



Animal husbandry from the Middle Bronze Age through the Iron Age in the Shephelah—faunal remains from the new excavations at Lachish

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Abstract

Lachish (Tell ed-Duweir) is located in the southern part of the Judean foothills, known as the Shephelah, and is one of the larger and most extensively excavated multi-period sites in the southern Levant. We present the faunal results of the first three seasons of the most recent excavations, the Austrian-Israeli Expedition to Tel Lachish. The expedition focusses on two areas of the tell encompassing the Middle Bronze Age III through the Iron Age II, area S (deep section) and area P (palace area). The aims for the faunal analysis are threefold: comparing the results between the two areas, seeing how our results compare to previous analyses, and comparing Lachish to other synchronous sites in the Shephelah. We observe differences in subsistence strategies between the areas in addition to diachronic differences. Ovicaprids dominate all assemblages, but we see shifts in the sheep to goat ratio and mortality profiles through time indicating changes in subsistence strategies. Our new results largely agree with the results from previous analyses, showing the value of previous studies and their potential compatibility with newer research. A synchronic comparison of Lachish within the Shephelah shows the occupants of the site were largely self-sufficient but possibly engaged in an exchange of resources in the vicinity.

Keywords Levant · Middle Bronze Age · Late Bronze Age · Iron Age · Zooarchaeology · Subsistence

Introduction

Lachish (Tell ed-Duweir, 31° 33' 54" N, 34° 50' 56" E) is one of the larger tells in the southern Levant, covering 12 ha, and lies in the southern part of the Judean foothills, referred to as the Shephelah. Scholars believe the site was settled as early as the Pottery Neolithic (Ussishkin 2004), but in this study, we concentrate on the Middle Bronze Age (MBA, 2000–1550 BCE), Late Bronze Age (LBA, 1550–1200 BCE), and Iron

Age II (IA II, 975–586 BCE) (period ranges follow Kamlah and Riehl *in press*). The political importance of Lachish during the Bronze and Iron Age is confirmed by the Assyrian annals describing its conquest by Sennacherib depicted in the Lachish reliefs in his palace in Nineveh (Ussishkin 1982), the El-Amarna letters (Cochavi-Rainey and Rainey 2015), and Papyrus Hermitage 1116A (Golénischeff 1913; Webster et al. 2019).

We discuss the faunal remains from the Austrian-Israeli Expedition to Tel Lachish (2017–2019), led by Streit and Höflmayer, in the framework of the ‘Tracing Transformations’ project. The excavation focusses on two areas of the tell area S (deep section) and area P (palace area) (Fig. 1). Area S contains a long stratigraphic sequence from the LBA to the IA representing a settlement area (Table 1): strata S-1 and S-2 contain several pits and densely laminated layers rich in seeds, and stratum S-3 contains a monumental building consisting of several walls. Area S contains settlement assemblages, and Ussishkin (2004) found a public building accompanied by domestic structures in this part of the site. Area P provides a sequence of the MBA and LBA (Table 1):

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Table 1 Strata of areas P and S with their corresponding relative dating

Area P		Area S	
Relative dating	Stratum	Relative dating	Stratum
IA IIB-C	Post-IV	LBA IIB	VII
IA IIB	IV	LBA I-II	VII to S-3a
IA IIA	V		S-1?
LBA II	P-1/2		S-2
	P-3 or younger		S-2 to S-3a-c
MBA III	P-4	LBA I	S-3a-c
MBA II-III	P-5/6		S-3a-c to S-4

strata P-6 to P-3 contain the MBA palace, whereas strata P-2 and P-1 have domestic architecture dating to the LBA (Streit et al. 2018).

We have three goals for our analysis of the faunal material. First, we want to establish how subsistence strategies changed through time and whether we can determine differences between areas S and area P during the LBA II. Second, we investigate whether our results establish similar trends as previous analyses. Third, we compare the results of Lachish with other synchronous sites in the Shephelah region to determine how an important centre such as Lachish fits within the regional framework. Answering these questions will allow us to gain a better understanding of subsistence during the Bronze and Iron Age at Lachish and in the broader region.

Background

After the ‘collapse’ of settlements in the Early Bronze Age IV, the MBA I was a period of renewed urbanization in the southern Levant during which Lachish was resettled (Tufnell 1958; Ussishkin 2014). Major architectural finds include the remains

of a palace, and structures belonging to a cultic place, although archaeologists have found no images or cult objects (Tufnell 1958; Ussishkin 2004). During the MBA II, Lachish developed into a city-state, and a new palace was built in the centre of the tell. The most noticeable architectural feature is the massive fortifications surrounding the tell (Burke 2008). At the end of the MBA, the palace, and probably the entire city-state, was destroyed by a fire of an unknown cause. Afterwards, the site was home to a secondary settlement, though eventually Lachish was abandoned (Tufnell 1958; Ussishkin 2004).

Overall, the environment was semiarid, but stable oxygen isotope evidence from the speleothems at Soreq Cave indicates considerable fluctuation in palaeo-rainfall patterns throughout the whole Bronze Age which was of a relatively humid character (Bar-Matthews and Kaufman 1988). The $\delta^{18}\text{O}$ oscillations throughout this stage are characterized by four short dry spells, the last of which falls into MBA I.

During the LBA I Lachish was resettled, although it is not certain to what extent. The Fosse Temple, which existed throughout the LBA, was built, though as with the MBA II, scholars have recovered no images or cult objects. Bietak (2002) suggested the space would have been used as a place of gathering for funerary meals. At this time, the fortifications of the MBA were out of use.

During the LBA II, ancient Egypt became dominant in the region, and, under its patronage, Lachish became an important city-state. Around 1200 BCE, Lachish was again destroyed by fire, though it was rebuilt shortly thereafter (Tufnell 1958; Ussishkin 2004). Although the Fosse Temple was not restored, the Acropolis Temple and the Pillared Building, a large public structure, were constructed. Lachish grew into one of the largest cities in Canaan and prospered. Occupants developed overland and marine trade routes, with the presence of saltwater fish indicating trade with the Mediterranean areas

Fig. 1 Map of Lachish showing the location of the excavation areas P and S



(Lernau and Golani 2004). We can see Egyptian influence in the material culture (Koch 2014; Ussishkin 2004). Around 1130 BCE, Lachish was destroyed and burned by an unconfirmed enemy (Tufnell 1958; Ussishkin 2014).

The LBA pollen record from Galilee documents a similarly high number of Mediterranean tree species as already in MBA II-III with a sharp decline towards the end of the LBA, which may be in relation to the documented drop of the Dead Sea level, and with generally reduced settlement activity in region (Langgut et al. 2015).

After about two centuries, Lachish was resettled in the IA IIA. During this time, Lachish became the second most important city in Judah. This is attested to by the construction of a fortress city with a large civilian population. In 701 BCE, Lachish was destroyed by the Assyrian king Sennacherib (Ussishkin 2004, 1977). After an occupation gap, the site was briefly resettled before it was destroyed for the last time in 588/586 BCE by the Babylonian king Nebuchadnezzar (Tufnell 1953; Ussishkin 2004).

Stable carbon isotope evidence from IA Tel Burna, about 20 km south of Lachish indicate optimal soil moisture availability in the surroundings of the settlement, increasing throughout the IA IIB and IIC (Riehl and Shai 2015).

Although it is currently not possible to link the general environmental patterns to the settlement history of Lachish, it cannot be excluded that observable deteriorating environmental fluctuations may have contributed to the end of some of the settlement phases.

Previous work at Lachish

The first expedition to Lachish was the Wellcome-Marston Expedition (1932–1938), directed by Starkey, whose main goal was to put Lachish in a cultural and chronological framework. The results are published in three volumes by Tufnell (Tufnell 1958, 1953; Tufnell et al. 1940). Bate analyzed the faunal remains (Bate 1958, 1953), and Baden-Powell analyzed the shells (Baden-Powell 1958). Unfortunately, we cannot compare the results of these faunal analyses to our results since the older data lack the resolution of modern faunal analyses.

In 1966 and 1968, Aharoni (1975) excavated at Lachish, focussing on structures dating to the Persian period. Though Lernau (1975) analyzed the fauna of the sanctuary, most material is outside the temporal scope of our study (Late Bronze Age: NISP = 53, Iron Age: NISP = 298).

The longest endeavour at Lachish was the ‘Renewed Excavations’ directed by Ussishkin from 1973 until 1994. The main aim was to investigate the period of the Judean monarchy. The results are published in five volumes (Ussishkin 2004) and a public interest book (Ussishkin 2014). Several zooarchaeologists analyzed the material (Bar-Yosef Mayer 2004; Croft 2004a, 2004b; Drori and Horowitz

1989; Koch 2014; Lernau and Golani 2004). The analyses included fauna from area P and area S, which gives us a baseline for comparing the results from our current study.

From 2013 until 2017, Garfinkel, Hasel, and Klingbeil excavated at Lachish, focussing on the northern and north-eastern edge of the tell and west of the Solar Shrine. They have published some of their results (Garfinkel et al. 2019a, 2019b; Sass et al. 2015; Weissbein et al. 2019, 2016), but the faunal analysis is still in progress.

In 2015 and 2016, Ganor directed two seasons of excavation focusing on the IA gate complex for the Israeli Antiquities Authority. No faunal results have been published yet.

Methods

We analyze faunal remains from hand-collection and flotation from areas P and S recovered during the 2017, 2018, and 2019 seasons of the Austrian-Israeli Expedition. We present the data for the MBA III, LBA II, and IA II (merging IA II A, B, and C to increase the sample size). We measure specimens using Von den Driesch (1976) with 0.0-cm precision and weigh with 0.01-g precision using a digital scale. We identify specimens to skeletal element and bone portion, and assign them to the genus and species level when possible, otherwise to body size class (e.g. large mammal) (Stiner 2005). We focus on macro-mammalian remains, since these contributed most to animal husbandry practices. We choose NISP (number of identified specimens) as our primary quantification unit but calculate MNI (minimum number of individuals) and MNE (minimum number of elements) (Lyman 2018, 2008). We assess diversity in our assemblage by using the reciprocal of Simpson’s index, a measure of taxonomic evenness (Simpson 1949). When calculating 1/D, we only use species-specific identifications, with the exception of sheep and goats, which we combine into an ovicaprid category. To determine differences in taxonomic composition between samples, we perform a Pearson chi-square test using taxa determined to species.

We record bone surface modifications (Behrensmeier 1978; Fisher 1995; Lyman 1994; Stiner et al. 1995) and evaluate density-mediated attrition to check for preservation bias by comparing the MNE of the most frequent lower tooth with mandibular MNE (Stiner 1991). We also check for recovery bias, since most of the material was hand-collected. We do this by looking at histograms representing the bone length in millimetres for the most common taxon, in this case ovicaprids, per sample. In our histograms, we use bins representing a 5-mm range. We examine body part profiles by dividing the body into nine anatomical regions: horn, head (cranium and mandible), neck (atlas, axis, cervical vertebrae), axial column (thoracic, lumbar vertebrae, sacrum, ribs, and innominate), upper front limbs (scapula and humerus), lower

front limbs (radius and ulna), upper hind limbs (femur), lower hind limbs (tibia, astragalus, and calcaneum), and feet (metacarpal, metatarsal, phalanges) (Stiner 1991). Within these regions, we calculate minimal animal units (MAU) by dividing the observed number of elements by their expected numbers in a complete skeleton. This standardizes our MNE counts so we can examine anatomical profiles of major taxa. In our analysis, we assigned axial elements such as ribs; cervical vertebrae 3-5; and thoracic, lumbar, and caudal vertebrae to body size class (e.g. medium ungulate, large ungulate). In calculating our anatomical profiles, we provide species-specific profiles and also profiles based on body size class to make sure that elements underrepresented for a given species were not simply assigned to a general size class category.

We perform ageing using epiphyseal fusion, tooth wear, and tooth eruption. We use epiphyseal fusion of all long bones to calculate survivorship profiles for ovicaprids (Moran and O'Connor 1994) and cattle (Habermehl 1975). We represent survivorship in percentages using a non-cumulative line graph. We also analyze age at death using tripolar graphs, where we plot the frequency of juvenile, prime age adult, and old adult ungulates (Greenfield and Arnold 2008; Steele and Weaver 2002; Stiner 1990; Weaver et al. 2011). Juvenile animals are defined by deciduous fourth premolars. Prime age and old adults are differentiated by wear on fourth premolars, with old adults having more than half of the tooth surface worn off.

We differentiate sheep and goat morphologically (Boessneck 1969; Zeder and Lapham 2010; Zeder and Pilaar 2010) and morphometrically (Davis 2017) when possible in order to establish the sheep to goat ratio, which helps us interpret herding strategies. Keeping a mixed flock of both sheep and goats provides herd security, a common strategy to reduce risk since sheep and goats have different requirements and susceptibilities. For example, when disease strikes only half of the herd will be affected (Redding 1981; Sasson 2016). In addition to this, goats are flexible feeders that browse and graze, have lower water requirements, and reproduce faster than sheep (Redding 1981, 1984). Sheep are less versatile than goats in the sense that they are grazers, but they can provide wool (Redding 1981, 1984). Therefore, fluctuations in the sheep to goat ratio along with changes in their mortality profiles might indicate climatic constraints, or might reflect a preference for meat, milk, or wool production (Payne 1973; Redding 1981, 1984). Socio-political organization also may influence the sheep to goat ratio (Perevolotsky et al. 1989; Redding 1984). In addition to calculating the sheep to goat ratio, we determine sex ratios in ovicaprids using mixture analysis, which uses biometric data to determine the bimodality that most likely reflects sexual dimorphism (Monchot et al. 2005). In ovicaprids, males are typically larger than females due sexual size dimorphism, though sexual dimorphism is more pronounced in goats than in sheep (Davis 2000).

We could not differentiate pig from boar due to the small sample sizes and a lack of suitable skeletal elements at Lachish.

Results

In zooarchaeological assemblages, there is a well-known relationship with larger sample sizes and higher richness (i.e. number of species) (Lyman 2008), which can make it difficult to compare between contexts with different sample sizes. We checked the effect of sample size on richness in our assemblages at Lachish, which shows the relationship is not significant (Pearson's correlation, $r = 0.410$, $p > 0.05$). Since the r value is high enough, this could indicate a mild relationship so we performed individual rarefaction to check our result (SI 2.1). This indicates sample size and diversity are independent, so differences we see in the faunas are not because of variation in sample size (see SI 1 for a complete list of taxa per area and subperiod).

Species abundance

Area S

Area S is mostly represented by the LBA II (Table 2). The assemblage is dominated by ovicaprids, with goats outnumbering sheep (sheep to goat ratio = 0.34, see also SI 2.2 for morphometric data). The low number of wild taxa shows hunting played a minor role. The small presence of suids indicates occasional consumption. Dogs are overrepresented by NISP, due to the presence of an almost completely recovered young dog, reflected in the MNI value. The assemblage has a low diversity ($1/D = 1.85$) because of the large number of ovicaprids.

Area P

Area P is mostly represented by MBA III, LBA II, and IA II (Table 3). During the MBA III, the most common remains are ovicaprids, with a near-equal presence of sheep and goat (sheep to goat ratio = 0.88). Fish were an important part of the diet, followed by cattle. Suids were consumed moderately. Wild taxa are present in small numbers, as are birds and shells. The diversity is low ($1/D = 1.64$), reflecting the dominance of ovicaprids.

Ovicaprids are the most abundant group in the LBA II assemblage, with sheep outnumbering goats (sheep to goat ratio = 1.94). Suids were moderately consumed. There are more wild animals in the MBA III assemblage, and fish have a relatively high abundance. The LBA II has low diversity ($1/D = 2.00$) and is dominated by

Table 2 Taxonomic composition for LBA II in area S. Taxa are structures following body size classes

Taxon	NISP LBA II	%NISP LBA II	MNI LBA II
Large ungulate	329	11.1	-
Cattle (<i>Bos taurus</i>)	332	11.2	4
Medium-large ungulate	1	0.0	-
Medium ungulate	396	13.4	-
Donkey (<i>Equus asinus</i>)	26	0.9	1
Fallow deer (<i>Dama dama</i>)	24	0.8	1
Pig/boar (<i>Sus</i> sp.)	29	1.0	1
Ovicaprid	1011	34.2	11
Goat* (<i>Capra hircus</i>)	256	8.7	11
Sheep* (<i>Ovis aries</i>)	86	2.9	14
Gazelle (<i>Gazella</i> sp.)	35	1.2	2
Hare (<i>Lepus</i> sp.)	4	0.1	1
Tortoise	38	1.3	1
Large carnivore	2	0.1	-
Dog (<i>Canis familiaris</i>)	96	3.2	2.0
Cat (<i>Felis catus</i>)	3	0.1	1.0
Birds	54	1.8	-
Fish	64	2.2	-
Rodent	2	0.1	-
Shell	108	3.7	-
Mollusc	60	2.0	-
Total	2,956	100.0	-
Medium mammal	899	-	-
Small mammal	49	-	-
Small mammal or bird	7	-	-
Medium-small mammal	2	-	-
Grand total	3,913	-	-

*The counts for sheep and goat are included in the ovicaprid category

ovicaprids. The taxonomic composition between the MBA III and LBA II in area P is significantly different (Pearson's chi-square = 16.80, DF = 7, $P < 0.05$, Cramer's $V = 0.19$).

In addition to the large number of ovicaprids in the IA II assemblage (sheep to goat ratio = 0.70), cattle formed a large part of the diet. No suids are present in this assemblage, and wild animals only play a small role. The diversity is low because of the dominance of ovicaprids ($1/D = 1.2$). The assemblages between the IA II and LBA II at area P (Pearson's chi-square = 35.84, DF = 5, $P < 0.05$, Cramer's $V = 0.26$) are significantly different.

Comparisons between areas S and P

Though the two areas are largely similar, with an abundance of ovicaprids and occasional evidence for suid consumption, there are a few differences between the areas in

certain time periods. During the LBA II, areas P and S have a significantly different taxonomic representation from one another (Pearson's chi-square = 598.39, DF = 10, $P < 0.05$, Cramer's $V = 0.85$).

Body part representation

During the LBA II in area S, ovicaprids are most represented by lower hind limbs, front limbs, and head elements (Fig. 2a). Axial, neck, and feet are present in low numbers. Cattle (Fig. 2b) are mainly represented by front and hind limbs. Axial, neck, and feet elements are rare in the assemblage. Anatomical profiles for ovicaprids combined with medium ungulates and cattle combined with large ungulates can be found in SI 2.3, which confirm the pattern we see here.

MAU values are quite small for area P. During the MBA III in area P, we see feet elements are underrepresented in ovicaprids (Fig. 3a). The pattern continues

Table 3 Taxonomic composition for MBA III, LBA II, and IA II in area P. Taxa are structured following body size classes

Taxon	MB III		LB II		IA II				
	NISP	%NISP	MNI	NISP	%NISP	MNI	NISP	%NISP	MNI
Large ungulate	21	7.0	-	19	6.5	-	24	7.5	-
Cattle (<i>Bos taurus</i>)	25	8.3	2	22	7.5	1	12	3.8	1
Donkey (<i>Equus asinus</i>)	-	-	-	7	2.4	1	-	-	-
Medium ungulate	18	6.0	-	39	13.4	-	33	10.3	-
Fallow deer (<i>Dama dama</i>)	5	1.7	1	1	0.3	1	2	0.6	1
Pig/boar (<i>Sus</i> sp.)	5	1.7	1	4	1.4	1	-	-	-
Ovicaprid	150	49.7	5	140	47.9	4	215	67.2	12
Goat* (<i>Capra hircus</i>)	8	2.6	1	16	5.5	1	40	12.5	5
Sheep* (<i>Ovis aries</i>)	7	2.3	1	31	10.6	2	28	8.8	3
Gazelle (<i>Gazella</i> sp.)	3	1.0	1	3	1.0	1	4	1.3	1
Hare (<i>Lepus</i> sp.)	-	-	-	1	0.3	1	-	-	-
Dog (<i>Canis familiaris</i>)	7	2.3	1	15	5.1	1	3	0.9	1
Fox (<i>Vulpes</i> sp.)	-	-	-	5	1.7	1	-	-	-
Cat (<i>Felis catus</i>)	-	-	-	4	1.4	1	-	-	-
Bird	7	2.3	-	8	2.7	-	7	2.2	-
Fish	41	13.6	-	15	5.1	-	4	1.3	-
Rodent	2	0.7	-	-	-	-	2	0.6	-
Amphibian	8	2.6	-	-	-	-	-	-	-
Shell	10	3.3	-	3	1.0	-	4	1.3	-
Mollusc	-	-	-	6	2.1	-	10	3.1	-
Total	302	100.0	-	292	100.0	-	320	100	-
Medium mammal	178	-	-	84	-	-	135	-	-
Small-medium mammal	1	-	-	-	-	-	-	-	-
Small mammal	11	-	-	6	-	-	7	-	-
Small mammal or bird	2	-	-	-	-	-	1	-	-
Grand total	494	-	-	382	-	-	463	-	-

*The counts for sheep and goat are included in the ovicaprid counts

during the LBA II (Fig. 3b) and during the IA II in area P (Fig. 3c). Anatomical profiles for ovicaprids combined with medium ungulates can be found in SI 2.4, which confirm our patterns. Due to a small sample, we cannot reconstruct anatomical profiles for cattle in area P.

Ageing and sexing

We present epiphyseal fusion data for ovicaprids (Fig. 4a, Table 4) for the LBA II in area S. The majority of ovicaprids survive to be sub-adults, with a major drop in survival in

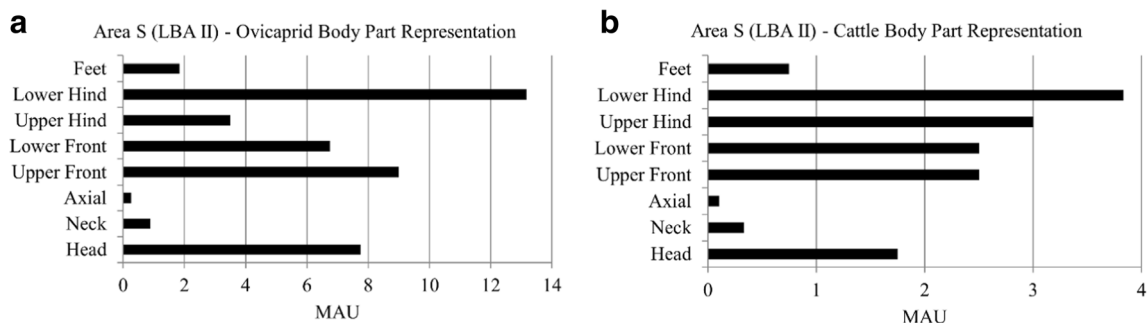


Fig. 2 Body part representation for ovicaprids (a) and cattle (b) during the LBA II in area S

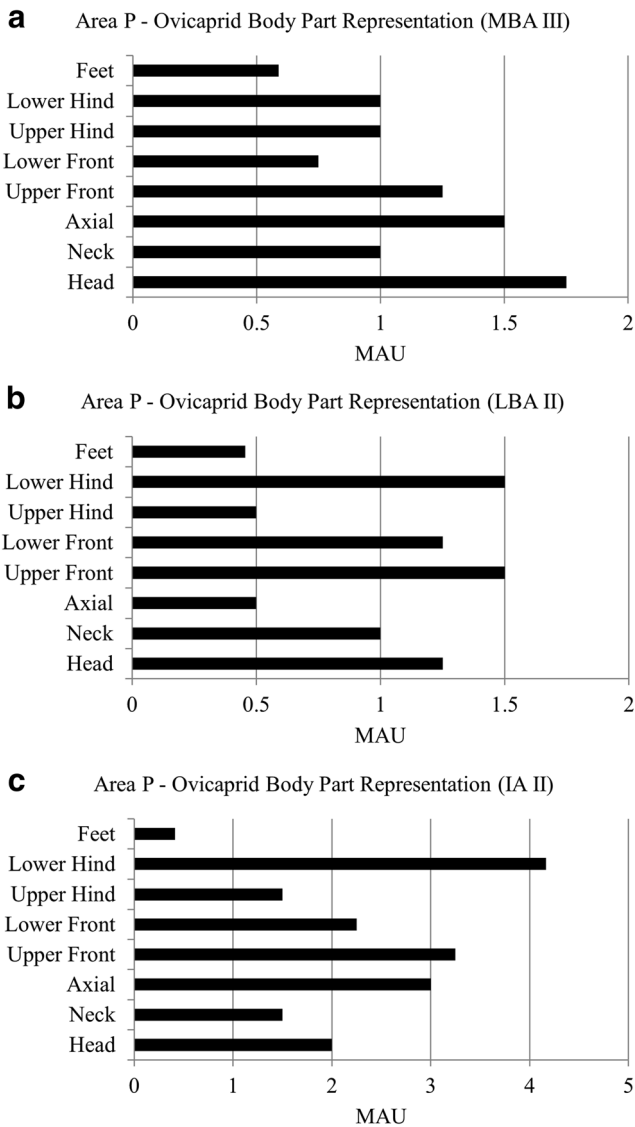


Fig. 3 Body part representation for ovicaprids through time in area P. A: body part representation during the MBA III, B: body part representation during the LBA II, C: body part representation during the IA II

adulthood. This corresponds to the results of the tripolar graph, which show the presence of mostly juvenile animals (Fig. 4b). Epiphyseal fusion for cattle (Fig. 5, Table 5) shows most cattle survive the first 2 years of life, with a major drop in survival at year 3, although we should consider the small sample size.

During the MBA III in area P, most ovicaprids (Fig. 6, Table 6) reached sub-adulthood, with a steep drop in survival in adulthood. During the LBA II, the pattern of ovicaprid survival (Fig. 6, Table 6) is similar, but with a higher survivorship in adulthood. The sample size of ageable elements for ovicaprids during the IA II is too small to be evaluated. The same applies to cattle in area P.

We determine the sex of ovicaprids for the LBA II in area S by using measurements of the distal breadth of the first

Table 4 Epiphyseal fusion data for ovicaprids during the LBA II in area S

Skeletal element	Fused	Unfused	%Survivorship
Humerus distal	23	3	-
Radius proximal	14	-	-
Young (first year)	37	3	92.5
Metacarpal distal	13	1	-
Tibia distal	19	5	-
Sub-adult (second year)	32	6	84.2
Radius distal	4	6	-
Femur proximal	3	6	-
Humerus proximal	3	1	-
Femur distal	4	7	-
Tibia proximal	2	3	-
Old	16	23	41.0

phalanx (Von den Driesch 1976) to perform mixture analysis ($N = 27$, mean = 11, standard deviation = 2.20; Fig. 7, Table 7). The measurements have a normal distribution (Shapiro-Wilk test, $W = 0.943$, $p = 0.1443$). The mixture analysis shows bimodality, with most specimens belonging to the group with the larger mean, indicating males outnumber females (AIC bi-model: 73.18, AIC tri-model: 76.74).

Taphonomy

We checked for the effect of density-mediated attrition in our assemblages (Table 8). We find an even tooth to bone ratio during the LBA II in area P, and an almost even tooth to bone ratio during the IA II in area P and during the LBA II in area S, indicating density-mediated attrition did not affect these assemblages and the trends we see reflect human subsistence

Table 5 Epiphyseal fusion data for cattle during the LBA II in area S

Skeletal element	Fused	Unfused	%Survivorship
Humerus distal	5	-	-
Radius proximal	3	-	-
2nd year	8	-	100
Metacarpal distal	5	1	-
Tibia distal	11	1	-
Metatarsal distal	1	-	-
3rd year	17	2	89.5
Humerus proximal	1	3	-
Radius distal	5	2	-
Femur proximal	2	3	-
Femur distal	1	-	-
Tibia proximal	2	3	-
4th year	11	11	50

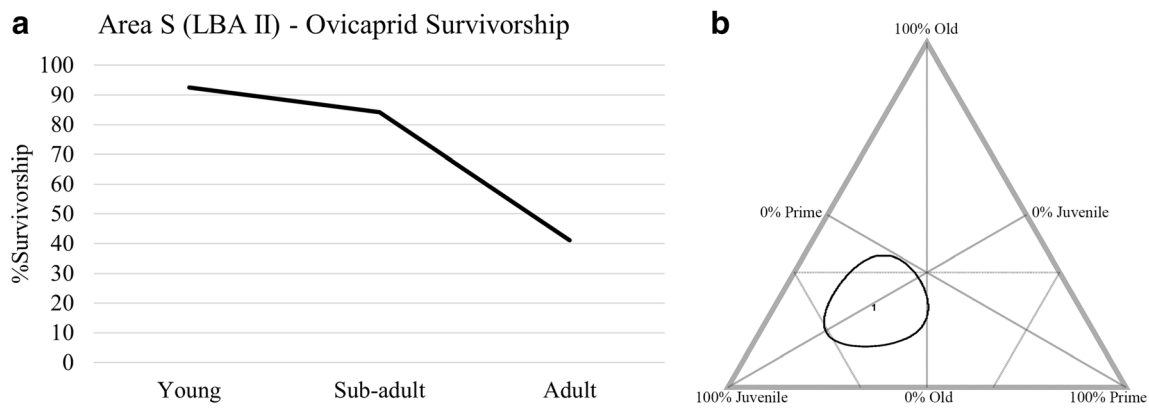


Fig. 4 Ageing for ovicaprids during the LBA II in area S. A: %survivorship graph based on epiphyseal fusion. B: tripolar graph represented by 29 juvenile, 14 prime aged adult, and 13 old specimens

strategies. In the MBA III of area P, the tooth to bone ratio indicates a higher preservation of bone compared to teeth. Since most of the material is hand-collected, we also checked analyzed effects of recovery bias by analyzing the bone length of the most common taxon, ovicaprids (SI2.5). It seems recovery bias is not an issue for the LBA II sample in area P and area S, since both these areas have most bone fragments in the smallest sized bins (5–20 mm). This is, however, not the case for the MBA III and IA II in area P, where most fragments are in larger bins (20–40 mm). Recovery methods were the same in the two areas, but the IA II contained the lowest number of materials coming from flotation samples which explains why we do not have that many bone fragments in the lower sized bins. Although the MBA III had more flotation samples than the LBA II in either area, the number of specimens in all MBA III flotation samples was lower than the LBA II samples. Nonetheless, this slight bias should not affect our interpretations too much, since we have flotation samples for all assemblages and bone fragments of 20 mm are still large enough to include most elements from ovicaprids.

Butchery evidence is rare at Lachish (Table 9). Forty-two bones show traces of butchery in area S, most of them dating

to the LBA II. All LBA II cutmarks are on ovicaprids, most of them on the humerus and astragalus. Five bones in area P show traces of cutmarks.

Burning is uncommon (1.1% carbonized, 0.3% calcined, Table 10) in area S; most is from the LBA II and occurs on medium ungulates and ovicaprids. Area P has low numbers of burned material (1.0% carbonized, 0.5% calcined), most occurring on MBA III and LBA II material. The MBA III has burning on medium mammals and ovicaprids; the LBA II has most burning on medium mammals and large ungulates

In area S, four LBA II specimens show pathologies and seven bones were worked by humans. Area P has two pieces of worked bone.

Discussion

Subsistence at Lachish during the MBA, LBA, and IA II

During the MBA III, the diet was dominated by ovicaprids, with sheep and goat playing an equally important role. Mixed flocks are more resistant than single taxon flocks, for example

Fig. 5 Ageing for cattle during the LBA II in area S

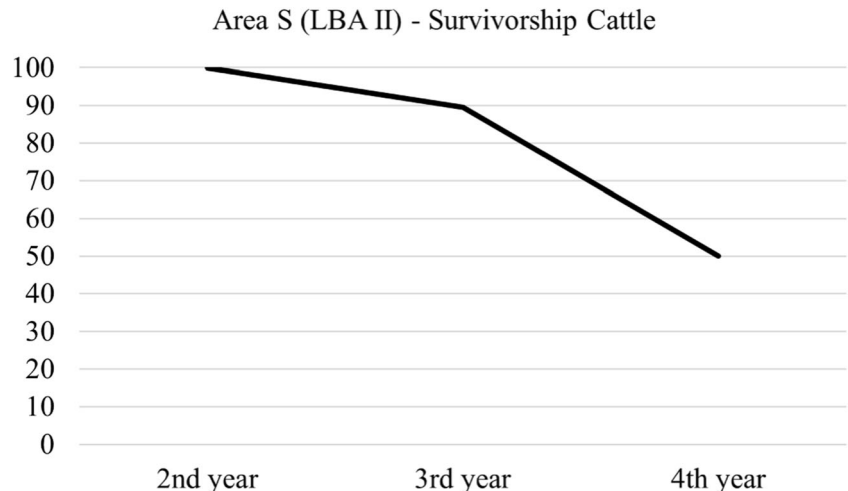


Table 6 Epiphyseal fusion data for ovicaprids in area P

Skeletal element	MBA III			LBA II		
	Fused	Unfused	%Survivorship	Fused	Unfused	%Survivorship
Humerus distal	3	-	-	4	1	-
Radius proximal	1	-	-	1	1	-
Young (first year)	4	-	100	5	2	83.3
Metacarpal distal	4	-	-	2	-	-
Tibia distal	1	1	-	1	1	-
Sub-adult (second year)	5	1	83.3	3	1	75
Radius distal	1	1	-	-	2	-
Femur proximal	-	-	-	1	1	-
Humerus proximal	-	2	-	-	-	-
Femur distal	-	2	-	1	1	-
Old	1	5	16.7	2	4	50

against disease or temperature changes (Redding 1981). Sheep and goat were slaughtered as they reached adulthood and their maximum size. Most ovicaprid remains consisted of head elements but the high abundance of lower limbs is noteworthy since these do not contain a lot of meat. Fish and cattle were important parts of the diet. Cattle remains are mostly represented by meaty limb elements. Suids were moderately consumed, and hunting did not play an important role in the diet.

The LBA II is represented by area S and area P. The assemblages in both areas are dominated by ovicaprids; in area S, goats outnumber sheep, whereas in area P, we see the opposite. We should note the small sample size for the ovicaprid differentiation in area P, which probably influences the sheep to goat ratio. Ovicaprids in both areas show similar mortality profiles, with a preference for adult animals. In both areas, ovicaprids are mostly represented by front limbs. Sex ratios of ovicaprids dating to the LBA II in area S show male ovicaprids were slaughtered more than females. Both areas

show cattle were an important part of the diet at the site. In area S cattle tended to be slaughtered as adults, indicating their use as traction animals (Bartosiewicz et al. 1997). Suids did not play an important role in the LBA II diet at Lachish, nor did wild animals. Fish played a smaller role in the diet compared to the MBA.

The IA II is dominated by ovicaprids, with goats slightly outnumbering sheep, indicating a strategy focussed on herd security (Redding 1981, 1984). This seems unrelated to environmental developments, which show the IA II occurred during favourable conditions for agriculture.

Comparison to previous analyses

We compare our results for the LBA II in area S to those of Croft (2004a). He divided the LBA into two subperiods, LBA II which is represented by strata in area S, and LBA III which is from two levels represented in several areas of the site. The bulk of the LBA material from Croft (2004a) came from area

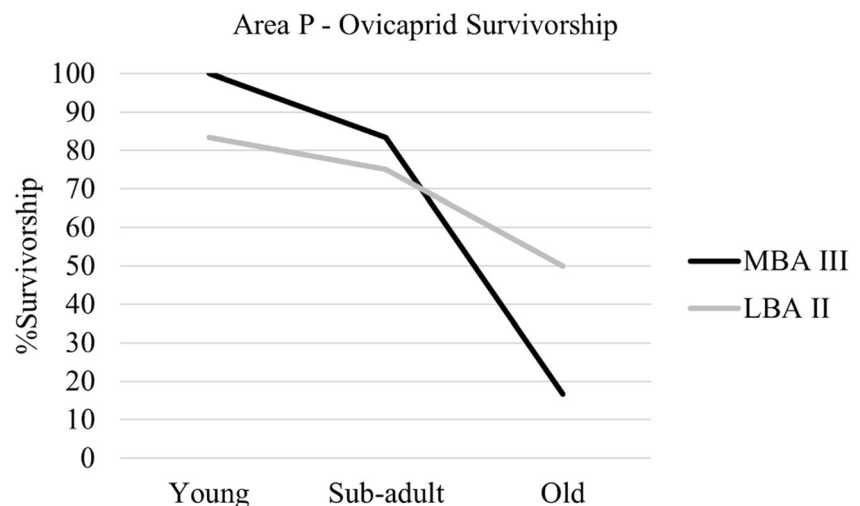
Fig. 6 Ageing for ovicaprids in area P through time

Table 7 Results of the mixture analysis performed on the distal breadth measurements of the first phalanx on ovicaprids

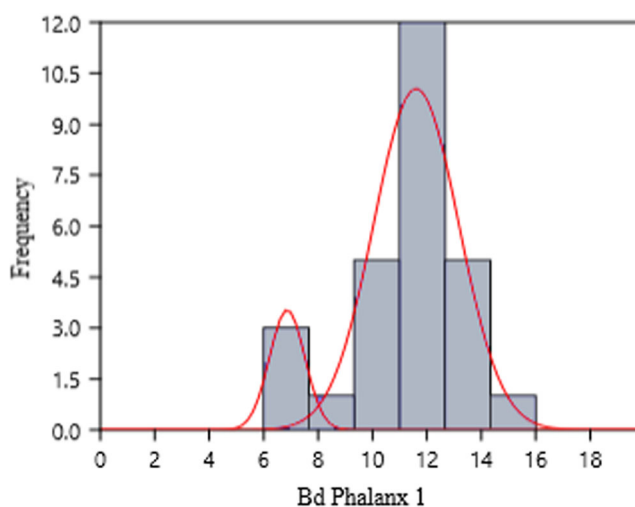
Skeletal element	N	Male			Female		
		Mean	St. dev.	%	Mean	St. dev.	%
Area S, LBA II							
Phalanx 1, Bd	27	11.605	1.5561	85.2	6.8658	0.64973	14.8

S, but there is also a larger sample from area P. His assemblage was dominated by ovicaprids, with the sheep to goat ratio remaining stable between subperiods, although there was a slight predominance of goats, like our results for area S. The mortality profiles differ slightly between our study and Croft's (2004a). Croft (2004a) found that more sheep than goats reached adulthood, since sheep were kept for their wool. Goats tend to be slaughtered at a younger age for obtaining milk (Croft 2004a). Our (smaller) sample is less nuanced and shows most ovicaprids are slaughtered as adults.

He concluded that areas P and S only differ in the ovicaprid to cattle ratio. Our assemblage also shows a difference in ovicaprid to cattle ratio between the two areas, keeping in mind the different sample sizes. Taxa such as pig, birds, and wild animals are represented in low numbers in both assemblages. Fish are present in larger numbers than in the MBA for the previous faunal work, and in similar proportions as our results (Lernau and Golani 2004).

Synchronic comparison of subsistence patterns in the Shephelah

We compare Lachish to other sites in the Shephelah region dating to the MBA, LBA, and IA II (Fig. 8). In doing so, we lose chronological resolution by broadening the

**Fig. 7** Mixture analysis for ovicaprids during the LBA II in area S**Table 8** Ratios between ungulate lower tooth and mandible MNE at Lachish

	Taxon	Tooth MNE	Bone MNE	Tooth to bone ratio
Area S				
LBA II	Cattle	6	3	2
	Fallow deer	2	1	2
	Pig	1	2	0.5
	Ovicaprid	37	27	1.4
	Gazelle	2	1	2
	Total	48	34	1.4
Area P				
IA II	Ovicaprid	7	8	0.88
	Total	7	8	0.88
LBA II	Pig	1	1	1
	Ovicaprid	5	4	1.25
	Gazelle	1	2	0.5
	Total	7	7	1
MBA III	Cattle	1	1	1
	Ovicaprid	1	3	0.33
	Total	2	4	0.5

time periods to gain more comparative material. We compare sites by looking at the sheep to goat ratio and their mortality profiles (Table 11). The sheep to goat ratios from Lachish in Table 11 differ from the values found in our study due to the larger sample sizes and changes in chronological resolution.

During the MBA, there is a clear preference for sheep over goats at Lachish. During the MBA, mostly adult animals were slaughtered, with sheep surviving into adulthood more frequently than goats, whereas goats were slaughtered more often at a young age for milk production (Croft 2004a). The smaller sample of our study shows most ovicaprids are slaughtered upon reaching adulthood. At Tell Miqne/Ekron and Tel Haror, sheep outnumber goats. Ovicaprids of all ages are slaughtered at Tell Miqne/Ekron, indicating an unspecialised economy (Maher and Hesse 2016b). At Tel Haror, mostly young animals were slaughtered for obtaining milk and meat products (Klenck 2002). Interestingly, Tell Nagila is the only site in the region to have no sheep but only goat, although Ducos (1968) mentions the possibility of two specimens perhaps being sheep. Mortality data show most goats were slaughtered between 1 and 3 years and only a few were older.

During the LBA, the sheep to goat ratio at Lachish was similar to that of Tel Beth-Shemesh and Timna, with sheep and goat being almost equally important indicating a focus on herd security. At Lachish, we see the same mortality pattern as during the later MBA (Croft 2004a). Ovicaprid mortality at

Table 9 Cutmarks found per area, time period, taxon, and skeletal element

Taxon	Skeletal element	Area S		Area P		
		LBA II	LBA IIIA	MBA III	LBA II	IA II
Large ungulate	Long bone shaft	1	-	-	-	-
	Rib	2	-	-	-	-
	Scapula	1	-	-	-	-
	Femur	1	-	-	-	-
Cattle	Mandible	1	-	-	-	-
	Pelvis	1	-	-	-	-
	Ulna	1	-	-	-	-
	Astragalus	1	-	-	-	-
Medium ungulate	Second phalanx	-	-	1	-	-
	Cervical vertebra	1	-	-	-	-
	Thoracic vertebra	-	1	-	-	-
	Rib	2	-	-	-	-
	Lumbar vertebra	1	-	-	-	-
	Pelvis	1	-	-	-	-
Pig	Metatarsal	1	-	-	-	-
	Atlas	1	-	-	-	-
Ovicaprid	Horn core	1	-	-	-	-
	Pelvis	2	-	-	-	-
	Scapula	1	-	-	-	-
	Radius	1	-	-	-	-
	Metacarpal	-	-	1	1	-
	Femur	2	-	-	1	-
	Astragalus	2	-	-	-	-
	First phalanx	-	-	-	-	1
Goat	Astragalus	1	-	-	-	-
Sheep	Humerus	6	-	-	-	-
	Radius	1	-	-	-	-
	Astragalus	1	-	-	-	-
Gazelle	Tibia	1	-	-	-	-
Medium bird	Femur	1	-	-	-	-
Medium mammal	Long bone shaft	1	-	-	-	-
	Rib	1	-	-	-	-
	Lumbar vertebra	1	-	-	-	-
	Pelvis	1	-	-	-	-
	Scapula	1	-	-	-	-
Total		41	1	2	2	1

Tel Beth-Shemesh (Tamar et al. 2013) and Timna (Lernau 1988) shows a focus on obtaining meat and secondary products. Tell Miqne/Ekron had sheep outnumbering goats, with a preference of slaughtering young and old ovicaprids. This indicates an unspecialised economy (Lev-Tov 2010, 2000). The occupants of Tel Burna show a strong preference for goats, but we have no age data available to check for economic strategies (Greenfield et al. 2017). The choice for goats could be connected to the arid climatic conditions prevailing during the LBA (Drori and Horowitz 1989; Langgut et al.

2015; Rosen 1986). Greenfield et al. (2017) mention the size of Tel Burna indicates it participated in regional politics. Since Lachish is only about 10 km away, there might have been an exchange of resources between the two sites.

During the IA II, the sheep to goat ratio at Lachish has slightly more sheep than goats and its economic strategy remains the same as during the late MBA and LBA. A focus on sheep husbandry during the IA II fits well with the archaeobotanical evidence in the Shephelah region. At Tel es-Safi a large number of grape pips have been found in IA

Table 10 Number of unburned, carbonized, calcined, and darkened (or mineral staining) bones per area and per time period

	MBA II–III	MBA III	LBA I	LBA II	LBA II–LBA IIIA	LBA IIIA	Late LBA	IA II
Area S								
Unburned	-	1	3	3853	12	65	5	-
Carbonized	-	-	-	46	-	-	-	-
Calcined	-	-	2	9	-	-	-	-
Darkened	-	-	-	5	-	-	-	-
Total	-	1	5	3,913	12	65	5	-
Area P								
Unburned	102	484	-	374	-	-	-	453
Carbonized	-	6	-	5	-	-	-	4
Calcined	1	4	-	2	-	-	-	-
Darkened	-	-	-	1	-	-	-	6
Total	103	494	-	382	-	-	-	463

II contexts (Mahler-Slasky and Kislev 2012), and occupants of Tel Burna cultivated demanding crop species, such as flax, which indicated high water availability (Orendi 2020). This interpretation is further supported by the stable carbon isotope data of barley grain (Riehl and Shai 2015). Tel Halif has more goats, and initially, the focus was on slaughtering prime adults for their meat. In the eighth century, this shifted to slaughtering both prime adults and older individuals for meat and secondary products and eventually slaughtering all age groups (Sapir-Hen 2015). The focus on goats at Tel Halif could be because the site is located close to the northern Negev region, with more arid conditions to which goats are better adapted. On the other hand, this could also reflect that management strategies at Tel Halif were less market-orientated and more for the consumption of people at the site (Sapir-Hen 2015). Tel Mique/Ekron and Tell el-Hesi had

sheep outnumbering goats. Age data at Tell Mique/Ekron indicates a preference for slaughtering prime adults but keeping enough stock alive into adulthood to profit from their secondary products, such as wool (Lev-Tov 2010, 2000; Maher and Hesse 2016). At Tell el-Hesi, mostly prime adults were slaughtered, indicating an economy focussed on meat (Peck-Janssen 2006).

Conclusion

In this study, we present new data on areas S and P at Lachish. First, we wanted to establish how subsistence strategies changed through time at Lachish and whether we could determine differences between the two areas during the LBA II. Ovicaprids dominate all assemblages,

Table 11 Data for synchronic comparison in the Shephelah. *S:G* = sheep to goat ratio, *OC* = ovicaprid. Tel es-Safi has very small sample sizes of species-specific identifications for sheep and goat for the LBA

Site	Sheep	Goat	OC	S:G	Reference
Lachish IA II	325	265	1,861	1.23	(Croft 2004a; Lemau 1975; this paper)
Tel Halif IA II	65	177	217	0.37	(Sapir-Hen, 2015)
Tell Mique/Ekron IA II	254	132	2,351	1.92	(Lev-Tov 2000, 2010; Maher and Hesse 2016)
Tell el-Hesi	49	28	380	1.75	(Peck-Janssen 2006)
Lachish LBA	957	1,181	11,111	0.81	(Croft 2004a; Lemau 1975; this paper)
Tel Beth-Shemesh LBA	194	200	3,451	0.97	(Tamar et al. 2013)
Tel Burna LBA	23	83	180	0.28	(Greenfield et al. 2017)
Timna LBA	113	142	2,891	0.80	(Lemau 1988)
Tell Mique/Ekron LBA	196	95	1,437	2.06	(Lev-Tov 2010, 2000)
Lachish MBA	295	147	2,751	2.01	(Croft 2004a; Lemau 1975; this paper)
Tell Mique/Ekron MBA	21	9	89	2.33	(Maher and Hesse 2016b)
Tel Haror MBA	927	8	24	2.83	(Klenck 2002)
Tell Nagila MBA	0	124	-	-	(Ducos 1968)

(sheep = 6, goat = 4, OC = 135) and IA II (sheep = 17, goat = 12, OC = 3835 (Kehati et al. 2018; Lev-Tov 2012), so we exclude them from this table

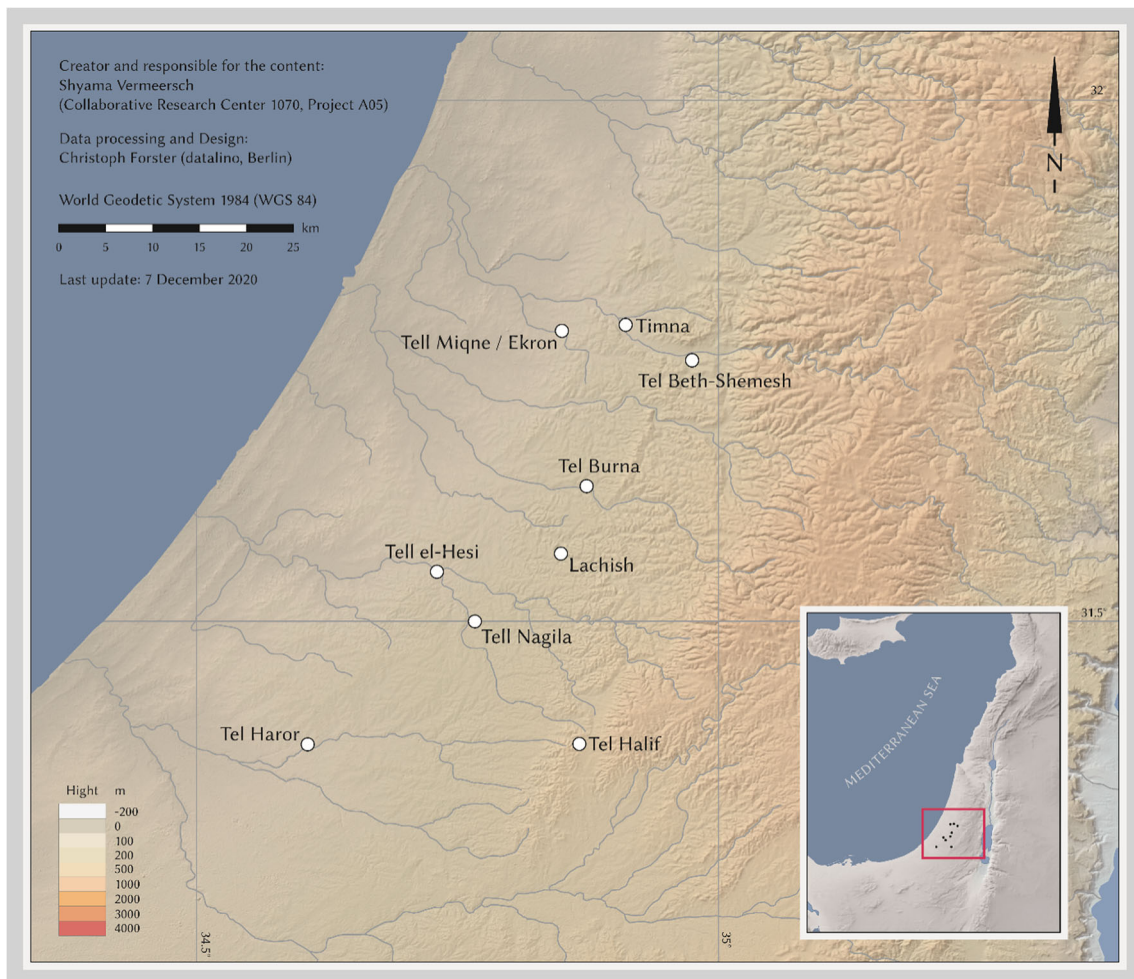


Fig. 8 Map showing the location of Lachish and the sites used for comparing subsistence patterns

although we see changes in the sheep to goat ratio. During the MBA III in area P, we see an almost equal presence of sheep and goat, indicating a strategy aimed towards herd security. During the LBA II in area S, which is characterized as being a settlement area, we see goats outnumbering sheep, with more male than female ovicaprids being slaughtered. This contrasts with the LBA II area P, which contains palace and settlement remains, where sheep outnumber goats. This could be an artefact of sample size, but perhaps in the future, these differences will help us interpret the ways in which the two areas were used. The IA II has goats slightly outnumbering sheep. We see a preference for slaughtering adult ovicaprids during the MBA III and LBA II. Throughout the history of Lachish, cattle played an important role in subsistence, although we see a sudden decrease in their abundance during the IA II. Fish were an important part of the diet, especially during the MBA III and the LBA II in area P. Suids were moderately consumed during the MBA III and LBA II. Wild animals appeared in low numbers, indicating hunting was not

important for subsistence or the economy. The animals were likely hunted locally since they consist of taxa such as fallow deer or gazelle, which are native to the environment around Lachish.

Second, we investigated whether our results establish similar trends as previous analyses. Though we could only compare the LBA II from our results with the LBA results (representing the LBA II and III) from Croft (2004a), our results correspond well with those of the previous analyses. This gives us confidence that previous studies done by different analysts will be useful one day for reconstructing even broader subsistence patterns at Lachish.

Third, we compared the results of Lachish with other synchronous sites in the Shephelah region to determine how the site fits within the regional framework. During the MBA, the ovicaprid economy is similar to other sites in the region, namely sheep outnumbered goats, with an unspecialised economy. During the LBA, subsistence strategies at Lachish fit in the regional framework, being similar to Timna and Tel Beth-Shemesh, with a focus on herd security. This pattern might also reflect drier environments during the end of the LBA

(Drori and Horowitz 1989; Langgut et al. 2015; Rosen 1986). The large size of Tel Burna suggests that it might have participated in regional politics which probably involved interactions with Lachish. Tell Miqne/Ekron is the only site in the region where sheep outnumber goats. Most sites during the LBA in the Shephelah tend to focus on a combination of obtaining meat from prime adults and secondary products from older individuals. During the IA II subsistence strategies at Lachish differ from the other sites in the region. Whereas the occupants of Lachish focussed on obtaining secondary products, people at other sites in the region focussed more on meat by slaughtering prime adults.

Lachish was one of the largest tells in the southern Levant, and its political importance, both on a regional and supra-regional level, is attested to by several sources (Cochavi-Rainey and Rainey 2015; Ussishkin 2004). By studying its faunal remains, we can reconstruct subsistence strategies more in-depth and get a better idea of how such a large settlement managed to feed its inhabitants. We demonstrated the merit of synthesizing previous and ongoing faunal analyses, and as excavations at Lachish continue, it will be possible to obtain more data to determine broader trends in subsistence strategies and animal husbandry at Lachish.

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Code availability Not applicable

Author’s contribution Shyama Vermeersch: conceptualization, formal analysis, writing—original draft, visualization. Simone Riehl: writing—review and editing. Britt M. Starkovich: writing—review and editing. Katharina Streit: resources, writing—review and editing. Felix Höflmayer: resources, writing—review and editing

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Data availability NISP, %NISP, and MNI values per time period are found in SI 1. Extra figures for analyses can be found in SI 2.

Declarations

Ethics approval Not applicable

Consent to participate Not applicable

Consent for publication (include appropriate statements) All authors agree with the content of this manuscript and approve of it being published.

Conflict of interest The authors declare no conflict of interest.

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