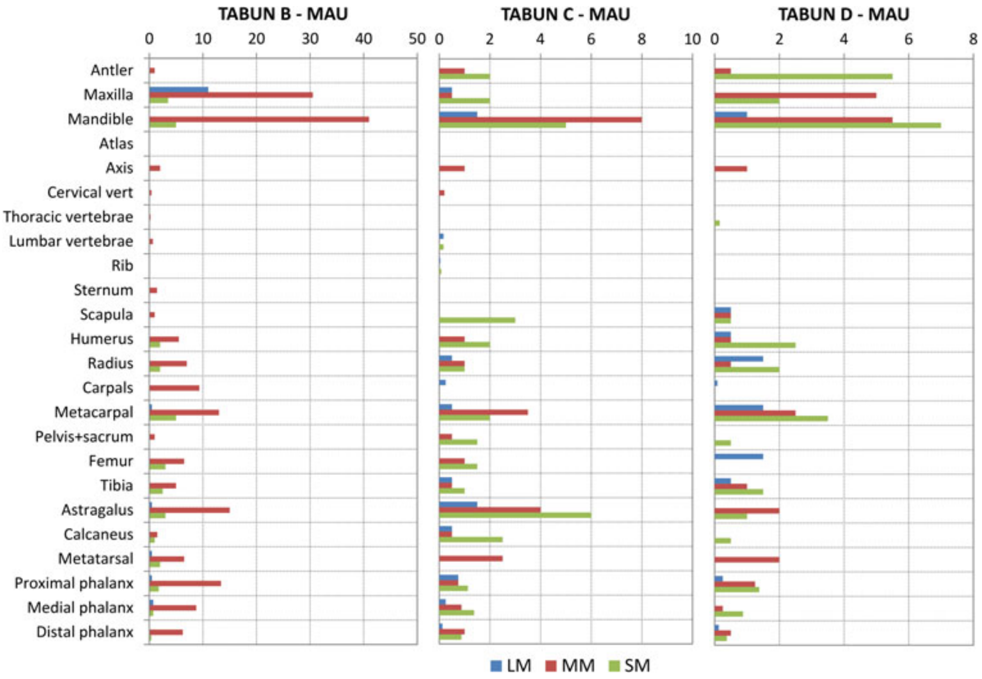

Fig. 5.4 Skeletal profiles of large, medium and small ungulates in terms of MAU

processing at the kill-site as a consequence of smaller catchment areas or a less residential use of the settlement.

In addition, to estimate how much the non-collection of shafts might have biased the economic interpretation of the assemblage, the MNE of the long bones (humerus, radio-ulna, femur, tibia and metapodials) was multiplied by two and by four, and the correlations with %MGUI and maximum bone density were repeated. The aim of this analysis was not to reconstruct the original assemblage, but rather to evaluate the possible loss of information that might have occurred. The results (see Table 5.5) point towards similar interpretations regarding the differential transport (the correlations are only a little less negative, but with no appreciable changes), which would support the use of the present information as representative of the subsistence behavior of the human groups. However, the presence of more long bones would have resulted in a more clearly-defined influence of attritional processes.

Seasonality and Ungulate Mortality Profiles

The mortality profiles of Tabun were assessed mainly by tooth eruption and wear stages and in some cases by bone fusion, for some species such as gazelle. Figure 5.5 shows the Tabun results together with those from other nearby

Table 5.5 Spearman's correlations between skeletal part representation and utility/survivorship of bones

MNE long bones	Correlation		Tabun B			Tabun C			Tabun D		
			Large	Medium	Small	Large	Medium	Small	Large	Medium	Small
x1	%MAU/%MGUI	ρs	**−0.42**	−0.30	0.18	−0.24	−0.28	−0.07	0.16	**−0.43**	−0.32
		p	**0.05**	0.17	0.40	0.27	0.20	0.76	0.47	**0.04**	0.14
	%MAU/Bone density	ρs	0.40	0.32	**0.63**	0.47	0.20	0.19	**0.72**	0.19	**0.74**
		p	0.08	0.18	**0.02**	0.14	0.49	0.52	**0.02**	0.56	**0.00**
x2	%MAU/%MGUI	ρs	**−0.42**	−0.20	−0.14	−0.21	−0.16	0.02	0.17	−0.37	−0.31
		p	**0.05**	0.37	0.53	0.33	0.47	0.94	0.45	0.08	0.15
	%MAU/Bone density	ρs	0.81	**0.57**	**0.84**	**0.62**	0.48	0.50	**0.81**	0.46	**0.75**
		p	0.10	**0.01**	**0.00**	**0.04**	0.07	0.07	**0.00**	0.13	**0.00**
x4	%MAU/%MGUI	ρs	**−0.42**	−0.14	−0.15	−0.22	−0.14	0.02	0.17	−0.34	−0.28
		p	**0.05**	0.52	0.49	0.32	0.54	0.91	0.43	0.11	0.19
	%MAU/Bone density	ρs	0.81	**0.73**	**0.89**	**0.87**	**0.59**	**0.73**	**0.85**	**0.69**	**0.77**
		p	0.10	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**	**0.00**	**0.01**	**0.00**

Values in bold imply statistically significant correlations

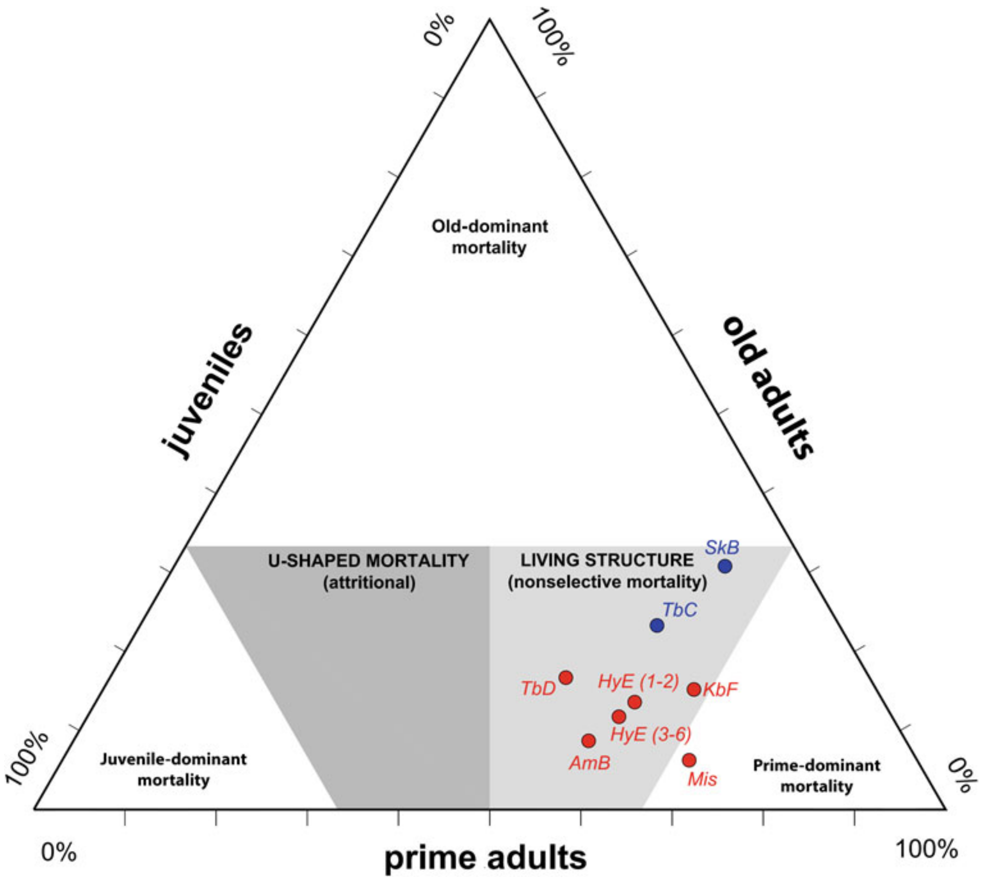

Fig. 5.5 Mortality profiles of ungulates at Tabun C and D, Skhul B (Marín-Arroyo 2011), Misliya (Yeshurun et al. 2007), Hayonim E (Stiner 2005), Amud B (Rabinovich and Hovers 2004) and Kebara VI-XIII (Speth and Tchernov 1998; Speth and Clark 2006). AMH occupation (*open circles*) and archaic ones (*filled circles*)

sites; Qafzeh was not included due to the fact that only bone fusion was used to determine age, which neglects the possibility of identifying old individuals. The mortality profiles reflect a general predominance of prime-age individuals, with a percentage in agreement with their typical abundance in natural populations. However, within this general trend a decrease can also be seen in the number of juvenile individuals in favor of elderly ones in the levels associated with AMH occupations (Tabun C and Skhul) which might imply a greater preference for more productive animals. Although not shown in the graphic, the age profile of Tabun B lies right in the centre of the living structure area, agreeing thus with the proposed natural origin of the deposit.

Concerning seasonality, apart from the winter occupations estimated by Lieberman (1993) for these levels, the identification of three mandibles of juvenile individuals with teeth in the first stage of eruption also points towards a late spring/early summer use of the cave in Levels C and D.

Human Mobility

Figure 5.6 shows the catchment areas corresponding to 1, 1.5 and 2 h of travel time around Tabun and other Middle Paleolithic sites. The surface area of plains and mountain biotopes, as identified with a 10 % slope threshold, is presented in Table 5.6, together with the so-called topographic factor (TF), obtained as a quotient between plain and mountain extensions (in km^2).

As can be seen, the higher proportion of plains in the surroundings of AMH occupations corresponds to a travel time of 1.5 h, whilst the lower proportion in the surroundings of archaic occupations is established in 1 h travel time. Given the comparative preference for plains ungulates among AMH (see Fig. 5.2), this would mean that they usually travelled longer distances to hunt their prey. Moreover, taking into account only Tabun levels C and D, the slightly higher dependence on plains ungulates seen in Tabun C (AMH occupation) is at odds with the reduction in plains biotopes in the surroundings of the cave due to the rise in sea level during MIS 5. A probable explanation for this incongruence would again be that AMH relied more heavily on logistic mobility than their predecessors, leading to greater travel distances during their expeditions which, in turn, would mean less residential mobility. A greater degree of carcass processing should then be expected then in Tabun C, which is consistent with the taphonomy of the analyzed assemblage.

To objectively test this hypothesis, bivariate correlations have been made between the topographic factor and the faunal preference for plains ungulates, represented by the

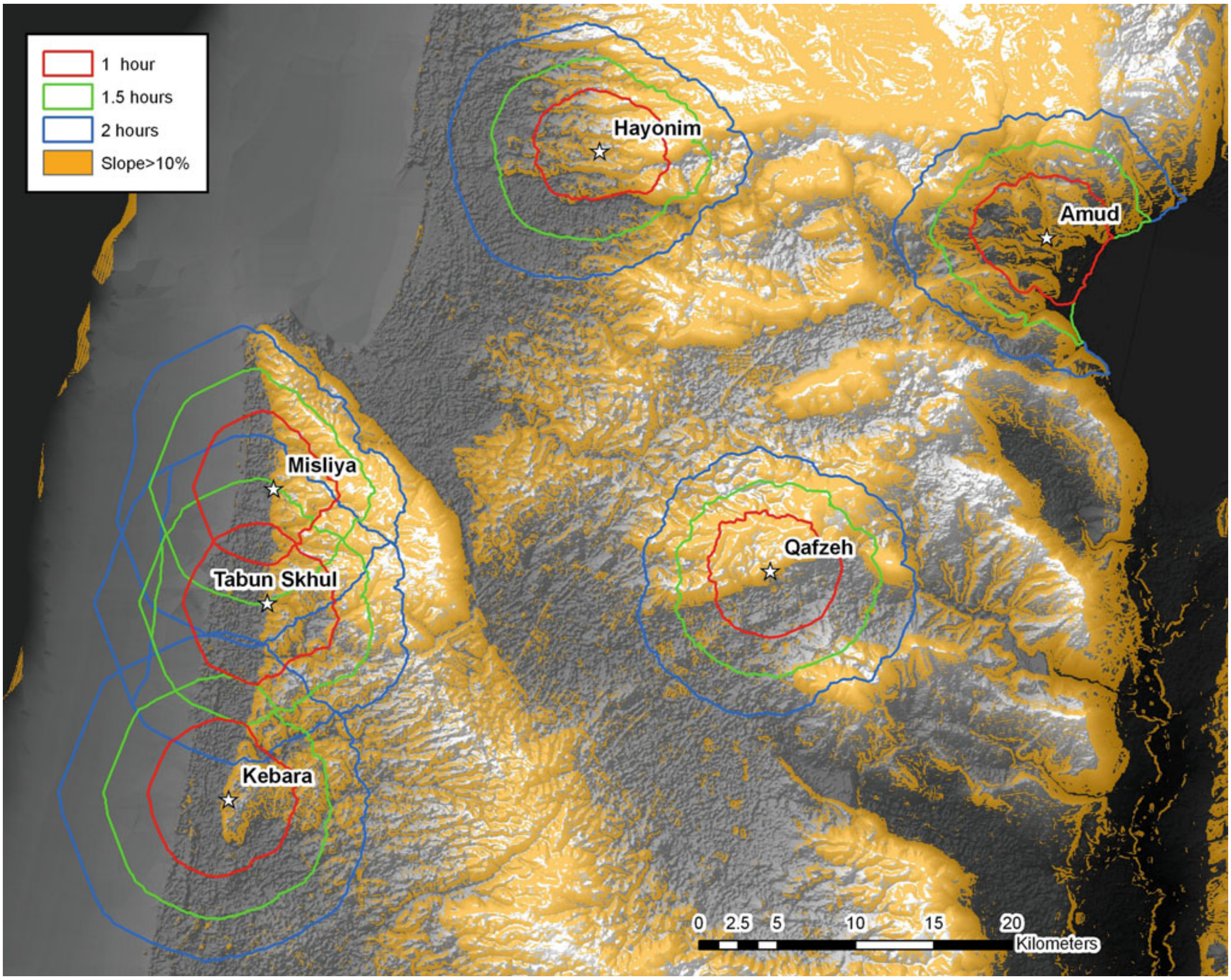

Fig. 5.6 Catchment areas for 1, 1.5 and 2 h of travel time over Digital Elevation Model showing zones considered less suitable for plains ungulates

quotient between plains and mountain NISP values at each site. Nine possible combinations of the three different travel times proposed for AMH and archaic populations (1, 1.5 or 2 h) were examined. The most probable combination in terms of Spearman's test ($\rho_s = 0.58$, $p = 0.10$) points towards travel times for AMH and archaic populations of 1.5 and 1 h respectively (see Fig. 5.7) thus reinforcing the idea of longer logistic movements amongst AMH.

Discussion

Subsistence Patterns in the Levantine Middle Paleolithic

The re-analysis of the faunal assemblage from Tabun Cave presented here, and its proper contextualisation with other Levantine Middle Paleolithic sites, allows the drawing of relevant conclusions on the subsistence patterns adopted by both AMH and archaic hominin populations in this key region for human evolutionary studies.

First, the origin of the assemblage has been clarified. Thus, Tabun B seems to have acted as a natural trap for ungulates (but also some carnivores) that would have fallen through the chimney (Bate 1937: 150; but see Kaufman 2002). Nontheless, there is evidence of human exploitation of some carcasses, probably scavenging the animals that perished there. On the other hand, the anthropogenic origin of Tabun C and D is clear, due to the presence of tool-marked bones and traces of burning, above all in level C, and the almost complete absence of carnivore marks. The location and abundance of butchering marks, including filleting, also corroborates the assumption that the human groups that inhabited the cave were capable of regular hunting episodes. In fact, the frequency of anthropogenic

Table 5.6 Topographic characterization of catchment areas in the Levantine Middle Paleolithic

Site	Human species	1 h catchment area			1.5 h catchment area			2 h catchment area		
		Plain (km²)	Mountain (km²)	TF	Plain (km²)	Mountain (km²)	TF	Plain (km²)	Mountain (km²)	TF
Tabun D	Archaic/ Neand.	51.5	20.3	2.54	120.7	44.7	2.70	217.2	80.1	2.71
Hayonim E (3–6)		20.6	26.4	0.78	69.1	50.0	1.38	142.1	85.6	1.66
Misliya		41.3	19.3	2.14	98.1	46.9	2.09	175.3	81.2	2.16
Hayonim E (1,2)		20.6	26.4	0.78	69.1	50.0	1.38	142.1	85.6	1.66
Amud B		24.2	27.3	0.88	42.9	63.0	0.68	73.2	110.2	0.66
Kebara F		57.6	11.8	4.87	143.1	24.1	5.93	264.7	43.8	6.04
Tabun C	AMH	51.5	20.3	2.54	117.2	44.7	2.62	180.6	80.1	2.25
Skhul B		51.5	20.3	2.54	117.2	44.7	2.62	180.6	80.1	2.25
Qafzeh V-XV		29.2	22.2	1.31	71.7	52.5	1.37	128.1	97.8	1.31
Average Archaic/Neand.				2.00			2.36			2.5
Average AMH				2.13			2.20			1.9

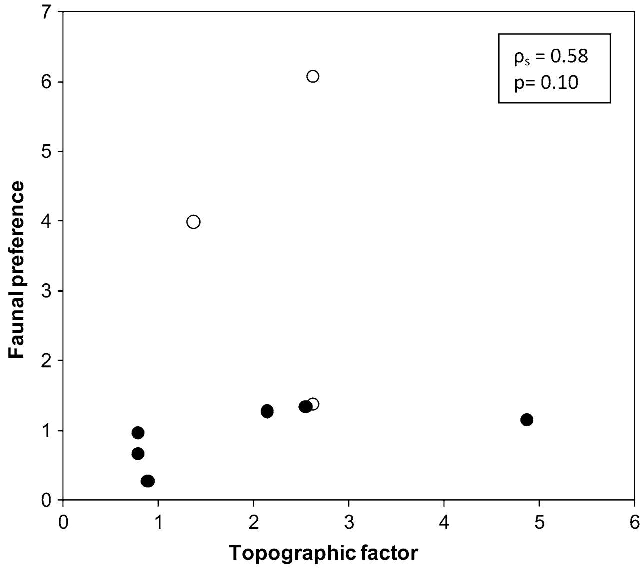

Fig. 5.7 Correlation between topographic factor in the surroundings of each settlement and faunal preference for the most probable combination of typical travel times: 1.5 h for AMH (*open circles*) and 1 h for archaic populations (*filled circles*)

evidence in the assemblage is higher than that from other well known human settlements, such as Qafzeh, where 2.3 % of bone remains show cut-marks or burn traces (Rabinovich and Hovers 2004) or Misliya, where 3–4 % of bone specimens bear cut-marks and 4–6 % impact notches (Yeshurun et al. 2007). The anthropogenic alteration of Tabun C is even more intense than in Kebara, which is seen as a long-term seasonal basecamp (Bar-Yosef et al. 1992). Scavenging as a usual subsistence strategy can then be ruled out in Tabun C and D, even more so taking into account the presence of large and relatively dangerous taxa in the assemblage, such as aurochs, rhinoceros, red deer or wild boar (Bar-Yosef et al. 1992; Speth and Clark 2006).

Secondly, there is a certain distinction in hunting strategies between AMH and archaic populations. The former would have depended more on high-ranked prey during MIS 5, dismissing small mountain gazelle to some extent. This trend could be seen as an incipient specialisation strategy (Rabinovich and Tchernov 1995; Rabinovich 1990) above all taking into account that it would mean longer expeditions to more distant plains areas, as ungulates related to plains habitats were bigger in the area of study. This trend towards more productive strategies is also slightly reflected in the mortality profiles, where juvenile individuals were partially substituted by prime-age or old ones (Stiner 2005; Stiner and Tchernov 1998). In terms of diet-breadth, the emphasis on large game typical of grassy plains or woodlands resulted in a significant broadening that could reflect the even exploitation of several different environments. The recognition of more efficient strategies and a higher territorial control is usually related to optimal foraging behavior, implying more advanced cognitive capacities. This would imply that the cognitive changes that were common during the Upper Paleolithic might have already been taking place (Klein 2009).

And thirdly, the more specialized economy recognized before is usually related to lower residential mobility. In the case of the Levantine Middle Paleolithic, this fact has also been tested by means of comparing the topographic relief in the surroundings of each site with the faunal preference. As a result, a greater reliance on logistic mobility has been suggested among AMH (with travel times usually 0.5 h longer), a fact that was also proposed by Wallace and Shea (2006) by analyzing differences in the production of lithic tools, and by Lieberman (1998) based on the age of death of gazelles. In addition, body size of carcasses seems to have played a greater role in transport decisions, probably involving more intense butchering at the kill-site (with the subsequent contribution of less-useful parts to the base camp) as prey-weight increases (Marín-Arroyo 2009c). Rabinovich and Tchernov (1995) also identified in Qafzeh a selective transport strategy of hunted prey for rhinoceros and red deer. In contrast, Stiner (2005) suggests an almost complete transport of carcasses during the archaic occupation of MIS 6 at Hayonim.

This pattern of mobility was probably favored among AMH by their particular anatomy; hence, their longer lower limbs and smaller body mass (Weaver and Steudel-Numbers 2005; MacDonald et al. 2009) would have reduced their energetic expenditure while travelling (from/to base camp) in their hunting expeditions, allowing them efficient exploitation of certain distant taxa. It is still unknown whether this more mobile pattern of AMH behavior and the subsequent depletion of the resources located close to the base camp led them to focus more on larger game in order to maintain the necessary energetic income, or perhaps instead it was changes in cognitive skills permitted them to better discern between different productive choices, allowing them to maintain more permanent occupations.

Implications for AMH Replacement in the Region

Interestingly enough, the economic behavior just noted amongst AMH did not provide them with a clear evolutionary advantage in terms of survivorship or adaptive skills, as they ceased to occupy the region at the end of MIS 5, being replaced by Neanderthals coming from northern latitudes (Tchernov 1998; Shea and Bar-Yosef 2005). Two possible explanations are currently proposed for this failure. The first involves climatic deterioration that would have significantly decreased terrestrial productivity during the MIS 5/4 transition ca. 75 ka (Shea 2008). This episode would have affected the number of available taxa (Davies et al. 2011; Dynesius and Jansson 2000) which, together with the great dependency on large ungulates seen in the archaeozoological record, would have reduced their numbers and even provoked their extinction due to overhunting (Haynes 2002; Miller et al. 2005; Marín-Arroyo 2009c; Speth 2004). In this scenario, AMH would have had to cope with dietary stress that, in other conditions, would have led to an expansion in diet-breadth, including previously considered low-ranked prey (Stiner et al. 1999). In a similar way, droughts and rapid shifts to colder conditions would have seriously limited *Homo sapiens*' ability to disperse during the Upper Paleolithic (Finlayson and Carrión 2007). However, either small or difficult-to-hunt animals such as lagomorphs, birds, etc. were not sufficient to maintain the existing human population due to their low calorific yield/low abundance, or the available technology of AMH was not sufficient to effectively exploit these kind of resources. For example, Shea and Sisk (2010) argue that it was not until projectile weapons of the kind used by ethnographic hunter-gatherers, such as the bow and arrow, and spear-thrower and dart, were developed in Africa between 50 and 100 ka that ecological niche broadening strategies were enabled (Brooks et al. 2006; d'Errico and Henshilwood 2007), which then allowed *Homo sapiens* to successfully colonize Eurasia at the Middle to Upper Paleolithic transition.

An alternative hypothesis would dismiss the effect that climatic worsening would have had on biomass production and consequently on resource availability (Frumkin et al. 2011), due to the existence of reliable and spatially dispersed seasonal food resources (Bar-Yosef et al. 1992; Hovers 2006). If that were the case, AMH would have not abandoned the region when Neanderthal populations arrived from northern latitudes, and thus, some kind of competition would have occurred between both human species (Shea and Bar-Yosef 2005) in which Neanderthals might possibly have prevailed, due to a better physical adaptation to the increasing glacial conditions of MIS 4.

There are several climate studies in the Levant that can shed light on this dilemma, above all isotope and growth-rate studies of speleothems, such as those from Soreq and Peqi'in Caves (Bar-Matthews et al. 1997, 2003a), Negev Caves (Vaks et al. 2006) and Jerusalem West Caves (Frumkin et al. 1999). Thus, according to Vaks et al. (2007) the arrival of AMH in the Levant was favored by a humid period in the Negev desert region between 140 and 110 ka, coinciding with an intensification of monsoonal effects in the Arabian Peninsula (Fleitmann et al. 2003) and the Sahara (Osmond and Dabous 2004), which would have provided a suitable land bridge between sub-Saharan latitudes and the Levant. This bridge seems to have disappeared afterwards, which would have isolated AMH populations during MIS 5, a period that became drier as seen both in the growth-rate of calcite (Vaks et al. 2006; Lisker et al. 2010) and in water level reconstruction of Lake Samra, the precursor of the Holocene Dead Sea (Waldmann et al. 2009). AMH populations probably dealt with this situation by migrating to the more humid central and northern regions to the West of the central mountain ridge of Israel (in caves such as Tabun, Skhul and Qafzeh). This isolated situation might have increased survival risks at times of rapid environmental change, as it constrained migration possibilities as well as reduced genetic flow. Why AMH did not expand farther north through Taurus-Zagros Mountains is still unknown. As a possible explanation, Frumkin et al. (2011) argued that the heterogeneity of the Levant ecosystems together with a colder climate in the mountain ridges, quite different from the African one, kept AMH within the region.

Based on the characterization of spelothem fluid inclusions of Soreq Cave, McGarry et al. (2004) determined a drop of around 4 °C in temperature between 80–86 and 73–74 ka. In addition, based on: (1) present measures of δ^{18}O abundance of rain and drip-water at the Soreq Cave site; (2) the similar isotopic depletion between the Eastern Mediterranean Sea and cave locations observed during the last 250 ka as evidenced in the δ^{18}O record of planktonic foraminifera species *Globigerinoides ruber* of a maritime core (Fontugne and Calvert 1992); (3) the similar climate of interglacial periods; and (4) the same δ^{18}O composition of the sea in Sapropel S3 event in comparison with present times (Kallel et al. 2000). Bar-Matthews et al. (2003b) were able to estimate an annual decrease in rainfall between 82 and 77 ka of 300 mm/year (from 500 to 200 mm/year). This trend has been confirmed by Almogi-Labin et al. (2009) when they eliminated the first-order "source effect" from the δ^{18}O record of Soreq Cave with the help of two eastern Mediterranean maritime cores. These authors found a significant drop in second-order δ^{18}O during the MIS 5/4 transition that was related to the so-called "amount effect" (Dansgaard 1964) and that also indicates a pronounced decrease in rainfall. This meteorological shift was also hydrologically recorded in the water level reconstruction of Lake Samra, which presents a 10 m drop between 80.2 and 71.5 ka (Waldmann et al. 2009) and in the δ^{13}C record throughout the region that reflects an increase in C4 vegetation.

The impact of this change in terrestrial productivity can be assessed by means of estimation of real evapotranspiration (ETr), i.e. the amount of water used by the vegetation cover, which has a direct relationship with existing biomass. There are two major forces that affect evapotranspiration: the availability of water (i.e. rainfall) and the availability of solar radiation and heat. The annual ETr can be roughly estimated as a function of mean annual temperature following Turc's equation (1954), later modified by Pike (1964). Therefore ETr at the onset of the MIS 5/4 transition would have been 450 mm/year whilst 10 ka later it would have decreased to 195 mm/year. According to Budyko (1974), this would have changed the environment from subhumid to subarid conditions, implying a major modification of resource availability.

Given this, the possibility of an AMH extinction before the arrival of Neanderthals is considered more plausible, above all as they did not possess the necessary technology to effectively broaden their diet (Shea 2009), which would have improved their survival chances (Betinger 1991), especially if they had intensively depended on large ungulates as has been argued before. There is, however, no direct proof for this assumption, as there is currently a lack of archaeozoological assemblages from this period that could show evidence of dietary stress, such as a progressive widening of diet-breadth or a greater consumption of old and juvenile individuals (Marín-Arroyo 2009c).

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