Developments in Subsistence Practices
from the Early Bronze Age through the Iron Age
in the Southern Levant

Dissertation

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Don't you know that I'm still standing better than I ever did

Looking like a true survivor, feeling like a little kid

Elton John, Bernie Taupin, 1983. *I'm Still Standing*. [lyrics] UK: Rocket, US: Geffen.

Contents

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Abbreviations

BA	Bronze Age
BCE	Before Common Era
CA	Correspondence Analysis
CCA	Canonical Correspondence Analysis
CE	Common Era
CRC	Collaborative Research Centre
DCA	Detrended Correspondence Analysis
EBA	Early Bronze Age
IA	Iron Age
Km	Kilometres
LBA	Late Bronze Age
Km	Kilometre
MAP	Mean Annual Precipitation
MAU	Minimal Animal Unit
MBA	Middle Bronze Age
Mm	Millimetre
MNE	Minimal Number of Elements
MNI	Minimum Number of Individuals
NISP	Number of Identified Specimens
%NISP	Percentage of Number of Identified Specimens

Abstract

The Bronze (3,600 BCE – 1,200 BCE) and Iron (1,200 – 586 BCE) Ages in the southern Levant witnessed major social, political, and cultural changes. These include the first development of complex urban-based settlements, and the genesis of new cultural identities. Such changes are deeply entangled with, and often driven by, developments in agriculture. Although many published botanical and faunal reports are available for sites dating to this period, there is a shortage of syntheses searching for general trends in subsistence developments, and to what extent such trends are related to cultural and/or environmental factors. Moreover, botanical and faunal remains are usually analysed independently from each other, limiting our understanding of agricultural practices and subsistence in past societies. This separation of animal husbandry and crop cultivation in archaeological research is an artefact of methodological differences between disciplines, which needs to be overcome to gain a more holistic understanding of how economic developments drove, and were driven by, major socio-political and environmental change.

I investigate the development of subsistence practices in the southern Levant from the Bronze through the Iron Age in three steps. First, I analyse the faunal material from two sites, Tell Lachish and Tell el-Burak, using traditional zooarchaeological methods to understand diet and animal husbandry strategies on a regional scale. Second, I establish a reference database consisting of the abundance data of published faunal reports. Third, I use correspondence analysis to investigate trends in animal-based subsistence strategies, and to integrate faunal and botanical data for obtaining a holistic view of subsistence and agriculture.

My results show changes in diet through time in the southern Levant, caused by cultural and environmental factors. There is a clear difference between the diet of people inhabiting sites dating to the Early and Middle Bronze age, and those dating to the Late Bronze and Iron Age. The former are associated with high numbers of pigs, wild faunal taxa, and emmer wheat. The latter are characterised by the appearance of zebu, camelids, and an increasing focus on free-threshing wheats. I reveal differences between the diet of people at sites of high and lower mean annual precipitation zones, and between those of sites located at lower and higher elevations.

My dissertation shows the value of site-specific analysis to reconstruct local subsistence patterns, the merit of using metadata to reconstruct trends in diet through time and space, and the benefits and potential of an integrative analysis to obtain a holistic understanding of subsistence developments of past societies.

Zusammenfassung

Die Gesellschaften der Bronze- (3,600 BCE – 1,200 BCE) und Eisenzeit (1,200 – 586 BCE) in der südlichen Levante erlebten fundamentale soziale, politische, und kulturelle Änderungen. Diese beinhalteten die Entwicklung von komplexen urbanen Zentren und die Entstehung neuer kultureller Identitäten. Solche Veränderungen sind eng mit Entwicklungen in der Landwirtschaft verknüpft und werden oft von diesen vorangetrieben. Obwohl es zahlreiche Publikationen über die Botanik und Fauna dieser Epochen gibt, konzentrieren sich nur wenige auf Synthesen und generelle Tendenzen der Subsistenzentwicklung, sowie die Frage, ob diese Prozesse von kulturellen oder naturräumlichen Faktoren beeinflusst wurden. Dazu werden botanische Reste und Tierknochen meistens unabhängig voneinander analysiert, was unser Verständnis der Landwirtschaft und Subsistenz in der Vergangenheit stark limitiert. Diese Trennung von Tierhaltung und Ackerbau in der archäologischen Forschung ist ein Artefakt der methodologischen Unterschiede zwischen beiden Disziplinen, was wir überwinden müssen, wenn wir ein holistisches Verständnis der Zusammenhänge zwischen ökonomischen, sozialen, politischen und ökologisch-klimatischen Veränderungen erlangen wollen.

Die Untersuchung der Subsistenzentwickelung in der südlichen Levante von der Bronze- bis in die Eisenzeit gliedert sich in drei Schritte. Zunächst analysiere ich die Tierknochen der beiden Siedlungen Tell Lachish (Israel) und Tell el-Burak (Libanon) mittels traditioneller archäozoologischer Methoden, um die lokalen Ernährungsgewohnheiten und die Tierhaltung auf regionaler Ebene zu rekonstruieren. Im darauffolgenden Schritt erstelle ich eine Referenzdatenbank mit den Häufigkeitsdaten (NISP) von publizierten archäozoologischen Analysen. Abschließend analysiere ich die gesammelten Datensätze mittels der Korrespondenzanalyse, um Entwickelungen in der Tierhaltung im Zusammenhang mit Veränderungen im Ackerbau zu untersuchen. Diese integrierte Analyse von Tier- und Pflanzenresten stellt einen wichtigen Schritt dar, um ein holistisches Bild der Subsistenzentwicklung bronze- und eisenzeitlicher Gesellschaften der südlichen Levante zu erhalten.

Meine Ergebnisse zeigen zeitliche Entwicklungen in der Ernährung der untersuchten Kulturen, die durch kulturelle und naturräumliche Faktoren beeinflusst wurden. Die Ernährung während der Früh- und Mittelbronzezeit ist mit hohen Anteilen vom Hausschwein, verschiedenen Wildtieren und Emmer verbunden, während in der Spätbronze- und Eisenzeit neue Nutztiere wie das Zeburind und Kamele auftauchen und Nacktweizen im Ackerbau wichtiger werden.

Daneben gibt es Unterschiede in der Ernährung zwischen Siedlungen in höheren und niedrigeren Niederschlagsregionen sowie zwischen Siedlungen im Tiefland und in höheren Lagen.

Meine Dissertation kombiniert fundstellenspezifische Analysen mit der Auswertung von Metadaten, um Muster und Entwicklungen in Subsistenzstrategien in Zeit und Raum zu rekonstruieren. Die Ergebnisse zeigen den Vorteil einer integrativen Analyse, die ein holistisches Verständnis vom Zusammenhang der Tier- und Pflanzenwirtschaft in der Vergangenheit zu erreichen.

List of Publications

Accepted publications:

1. **Vermeersch, S**., Riehl, S., Starkovich, B. M., Kamlah, J., 2021. Developments in subsistence during the Early Bronze Age through the Iron Age in the southern and central Levant: Integration of faunal and botanical remains using multivariate statistics. *Quaternary Science Reviews,* 253, p.106776.

2. **Vermeersch, S**., Riehl, S., Starkovich, B. M., Streit, K., Höflmayer, F., 2021. Animal husbandry from the Middle Bronze Age through the Iron Age in the Shephelah – Faunal remains from the new excavations at Lachish. *Archaeological and Anthropological Sciences,* 13(3), pp.1-16.

3. **Vermeersch, S.,** Riehl, S., Starkovich, B.M. and Kamlah, J., 2021. Integrating faunal and botanical remains using multivariate statistics to reconstruct (pre) historic subsistence developments. *MethodsX*, 8, p.101336.

Manuscripts ready for submission:

4. **Vermeersch, S**., Starkovich, B. M., Orsingher, A., Kamlah, J., Subsistence practices in the Phoenician heartland – Tell el-Burak (Lebanon) in its regional context during the Iron Age II. Planned submission to *Journal of Anthropological Archaeology* in 2021.

Personal Contributions

Below is an overview of my personal contribution and those of my co-authors for all collaborative manuscripts used in this dissertation, following § 6,2 of the Doctoral Degree Regulations of the Faculty of Science at the University Tübingen.

I am the first and corresponding author on all manuscripts provided here. I conceptualised the project ideas, conducted all archaeozoological and statistical analyses, and created all graphs.

Britt Starkovich provided help with taxonomic identifications of faunal remains for manuscript 4. She also provided editorial input, helped develop the interpretations, and supervised the studies for all manuscripts provided here.

Simone Riehl helped conceptualise the project idea and methodology for manuscripts 1 and 3. She provided editorial input on these two manuscripts and manuscript 2.

Jens Kamlah provided editorial input for manuscripts 1, 3, and 4. He also provided in-depth archaeological information for manuscripts 1 and 4.

Katharina Streit and Felix Höflmayer are directors of the Tel Lachish excavations and provided the faunal material. Both provided editorial input for manuscript 2.

Adriano Orsingher provided editorial input and in-depth archaeological information for manuscript 4.

Chapter 1: Introduction

The cultures of the Bronze and Iron Ages (3,000 – 586 BCE) in the southern Levant are well-studied by scholars, and the subject is very popular with the public, as testified by many documentaries, movies, and popular books on the topic. It is also of key importance to understand the historic background of two of the largest monotheistic religions, Judaism and Christianity. Understanding subsistence strategies is important for archaeologists specialised in this time and region since subsistence and agricultural practices play an important role in social and political changes (Butzer, 1997; Fall et al., 1998; Zeder, 1988). One way to increase our knowledge of these past subsistence strategies is by studying the archaeological faunal and botanical remains. Many reports on the faunal and botanical remains have been published for individual sites, investigating the developments of subsistence on a local scale, which contributes to the frameworks archaeologists use to understand socio-political, cultural, and environmental change. However, at the time of writing, there are no syntheses available on the diachronic developments of crop cultivation, and only a few studies are available for animal husbandry, although these usually focus on the proportion of abundance or mortality profiles of the main domesticates such as sheep, goat, cattle, and pig, and rarely cover the entire Bronze and Iron Age (Gaastra et al., 2020; Sapir-Hen, et al., 2014; Sasson, 2008; Tchernov and Horwitz, 1990). Although site reports and syntheses add to our understanding of past diet, they only manage to provide us with one aspect of subsistence strategies since the distinction between animal husbandry and crop cultivation in the archaeological record is arbitrary. It is based on methodological differences between the disciplines of zooarchaeology and archaeobotany rather than historic reasons. In agricultural systems of the past and present, animals and plants are closely interlinked (Bogaard, 2005; Butzer, 1996) and only by viewing them as such, can we truly understand past subsistence practices. This means that, although there is an abundance of data on subsistence practices from the Bronze and Iron Ages, we still lack comprehensive syntheses and integrative approaches.

The southern Levant is situated in south-western Asia and corresponds to modern-day Jordan, Palestine, Israel, and southern Lebanon (fig. 1). Although this region only encompasses a small territory, it is home to highly diverse topographical conditions and climatological differences, the latter will be discussed more in-depth in section '1.2. Climatic Background'. There are four different longitudinal topographic belts in the southern Levant: the coastal plain, the western

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mountain region, the Jordan Valley, and the Transjordan Plateau (Zohary, 1962). While the coastal plain is characterised by a true Mediterranean climate (Zohary, 1962), the western mountain regions consist of different zones. The western, sloping side of the mountain ranges have a Mediterranean climate and vegetation, whilst the eastern slopes are mostly desert or semidesert (Zohary, 1962). As part of a rift valley, the Jordan Valley is bordered by mountains on both sides. The northern part of the valley includes swamps and a Mediterranean wood climax area, whereas the southern part consists of deserts, salines, and tropical oases (Zohary, 1962). The Transjordanian Plateau is characterised by the Syrian Desert towards the east and a series of latitudinal rivers to the west (Zohary, 1962).

Chronology in the southern Levant is a much debated topic and no consensus has been reached yet (Finkelstein and Piasetzky, 2011; Mazar, 2005; Regev et al., 2014). Relative chronology in this region is usually based on changes in ceramic types through time, although there has been an increase in the application of radiocarbon dating to determine absolute dates. In this study, we follow the chronology presented by Kamlah and Riehl (in press), which is based on Sharon (2014) (table 1).

Table 1: Chronology from the EBA to the IA as used in this dissertation.

Relative Dating	Abbreviation	Absolute Dating
Early Bronze Age I	EBA I	3,600 – 3,000 BCE
Early Bronze Age II-II	EBA II-III	3,000 – 2,400 BCE
Early Bronze Age IV	EBA IV	2,400 – 2,000 BCE
Middle Bronze Age	MBA	2,000 – 1,550 BCE
Late Bronze Age	LBA	1,550 – 1,200 BCE
Iron Age I	IA I	1,200 – 975 BCE
Iron Age IIA	IA IIA	975 – 800 BCE
Iron Age IIB	IA IIB	800 – 700 BCE
Iron Age IIC	IA IIC	700 – 568 BCE
Iron Age III	IA III	568 – 332 BCE

Fig. 1: Map of the southern Levant showing the regions as used in project A05 of the SFB 1070. The coastal plain consists of the southern and central coastal plain, the Carmel range, the northern coastal range, the Tyrian coastal, and the Sidonian coastal plain. The western mountain region consists of the Negeb, Shephelah, southern and central hill country, Jezreel Valley, lower and upper Galilee, and Mount Lebanon. The Jordan Valley consists of the Arabah, the southern, central, and northern Jordan Valley, and the Beqa' Valley. The Transjordan Plateau consists of the southern Transjordan, the central Transjordan (north and south), the northern Transjordan, the Golan Heights, and the anti-Lebanon range.

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1.1. Objectives of Study

This dissertation seeks to investigate developments in subsistence from the Early Bronze Age through the Iron Age in the southern Levant by the analysis of archaeological faunal remains. The Bronze and Iron Ages are periods where major climatic (see chapter 1.2), socio-economic, and political changes, such as the first development of complex urban-based settlements (see chapter 1.1), take place. Because developments in animal husbandry and crop cultivation are deeply entangled with such developments (Butzer, 1997; Fall et al., 1998; Zeder, 1988), reconstructing how diet changes through time is key to understand the economic background of social and political developments.

My dissertation focusses on three main research questions:

- What trends in subsistence strategies are visible in the faunal assemblages dating from the Early Bronze Age through the Iron Age in the southern Levant?
- What cultural and environmental factors influence these trends?
- Does the integrative analysis confirm trends visible in animal-based subsistence developments by considering botanical data as well?

With these questions I not only aim at enhancing our understanding of subsistence and agricultural practices through the Bronze and Iron Age but will provide a better contextualisation of the economic background of socio-cultural and political changes during the Bronze and Iron Ages in the southern Levant as well.

As mentioned earlier, investigating faunal and botanical remains in an integrative analysis is crucial since animal husbandry and crop cultivation are closely interlinked in agricultural systems (Bogaard, 2005; Dalman, 1939, 1937; Miller, 2001). Despite this, integrative analyses are not common when analysing agricultural activities in this time and region. This is due to the challenges in integrating datasets related to the different materials and methodologies of faunal and botanical remains. However, if we want to gain holistic insights into the developments of mixed farming systems during the Bronze and Iron Ages, it is crucial to apply integrative analyses. To achieve this, I adopt the approach first applied by Smith and Munro (2009) which uses correspondence analysis as a means to integrate archaeological plant and faunal remains. I take their work one step further by analysing how the independent variables chronology, mean annual precipitation and elevation influence developments based on faunal and botanical data, using the largest bioarchaeological database compiled to date for the study region.

I approach my research questions in three interrelated steps: site-specific faunal analyses, region-specific metadata analyses, and a multivariate statistical approach to reveal major geographical and chronological patterns in animal-based subsistence strategies. This third step also includes an integrative multivariate analysis based on faunal and botanical data. First, I perform traditional faunal analysis on the material of two sites, Tell el-Burak (Lebanon) and Tell Lachish (Israel), to understand the development of subsistence strategies on a local scale. Second, I perform a metadata analysis, for which our project collected faunal reports published between the beginning of the 20th century and 2019. I use these data to contextualise the results from my site-specific faunal analyses and to recognise larger patterns in regional subsistence developments. In the last step, I use multivariate statistics, specifically correspondence analysis, to recognise trends in animal-based subsistence. Here I test how chronology, mean annual precipitation and elevation influence subsistence practices.

1.2. The Collaborative Research Centre 1070

This dissertation is part of the A05 project *"The Land Flowing with Milk and Honey". Development and Significance of Agrarian Resources in Bronze and Iron Age Palestine'* of the CRC 1070 ResourceCultures, funded by the DFG. The phrase 'a land flowing with milk and honey' comes from the Bible and refers to Canaan (the region of the southern Levant). The presence of large quantities of milk and honey can be interpreted symbolically, meaning the land was very fertile with milk indicating abundance and honey suggesting pleasure. Besides literary interpretations, there is archaeological evidence for milk and honey in the southern Levant. Milk can be attested through the dairying of animals such as sheep, goats, and cattle, which can be found through lipid analyses of ceramics or investigating the mortality profiles of the animals. Honey is attested by the discovery of a large apiary at Tel Rehov dating to the Iron Age IIA, which is the first of its kind to be uncovered for this period (Mazar and Panitz-Cohen, 2007).

 The CRC 1070 aims to study socio-cultural dynamics by investigating the way resources are used (CRC 1070, 2020). Previously, the concept of 'resources' and how these are defined had not been discussed within the humanities, which led to an artificial distinction of resources as being either natural or cultural (CRC 1070, 2020; Hardenberg et al., 2017). Therefore, a discussion on the terminology of resources was initiated, resulting in the CRC 1070 introducing new definitions related to resources. The CRC 1070 defines resources as the tangible and intangible means to create, sustain or alter social relations, units or identities within the framework of cultural ideas and practices (CRC 1070, 2020; Hardenberg et al., 2017). These

resources do not appear as individual elements but often appear in combination with other resources (Hardenberg et al., 2017). When this phenomenon is observed, the CRC 1070 defines it as a 'ResourceComplex'. A ResourceComplex consists of a combination of things, people, knowledge, and practices (CRC 1070, 2020; Hardenberg et al., 2017). However, resources might be defined and used differently in different cultures, which allows us to identify different 'ResourceCultures', which we can compare to each other. ResourceCultures are dynamic models which connect resources, socially determined ways to use them (based on the culture's ideas, values, and practices), social relationships, units, and identities (Hardenberg et al., 2017). ResourceComplexes within ResourceCultures can change throughout time since the context and importance of resource are dynamic. 'ResourceAssemblages' are these diachronic developments observed in ResourceCultures.

The use of resources in such a holistic system means we can observe several socio-cultural dynamics, the CRC 1070 focussing on developments, movements, and valuations (CRC 1070, 2020). For investigating this, the CRC 1070's main aims are:

1. Re-conceptualising the definition of resources in cultural studies,
2. Identifying socio-cultural and political developments through time,
3. Understanding how identities are formed concerning human migrations,
4. Increasing our understanding of the symbolism of resources.

How can I apply this research framework provided by the CRC 1070 to this dissertation? First, I begin with what constitutes a resource within our project. Within the Bronze and Iron Age societies of the southern Levant, animals are a tangible resource which has certain values. This value is not just nutritional but can also be symbolic and social. The use of animals depends on the quality of their meat, the possibility of secondary product exploitation (e.g., milk, eggs, fur), labour, the valuation of the animal by societies, and the presence of the animal's habitat. How the animal is regarded and used within societies can be used to establish identity. The resource animal also depends on intangible resources, such as understanding of the animal (e.g., its habitat, behaviour, reproduction) and knowledge on how to hunt wild animals and keep domesticates. Using animals as a resource requires specific equipment, infrastructure, and knowledge such as hunting tools, butchery tools, herding strategies, animal pens, ploughs, trade networks, transport vessels, etc. The availability of these influences the practices used for the resource animals. Depending on these practices and knowledge, symbols and myths may appear, which in turn can influence practices. The ResourceComplex of animal husbandry encompasses all these facets and can form, sustain, or alter social identities, social units, and social relations

between people. People will identify themselves according to the way they deal with animals, their learned practices, and by performing similar labour, for example as farmers, butchers, consumers, or craftsmen, or between cultural identities. I investigate the ResourceComplex of animal husbandry in the ResourceCulture of the Bronze and Iron Age societies in the southern Levant, which constitute themselves by their handling of agriculturally relevant resources. Finally, I determine ResourceAssemblages by observing diachronic developments in animal husbandry from the Bronze Age through the Iron Age in the southern Levant and determining the cultural and ecological reasons for these developments.

1.3. Historical Background

1.3.1. The Early Bronze Age I (3,600 – 3,000 BCE)

We do not understand yet how or why the transition from the Late Chalcolithic to the EBA I happened. In most places in the southern Levant, this change happens quite abruptly, the exception being the southern coastal plain where the transition happened gradually (Braun 2011). We see, however, that the EBA I is a new beginning due to differences in settlement, social practices, material culture, and foreign relations (de Miroschedji, 2014). During the Late Chalcolithic many settlements are abandoned, however, during the EBA I these settlements do not get repopulated. Instead, the EBA I sees the foundation of numerous new settlements, implying a strong sedentarisation process as opposed to the more mobile society during the late Chalcolithic (de Miroschedji, 2014). A large number of new settlements indicates a rise in the demography of the sedentary population (de Miroschedji, 2014). It is not just the number of sites that increases compared to the Late Chalcolithic but previously largely unsettled areas such as the hilly areas and central highlands are now home to many small settlements (de Miroschedji, 2014; Getzov et al., 2001). We see small settlements being founded in the semi-arid southern margins of the Negev, which are inhabited by transhumant pastoralists (Rosen, 2008). With a few exceptions, the settlements of the early EBA I phases can be thought of as villages about five hectares large (de Miroschedji, 2014). Towards the later EBA I we see an increase of dwellings in settlements, indicating increasing urbanisation processes taking place (de Miroschedji, 2014). During this time, the Faynan region in Jordan plays an important role in trade by providing copper, attested by village workshops near the mines (Richard, 2014). We do not have a lot of information regarding settlement structure and agricultural practices during the EBA in Lebanon due to a lack of systematic excavations and surveys (Genz, 2014). During the EBA I, new subsistence practices are in place, resulting in a mixed agropastoral economy based on animal husbandry, agriculture, and horticulture (Kamlah and Riehl, 2020). Some of the important innovations during this time are the domestication of the donkey (Hizmi, 2004;

Milevski, 2013; Ovadia, 1992), the possible introduction of the plough and the development of floodwater farming (Rosen, 2007).

An important aspect of the EBA I in the study area is the influence of Ancient Egypt, which establishes colonies in the southwestern part of the southern Levant. The Egyptian's main interest is to export local products such as wine, oil, and copper to Egypt. Towards the end of the EBA I, Egyptian officials are in charge of southern Levantine colonies and live in trading outposts such as Tel Erani (Brandl, 1989), and settlements such as En Besor and Tell es-Sakan (de Miroschedji, 2014).

1.3.2. The Early Bronze Age II-III (3,000 – 2,400 BCE)

The transition from the EBA I to the EBA II is marked by a sudden change in settlement features, namely the appearance of fortified cities and city-states, which impacts the ways settlements are organised and the material culture of the time. The accelerated urbanisation process leads to the abandonment of many EBA I settlements in favour of the fortified urban centres (de Miroschedji, 2014). It is not easy to recognise the transition between the EBA II and EBA III (which is why they are often grouped) but the EBA III is generally characterised by a difference in material culture such as the introduction of Khirbet Kerak Ware in the north of the southern Levant (de Miroschedji, 2014), which is attested as far as Bad edh-Dhra in the south of present-day Jordan (Richard, 2014). During the EBA III, settlements reach their maximum extensions and we see the development of monumental architecture (de Miroschedji, 2014). The increased urbanisation leads to a hierarchy of settlements, which often is based on the size of their fortifications, with large, fortified sites being the most important. Here, it is interesting to note the reason why such massive fortifications appear during the EBA II-III. The construction of fortification, and also ramparts, is a response to the political situation where rival city-states engage in local conflicts (de Miroschedji, 2014). We see the appearance of large public buildings during the EBA II-III, which are determined not only by their size but also their layout and the high quality of building techniques (de Miroschedji, 2014). One good example related to agricultural practices is the monumental EBA III granary at Beth Yerah (Greenberg et al., 2012; Mazar, 2001). Due to the intensification of metal production, the Faynan region now becomes specialised in smelting at settlements near the mines and these practices peak during the EBA III (Adams, 2002; Richard, 2014). In Jordan, we see specialisations in olive oil and wine production, for example at Tall as-Saʿadiya) (Richard, 2014).

During the EBA II-III relationships are much more interregional and international than previously. With the establishment of several newly founded city-states with local leaders during the

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EBA II, Egypt chooses to directly interact with these and abandons its colonies in the southern Levant (de Miroschedji, 2014). Whereas during the EBA I the Egyptians were interested in oil and wine, this now shifts to wood, resins, and perfumed oil (Sowada, 2009). These commodities are available in the northern part of the southern Levant, so Egypt increasingly concentrates on maritime trading routes than those on land. In exchange for these products, Egypt offers presents such as stone vessels (Amiran, 1970; de Miroschedji, 2014). This situation changes in the EBA III when Egypt becomes more interested in obtaining cedarwood and enhances its maritime technology. This leads to Egypt having a privileged relationship with Byblos in present-day Lebanon, and the trading focus shifts north, away from the southern Levant (Marcus, 2002; Sowada, 2009). However, relations do not only exist between the southern Levant and Egypt. The presence of Khirbet Kerak Ware in the southern Levant indicates northern contacts. The sheer number of these ceramics in the southern Levant suggests that they are brought here with the arrival of immigrants (de Miroschedji, 2000; Greenberg, 2007).

1.3.3. The Early Bronze Age IV (2,400 – 2,000 BCE)

At the end of the EBA III, the majority of settlements are abandoned, and we see a clear break in material culture and stratigraphy (Prag, 2014) in the EBA IV (also known as the Intermediate Bronze Age or Middle Bronze Age I). The EBA IV is characterised as a period of intense regionalism, most settlements being of a temporary nature (Kamlah, 2001; Prag, 2014). We see a rural subsistence economy, with society placing a greater emphasis on family-based production, long-distance trade and pastoralism (de Miroschedji, 2014; Falconer and Fall, 2019; Prag, 2014; Richard, 2020, 2003, 1987). There is no sign of a settlement hierarchy or centralisation (Prag, 2014). We should note the importance of the Jordan Valley during this time, which contains several larger, unwalled settlements. But why did society and settlements change so much during the EBA IV? Several hypotheses are in place, although none of them can be confirmed and it seems probable that a combination of factors led to the intense regionalism during the EBA IV. Originally the Ammorite invasion was blamed for the change (Kenyon, 1960) but this hypothesis is considered outdated nowadays. Alternatively, an explanation has been put forward indicating Egypt as the main catalyst. In this case, the transformation was caused by either Egypt's military campaigns during the 5th and early 6th dynasties (Prag, 2014) or the failure of the late 6th dynasty which led to a decline in trade with the southern Levant. Another hypothesis points to a combination of environmental and political events, along with immigration from central Syria. However, in recent years scholars favour the hypothesis of such changes in society being part of a reoccurring cycle of urbanisation and de-urbanisation, increase and decrease

of economy, and specialisation and de-specialisation (Geraty et al., 1986; LaBianca, 1990; Richard and Long, 1995).

1.3.4. The Middle Bronze Age (2,000 – 1,550 BCE)

The MBA is considered to be a period of re-urbanisation in the southern Levant. Once again, we see large urban centres developing in the landscape (Cohen, 2014). For a long time, scholars thought this was the result of northern foreign influences, which was called the 'Amorite hypothesis' (e.g., Dever, 1976; Kenyon, 1966). It suggests a large influx of people, called the Amorites, migrated into Canaan and were responsible for all the changes happening during the MBA: re-urbanisation, a new material culture, and novel developments in society (Cohen, 2014). Other popular theories suggest international trade as the main driver for the changes during the MBA (Gerstenblith, 1983), still seeking the main drive for the new phase of re-urbanisation outside of the southern Levant. Newer research brings another, more reasonable, hypothesis into place, where the MBA culture in the southern Levant is not only defined by external forces but based on local developments as well (Cohen, 2014).

The beginning of the MBA sees an increase in settlements, especially along the coastal plains and close to important trade and communication routes (Cohen, 2014). The re-urbanisation processes in the southern Levant do not happen at the same pace everywhere, change happens more gradually more inland and in the southern part of the southern Levant. The main indicators for the renewed urbanisation are the massive fortifications of settlements, 'palace' architecture, and public structures. The influence of the northern societies is seen in the appearance of large mud-brick fortifications, for example at Dan and Ashkelon (Cohen, 2014). During this time, there is a hierarchy in settlements based on their fortifications. The increasing number of public buildings testifies to the centralised nature of settlements and indicates the beginning of 'palace economies' (Cohen, 2014). This is an economic and political concept where a few urban centres hold centralised power and control the settlements and resources in their hinterland, since they rely on these resources and materials for continued growth, power, and maintenance (Cohen, 2014). Towards the end of the MBA smaller rural settlements are abandoned, in favour of the larger urban settlements, indicating increasing centralisation (Broshi and Gophna, 1986). Due to the paucity of material, it is difficult to reconstruct settlement patterns in Lebanon (Charaf, 2014). Towards the end of the MBA, we see independent polities with a large, fortified central site along with a series of border fortresses (Bourke, 2014).

At the beginning of the MBA, we see few imports coming from the northern Levant, while Egyptian imports are even rarer. These imports are mainly found in coastal settlements, and

settlements close to trade and communication routes (Cohen, 2014). During this time, Egypt has a major economic and political influence on the developments in the southern Levant, where it contributes to profound social, economic, and political developments (Cohen, 2002). However, we should acknowledge the influence of the hinterland of the southern Levant, which provides the resources for engaging in trade (Cohen, 2014). Toward the middle and the end of the MBA more imports are present, especially in tomb groups (Cohen, 2014). On the other hand, we also see more Canaanite exports in Egypt, such as storage jars which probably held wine or olive oil. This indicates an international trading network was in place, which would have benefited both parties (Cohen, 2014). In Lebanon, coastal cities are part of a trade network, specialising in the trade of olive oil, wine, and wood (Charaf, 2014). Toward the end of the MBA, we see clear traces of international connections between Jordan and Egypt by the abundant presence of the so-called 'Hyksos scarabs' (Eggler and Keel, 2006). The Fayan copper production is not exploited anymore during this time (Philip et al., 2003).

1.3.5. The Late Bronze Age (1,550 – 1,200 BCE)

The LBA is known as the 'age of internationalism' due to the economic and cultural exchange taking place between the empires at the time of Egypt, Mesopotamia, Anatolia, the Mycenaean world, the northern Levant, and Cyprus (Panitz-Cohen, 2014). The southern Levant plays an important role in this world, since it forms a buffer zone between Egypt and the Hittite Empire, and is an area where economy, culture, and politics of different regions could interact (Leonard, 1989; Panitz-Cohen, 2014). During this time, the city-states in the southern Levant are vassal states of Egypt, but they receive some autonomy to take part in this international trading network. The Canaanites are involved in shipbuilding and maintenance, while also being seamen and merchants who actively take part of trade by being middlemen, mercenaries, or free agents (Artzy, 1998, 1994; Panitz-Cohen, 2014).

The LBA in the southern Levant is characterised by the dominance of Egypt, turning the city-states in the southern Levant into vassal states. As Egypt's relations with the northern Mitanni kingdom increase, the value of the southern Levant increases as well. Egypt now considers this area not only as a buffer zone but also as a place to obtain economic resources (Ahlström, 1993; Hasel, 1998; Killebrew, 2005; Leonard, 1989; Morris, 2005). The impact of Egypt on the southern Levant, however, is not always beneficial. Egypt demands tributes, takes labour forces, imposes taxes, and confiscates land (Knapp, 1987; Redford, 1992). On the other hand, the new elite established by Egypt, which includes civilians and military functionaries, means some people could benefit from a new social status with came with economic benefits (Panitz-Cohen,

2014). During the 19th Dynasty, Egypt builds more governors' residencies and garrison stations in strategic locations. We see the effect of Egyptian domination in the social and cultural life of people, for example, there are more temples dedicated to Egyptian gods, and there is an increase in Egyptian and Egyptian inspired objects, and Egyptian anthropoid coffins (Ahlström, 1993; Gonen, 1992; Higginbotham, 2000; Killebrew, 2005, 2004; Killebrew et al., 2006; Oren, 1984; Panitz-Cohen, 2014; Singer, 1994; Weinstein, 1981). Once again, the information we have on Lebanon during the LBA is limited, however, we know the culture would have been urban. It would have consisted of urban centres, surrounded by villages in its hinterland (Heinz and Kulemann-Ossen, 2014). Lebanon would have been a desirable region, due to the presence of cedar trees in its mountainous regions. Cedarwood is a much sought-after commodity in the ancient world, especially by countries which do not have a large supply of wood, such as Egypt. Besides this, the geographical location of Lebanon is advantageous, due to its location at major overland trade routes (Heinz and Kulemann-Ossen, 2014). It is worth noting that the Transjordan, apart from parts of the Jordan Valley, is never directly ruled by Egypt. As long as the Jordanian city-states pay their tribute in the form of agricultural products, and do not cause conflict, they are free to do as they pleased (Fischer, 2014).

The final phase of the LBA is a period of a gradual decline, which used to be referred to as a 'collapse'. This decline is the result of a combination of different factors (Knapp and Manning, 2016; Millek, 2019). The weakening of international trade, along with an increase in aridity, the destruction of many sites by an unknown people, and an increase in mobility, all contribute to the collapse of the LBA world (Knapp and Manning, 2016).

1.3.6. The Iron Age I (1,200 – 975 BCE)
The IA I sees the disappearance of two major players in the ancient world, the Egyptian and Hittite Empire, meaning for the first time in centuries the societies of the southern Levant are independent (Gilboa, 2014; Killebrew, 2014a; Levy and Holl, 2002). Especially in the south of the region, settlements enjoy the benefits of no longer paying taxation to Egypt, or accommodating armies passing by. It also leads to a change in social structure, since now the Egyptian bureaucracy could not legitimate political and elite power, which leads to social change and influxes of new people (Gilboa, 2014).

We see the emergence of many new identities during the IA I, which tend to differ according to geographic region. Among these new identities are the Phoenicians, Philistines, Israelites, Judahites, Ammonites, Moabites, and Edomites. The vast international trading network which was present during the LBA is now replaced by local trading networks led by entrepreneurs,

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economic mercenaries, or hirelings and towards the end of the IA I we see trading relations with Greece and Anatolia (Artzy, 1997; Gilboa, 2014; Klengel and Bunnens, 2000; Liverani, 1987). In Phoenicia, there is continuity from the LBA to the IA I, reflected by the similar material culture (Killebrew, 2014a). The southern coastal plain sees more diverse changes. Some settlements are destroyed and then resettled (e.g., Ashdod), whereas other settlements keep their function as Egyptian administrative centres (e.g., Aphek). Nonetheless, there is continuity from the LBA attested by the presence of ceramics typical of the LBA. Once the southern coastal plain is freed from Egyptian dominance, we see the establishment of large urban centres. A large number of Aegean-styled ceramics indicates the arrival of the Philistines, also known as the '*Peleset*' (Gilboa, 2014; Killebrew, 2005). Their material culture suggests they are closely involved with Cyprus and Cilicia (Gilboa, 2014; Killebrew, 2006, 2000; Mountjoy, 2013), although enough variety can be observed between Philistine material culture to suggest mixed origins (Mountjoy, 2010). Settlements in the inland of the southern Levant are represented by an increasing number of small agricultural villages (Gilboa, 2014). Here, there is continuity in the material culture, but a discontinuity in the settlement patterns and populations. The Jordan Valley sees a continuation of LBA material culture and is has larger settlements. In the highlands regions, we often see fortified sites (e.g., Ammon), whereas west of the river Jordan we see smaller settlements (Killebrew, 2014a).

1.3.7. The Iron Age II (975 – 586 BCE)

The IA II is characterised by the establishment of many new identities in the southern Levant, the creation of kingships with a royal residence and hinterland, and the Neo-Assyrian conquest of the region. The Assyrian contacts with the southern Levant can be distinguished into two phases. The first phase is represented by the Assyrian expansion in the 9th century, led by Assurnasirpal II and Shalmaneser III (Steiner, 2014a). The second phase starts with Tiglath-Pileser III (724 - 727 BCE) and is represented by a period where Assyria was in control of many territories, most of which become Assyrian provinces (e.g., Israel) or vassal states (e.g., Judah) (Steiner, 2014a). Most of the information we have on the Assyrian impact on the southern Levant comes from textual sources since the archaeological record and material culture of the time does not show major Assyrian influences. The arrival and domination by the Assyrians does cause changes in the economy of the southern Levant. In the seventh and sixth century BCE the Assyrians develop a global economic system, meaning goods could now be produced and exported on a much larger scale (Steiner, 2014a). The presence of the Neo-Assyrian Empire also affects agricultural practices in the southern Levant, which are used to adjust the economy to

Assyrian needs. The Assyrians are particularly interested in olive oil production and wool, both of which can be transported and taxed (Ben-Shlomo, 2014; Finkelstein, 1999; Postgate, 1974).

The rise of the Phoenicians is closely linked to the rise of Tyre as an economic and political power. Tyre manages to rise to power thanks to the destruction of Ugarit in the 12th century, the decline of Egypt, and the absence of economic competitors in the Levant. The Phoenicians manage to take up the role of trade intermediaries by distributing the raw materials and products made by others. They use different trading routes than those used during the LBA, but the destinations remain the same (e.g., Cyprus and the Aegean). Even after the Assyrian colonisation of the Phoenician heartland, they are still allowed to continue their trading activities, which benefits the Assyrians as well (Aubet, 2014).

The Philistines are represented by four excavated settlements: Tell es-Safi/Gath, Ashdod, Tell Miqne-Ekron and Ashkelon. During the Assyrian control, Philistia is turned into a tribute-bearing state, since the trading network between Philistia, Egypt, and Phoenicia would have been advantageous for the Assyrians (Master, 2003; Tadmor, 1966). Another advantage Philistia has for the Assyrians is that this area functions as a buffer zone between Assyria and Egypt (Tadmor, 1966). Power shifts between the different Philistine centres throughout the IA II (Ben-Shlomo, 2014). Ashkelon is a large commercial city consisting of a 'market quarter' and a 'royal' wine press area (Stager, 2008). The market has shops and storerooms supporting the idea that wine is a traded commodity here. It also has a lot of agricultural products which are found in situ, such as imported cereals from Judah and the Shephelah region (Ben-Shlomo, 2014; Stager, 2008). Notable is the scale of the wine industry at Ashkelon (Stager, 2008). Ekron is the largest centre for producing olive oil in the ancient world, attested by the presence of 115 olive oil installations (Dothan and Gitin, 1993).

Israel, also known as the northern kingdom, encompasses the areas of the northern central hill country, the Galilee, the Sharon Plain, and the Jordan, Jezreel, and Huleh Valleys. During the IA II, many new settlements are founded in this region, including large, fortified sites. Most of the population, however, would have lived in rural settlements. The presence of large public architecture (e.g., fortifications, royal enclosures, and palaces/residencies), along with political and economic consolidation, may indicate the first steps to state formation (Killebrew, 2014b). During the Assyrian expansion, Israel becomes a vassal state paying tribute and gives Assyria control over trading networks. This emphasises Assyria's main interest is gaining economic control, and not so much territorial gain (Bedford, 2009). During this time Israel gains territory and is economically prosperous. This lasts until the second half of the eighth century, a time of

protests and revolts by the Israelites against the Neo-Assyrian Empire. In turn, they destroy numerous settlements, deport many Israelites to Mesopotamia, and bring foreign populations to occupy Israel instead (Killebrew, 2014b). These measures lead to an influx of Israelites in Judah, and especially Jerusalem sees a massive expansion during this time (Hardin, 2014).

Judah, also known as the southern kingdom, encompasses the areas of the Shephelah, coastal plains, and Judean Hills. During the IA II, we see the development of fortified settlements (e.g., Jerusalem), regional centres (e.g., Lachish), and fortresses (e.g., Kuntillet Ajrud) (Hardin, 2014). This attests to a trend of increasing urbanisation and centralisation in Judah, which eventually leads to the formation of a monarchy. Judah also takes part in long-distance trade, strategically building structures along the trade routes to ensure the movement of goods from the south through Judahite territories (Blakely, 2002). During the Neo-Assyrian conquests, Judah becomes a vassal state which must pay taxes and tributes. Besides this, it serves as a buffer zone between Assyria and Egypt. During the seventh century BCE, however, Judah starts to rebel under Hezekiah who manages to take back some areas. In turn, Assyria responds with military campaigns, which can be attested in the numerous destruction layers in the Shephelah and northern Negev (Hardin, 2014). A good example of these activities can be seen at Lachish, where the remains of a siege ramp are located on the side of the tell, with a counter-ramp, but also a destruction layer inside the city as well (Hardin, 2014; Ussishkin, 1983).

Ammon is situated on the central Jordanian Plateau and the river Jakob and its tributaries from its borders, although the extent of Ammon's borders is still being discussed by scholars (Younker, 2014). This area is located on a major caravan route which would connect Arabia with the Fertile Crescent. It seems that during the beginning of the IA II, Ammon would have paid tributes to Judah (Barton, 2002). During the later IA, Ammon reaches the height of its political and economic power whilst being controlled by Assyria. In fact, out of all states, Ammon has to pay the highest tributes to Assyria (Younker, 2014). We see many well-planned agricultural complexes which would have provided a solid economic foundation. This in turn would have led to gaining more political power (Younker, 2014). After a rebellion which was potentially instigated by the Ammonites, Assyria delivers punitive campaigns to Ammon, but this does not seem to affect their prosperity through time (Younker, 2014).

Moab is located to the north and south of the Wadi Mujib, although the northern borders of this area are disputed terrain during the IA II. Unfortunately, we do not have a lot of information regarding Moab, since most of the archaeological work in the region is still on-going, the availability of a few final publications regarding such projects, and lack of multi-period settlements

(Steiner, 2014b). Moab would have had a two-tiered hierarchy, consisting of fortified settlements and fortresses, and small agricultural settlements (Steiner, 2014b). During the Assyrian campaigns, Moab becomes a vassal state which pays tributes, although Assyria is more interested in obtaining the trading routes from Egypt to Syria which pass through Moab (Steiner, 2014b).

The archaeological evidence we have for Edom, which is located between Moab, the Arabah, and the Arabian Desert, is incomplete, most information comes from surface surveys, and only three sites have been fully published (Bienkowski, 2014). During the IA II, Edom would have been intensively settled with open villages and farms, but we see a lot of regional variation between them. Busayra is thought to be the capital of Edom, which would have functioned as an administrative and religious centre (Bienkowski, 2002). The Petra region consists of many mountain-top settlements which would have been hard to access and had no direct access to water. They would have had terraces to perform agriculture on a small scale (Bienkowski, 2014). During the Assyrian conquests, Edom becomes a vassal state which has to pay tributes (Bienkowski, 2014).

1.4. Climatic Background

To fully understand the historical processes happening during the BA and IA, we need an understanding of the climate at the time during which these events took place. There are many climatic proxies available to reconstruct the paleoclimate: for example, changes in sea level, pollen analyses, and stable isotopic analyses on plants, stalagmites, and speleothems. The sources for most of these proxies are situated in the northern and eastern regions of the southern Levant, which tend to have higher mean annual precipitation (Rambeau, 2010), whereas the regions east of the Dead Sea and Jordan Valley have not yielded many paleoclimatic data yet (Rambeau, 2010). Reconstructing the paleoclimate using such proxies does not come without its problems. The first major problem is the inability to extrapolate climatic data taken from a local climatic proxy to the entire region of the southern Levant (Rambeau, 2010). This is due to the climatic and environmental gradients in the southern Levant, which can profoundly differ over as little as ten kilometres. These gradients determine where climatic proxies are found, but also partly explain the differences in paleoclimate between climatic proxies in different regions (Rambeau, 2010). Finally, there is the challenge of recognising seasonality, which will affect the precipitation in a given area (Rambeau, 2010). Besides this, when dealing with different climatic proxies the differences in quality of the absolute dating, and the temporal resolution needs to be taken into account (Rambeau, 2010). To circumvent these issues, it is best to

consider different climatic proxies for a specific location and take these issues into account when reconstructing the paleoclimate for the region (Rambeau, 2010).

The paleoclimatic background is based on sites given in figure 2. Below I provide a list of the available sources, along with the analyses performed on them:

- <u>Jeita Cave:</u> petrography, and stable oxygen and carbon isotopic composition are analysed from a stalagmite. The cave is located 15 km north of Beirut and is five km east of the Mediterranean coastline (Verheyden et al., 2008).

- <u>Lake Birkat Ram:</u> sedimentological and palynological analyses are done on three cores, the lake is in the northern Golan Heights (F. Neumann et al., 2007; Schwab et al., 2004).

- <u>Sea of Galilee:</u> stable carbon and oxygen isotope ratios are analysed from 41 stalagmites taken from ten caves and an additional lake sediment core is investigated for pollen (Langgut et al., 2013).

- <u>Hirbet ez-Zeraqon:</u> stable carbon isotope analyses on charred botanical material (Riehl et al., 2008).

- <u>Nahal Qanah cave:</u> a speleothem is analysed for its stable oxygen and carbon isotopic composition. The cave is in the western Samaria hills (Frumkin et al., 1999).

- <u>Soreq Cave:</u> stable oxygen and carbon isotopic composition are analysed from a broken speleothem. The cave is in the Judean Hills anticline, about 30 km west of Jerusalem (Bar-Matthews and Ayalon, 2011).

- <u>Tel Burna:</u> stable carbon isotope analyses are done on charred botanical material (Riehl and Shai, 2015)

- <u>Qubur al-Walaydah:</u> stable carbon isotope analyses are done on charred botanical material (Riehl et al., 2014).

- <u>Dead Sea:</u> sedimentological and palynological studies are performed on two sections located in erosion gullies on the western shores: Ein Feshka and Ze'elim (F. H. Neumann et al., 2007; Neumann et al., 2010). Pollen are analysed on a lake sediment core from Ein Gedi spa at the western shore (Litt et al., 2012).

Fig. 2: Map of the southern Levant showing the location of sites from where the paleoclimatic proxy data discussed in the text were analysed. (Source: Google Earth)

Some of the paleoclimatic proxies provide us with broad climatic trends. Results from Jeita Cave show the climate in Lebanon was relatively dry from 3,850 BCE - 850 CE, a period encompassing the BA and IA, except for a wetter climate during 2,050 BCE - 1,050 BCE which corresponds to the MBA - LBA (Verheyden et al., 2008). This contrasts with the results from the Dead Sea cores, which show a major wet phase between 3,650 BCE – 1,550 BCE (EBA I - MBA) in the Jordan Rift Valley, indicated by rising levels of the Dead Sea during this time (Migowski et al., 2006). Furthermore, pollen results from the Dead Sea indicate a relatively wet and cool period from the Chalcolithic to the LBA, followed by rapid warming and drying of the climate (Litt et al., 2012). Results at Birkat Ram indicate a dry climate from the MBA/LBA to the IA, evidenced by a decrease in the numbers of deciduous oak forest, and low cereals and olive frequencies (F. Neumann et al., 2007; Schwab et al., 2004).

During the BA, results from Nahal Qanah cave indicate a wet climate from the EBA I until the EBA IV (Frumkin et al., 1999), similar to the climate near the Dead Sea. Pollen results from Birkat Ram attest to the importance of olive processing by the abundance of olive pollen. The frequency of olive pollen declines towards the end of the EBA, indicating a decline in agriculture (F. Neumann et al., 2007; Schwab et al., 2004)

The EBA I is a humid period in the region of the Sea of Galilee, indicated by the abundance of arboreal and olive pollen. This also emphasises the importance of olives in the economy (Langgut et al., 2013).

The EBA II – III transition happens at the peak of wet climatic conditions near Soreq Cave (Bar-Matthews and Ayalon, 2011). However, results of the Sea of Galilee and Hirbet ez-Zeraqon indicate a period of desiccation, suggested by a reduction of arboreal pollen and a decrease in carbon isotopic fractionation in charred botanical material (Langgut et al., 2013; Riehl et al., 2008). During this transition, we see a decrease in olive pollen which is probably related to geo-political changes rather than climatic (Langgut et al., 2013).

The EBA IV experiences a dry climate, as evidenced by the results of climatic proxies at the Nahal Qanah cave (Frumkin et al., 1999), the Sea of Galilee (Langgut et al., 2013), and by the decreasing Dead Sea levels (Migowski et al., 2006). Interestingly, we do not see such an aridification phase happening in the Golan Heights (F. Neumann et al., 2007; Schwab et al., 2004).

During the MBA paleoclimatic proxies indicate a dry climate, although moisture levels gradually increase throughout this period. This is indicated by the results at Nahal Qanah cave (Frumkin et al., 1999), Sea of Galilee (Langgut et al., 2013), Hirbet ez-Zeraqon (Riehl et al., 2008), and Soreq Cave (Bar-Matthews and Ayalon, 2011). The most arid climate is at 2,250 – 2,100 BCE (Bar-Matthews and Ayalon, 2011). Starting from 1,800 BCE more moisture is available, indicated by an increase in Mediterranean tree pollen values (Langgut et al., 2013). The data of the Dead Sea point to slightly different paleoclimate in that region. Here the climate was humid, which is indicated by a decrease of chenopods, an increase of olives., and low numbers of summer and evergreen oaks. At around 2,030 – 1,630 BCE, the climate becomes arid, indicated by a decrease in oaks and olives (F. H. Neumann et al., 2007) which is similar to the other regions in the southern Levant. The Dead Sea sediment cores show an arid event happening at 1,550 BCE, the end of MBA, by a decrease in Dead Sea levels (Migowski et al., 2006).

The LBA has a wet climate, attested by the results from Nahal Qanah cave (Frumkin et al., 1999). The results of the Sea of Galilee indicate a wet climate as well, due to a high frequency

of arboreal pollen, but towards the end of the LBA, between 1,250 BCE – 1,100 BCE, we see the lowest frequency of arboreal pollen indicating severe aridity (Langgut et al., 2013). Studies performed on the Dead Sea indicate arid conditions in this area, attested by low numbers of arboreal, olive, and cultivated plants pollen and an abundance of chenopods, Poaceae, and Asteraceae. Herb pollen is at a maximum during this period (F. H. Neumann et al., 2007; Neumann et al., 2010).

The beginning of the IA I is arid, as shown by high chenopod pollen frequencies in the Dead Sea cores (F. H. Neumann et al., 2007). During the mid-first millennium BCE values of deciduous oak decrease drastically, which might be explained by wood consumption or clearing to make space for settlements (F. Neumann et al., 2007; Schwab et al., 2004). Stable carbon isotope analyses on archaeological botanical material of Qubur al-Walaydah indicate the plants obtained enough water, indicating a good environment (Riehl et al., 2014).

Throughout the IA, and especially during the IA II we see a strong increase in oaks and a decrease in chenopods, indicating the climate becomes more humid, attested by the results of the Dead Sea and the Sea of Galilee. We see a rise in the frequency of olives (Langgut et al., 2013; F. H. Neumann et al., 2007; Neumann et al., 2010). Around 700 BCE a drier climate would have been found, evidenced by a slight reduction in arboreal pollen and precipitation. During this time the frequency of olive pollen reduces, which could be caused by reduced moisture or by economic choices made by the Assyrians (Langgut et al., 2013). Towards the end of the IA II stable carbon isotope analyses on archaeological botanical material of Tel Burna suggest sufficient water supply (Riehl and Shai, 2015).

1.5. Archaeological Background of the Studied Sites

1.5.1. Lachish

Lachish, also known by its Arabic name Tell ed-Duweir, is one of the bigger tells in the southern Levant and is situated in the Shephelah, the southern part of the Judean foothills. The tell covers twelve hectares. The Assyrian annals describing the conquest of Lachish by Sennacherib, which are depicted in his palace in Nineveh (Ussishkin, 1982), along with the El-Amarna letters (Cochavi-Rainey and Rainey, 2015), and the Papyrus Hermitage 1116A (Golénischeff, 1913; Webster et al., 2019) testify to the political importance of Lachish during the Bronze and Iron Ages.

The earliest settlement remains at Lachish date to the MBA I, which corresponds to a period of re-urbanisation in the southern Levant (Tufnell, 1958; Ussishkin, 2004). Excavations have unearthed the remains of a palace, and structures belonging to a cultic place dating to this time.

Due to the lack of cultic objects or images, archaeologists are not sure to whom or what this cultic place is dedicated (Tufnell, 1958; Ussishkin, 2004). During the MBA II, Lachish becomes a city-state. The archaeological features found dating to this period are a new palace, which is built in the centre of the tell, and the huge fortifications surrounding the tell (Burke, 2008). Towards the end of the MBA, the palace and probably all of Lachish are destroyed by a fire of which the cause is not known. Following this destruction, a secondary settlement is created at the site but eventually, this too is abandoned (Tufnell, 1958; Ussishkin, 2004). Lachish gets resettled again during the LBA I, but we do not know the extent of the resettlement yet. During this time, the Fosse Temple is built but once again, no cultic images or objects are found. It has been hypothesised the temple would have been a space to gather for funerary meals (Bietak, 2002). The massive fortifications of the MBA II are out of use during this period.

During the LBA II Lachish once again becomes an important city-state, now under the patronage of Ancient Egypt. The settlement is destroyed by fire in 1,200 BCE but is rebuilt soon after (Tufnell, 1958; Ussishkin, 2004). Archaeological structures found dating to this period are the newly built Acropolis Temple and the Pillared Building, which is a large public building. The Fosse Temple does not get restored after the fire. This period is beneficial to Lachish, it prospers and becomes one of the largest cities in Canaan. Overland and marine trade routes are developed, as testified by the presence of saltwater fish at Lachish which indicated trade with Mediterranean areas (Lernau and Golani, 2004). Lachish is once again destroyed and burned, although it is not known by whom, around 1,130 BCE (Tufnell, 1958; Ussishkin, 2004).

After a brief occupation hiatus, Lachish is resettled during the IA IIA, during which it becomes the second most important city in Judah. A fortress city with a large civilian population is constructed during this time but the city is destroyed in 701 BCE by the Assyrian king Sennacherib (Ussishkin, 2004, 1977). After a brief resettlement period, the site is destroyed for the last time in 588/586 BCE, this time by the Babylonian king Nebuchadnezzar (Tufnell, 1958; Ussishkin, 2004).

Due to the large size of the tell and the political importance it had in the past; the site has been the object of many excavations. The first archaeological mission to Lachish is the Wellcome-Marston Expedition (1932 – 1938) directed by James L. Starkey. This mission aimed to understand Lachish in its cultural and chronological framework (Tufnell, 1958, 1953; Tufnell et al., 1940). The next excavations took place in 1966 and 1968 and were directed by Yohanan Aharoni. He focussed on archaeological structures dating to the Persian period (Aharoni, 1975). From 1973 until 1994 David Ussishkin directed the 'Renewed Excavations' at Lachish, which

have been the most extensive excavations at the site. The goal was to gain an understanding of the period of the Judean monarchy (Ussishkin, 2014, 2004). Yosef Garfinkel, Michael Hasel, and Martin Klingbeil took up excavation at Lachish from 2013 until 2017. They concentrated on the northern and north-eastern part of the tell and the area west of the Solar Shrine (Garfinkel et al., 2019a, 2019b; Sass et al., 2015; Weissbein et al., 2019, 2016). Two seasons of archaeological research were held in 2015 and 2016 by Saar Ganor for the Israeli Antiquities Authority. He focussed on the IA gate complex (Ganor and Kreimerman, 2019, 2018).

The most recent archaeological mission to Lachish is the Austrian-Israeli Expedition to Tel Lachish, directed by Katharina Streit and Felix Höflmayer. Three campaigns already took place (2017 – 2019) within the framework of the 'Tracing Transformations' project. The faunal remains I analyse for my dissertation come from these excavations. The excavation focusses on two areas of the tell: area S, and area P. Area S, which is a deep section, provides a long stratigraphic sequence from the LBA to the IA. It contains the remains of a settlement area. During the 'Renewed Excavations' a public building was found here along with domestic structures (Ussishkin, 2004). Area P, which is known as the palace area, contains a stratigraphic sequence from the MBA to the LBA and consists of an MBA palace, and domestic structures dating to the LBA (Streit et al., 2018). An overview of the relative dating and corresponding strata, a map of Lachish showing areas P and S, and a map showing the location of Lachish, can be found in table 1, figure 1, and figure 8, respectively, of Vermeersch et al. (2021b).

1.5.2. Tell el-Burak

Tell el-Burak is a coastal site located four km north of Sarepta (present-day Sarafand) and nine km south of Sidon. The settlement is irregularly occupied from the MBA until the Mamluk-Ottoman period (third millennium BCE – 13th/14th century BCE) (Kamlah and Sader, 2019).

During the MBA, the site is home to a monumental, fortified palace, which is the first of its kind to be found in present-day Lebanon (Sader and Kamlah, 2010). The building is constructed on top of the tell and would have been a central point for its surrounding. It contains many rooms, one of which is decorated with wall paintings showing Egyptian influence. Besides this building, a large retaining wall, and a tomb have been found dating to the MBA. Since no traces of a settlement are found, it is assumed the building was erected by the inhabitants of Sidon. The site is abandoned at the end of the MBA (Sader and Kamlah, 2010).

After a settlement hiatus of about a thousand years, during the late IA, either Sidon or Sarepta causes the resettlement of the site in the shape of an agricultural domain. It is occupied for four

centuries and is divided into three occupation periods: Early (ca. 720 – 600 BCE), Middle (ca. 600 – 550/500 BCE), and Late occupation (550/500 – 350 BCE). The Early occupation sees the foundation of the agricultural domain. The settlement is surrounded by an enclosure wall, called Structure I, and during this time House 1 and 3 are built. House 3 is abandoned towards the end of this phase. During the Middle occupation, House 1 is still in use, and House 2 is constructed. Structure II is built during the beginning of this phase and is believed to be a casemate wall (Kamlah et al., 2016a, 2016b). The Late occupation sees a gradual decline of the settlement. House 1 is used at the beginning but eventually is abandoned. House 2 is used throughout the Late occupation phase. The agricultural domain at Tell el-Burak is abandoned around 350 BCE (Kamlah et al., 2016a).

The Tell el-Burak Archaeological Project is a joint Lebanese-German mission between the American University of Beirut, the University of Tübingen, the German Archaeological Institute – Orient Department, and, since 2013, the University of Mainz. The excavations are directed by Jens Kamlah, Aaron Schmitt, and Hélène Sader. Excavations at the site started in 2001 and are still on-going until today, although social and political unrest, along with the Covid-19 pandemic, have obstructed yearly excavations. The faunal remains I analyse for this dissertation come from these excavations (campaigns 2014, 2015, and 2018) and predominantly date to the late IA assemblage. Faunal material is analysed from two areas: areas 3 and 4. Area 3 is situated on the top of the tell and consists of at least four buildings, Houses 1 to 4. These are bordered to the southwest and southeast by a terrace wall. Area 4 is located at the southern slope of the hill and consists of a large, well-preserved winepress (Kamlah et al., 2016a, forthcoming; Orsingher et al., 2020). The distribution of the areas and the location of Tell el-Burak can be found in fig. 1 and 4., respectively, of Appendix 4.

Chapter 2: A Tale of Sheep and Goat

Domestic sheep (*Ovis aries*) and goat (*Capra hircus*) are the most common taxa found in the faunal record during the BA and IA in the Levant. Understanding how and why these two live-stock species were exploited is key to understanding the subsistence, agriculture, and economy of the time in this region. This is possible by looking at herding and culling strategies for sheep and goat, but before we can do this, we first need to understand the behavioural and physiological differences between the two species, which influence the herder's decision on how to treat and compose their flocks.

Many studies on flock composition in south-western Asia conclude the presence of goat in a flock is necessary for two reasons. First, goats encourage sheep to greater activity, and second, goats provide leadership to the sheep (Redding, 1981). Goats are more mobile than sheep, which means they will travel further distances to obtain food. Since sheep will follow goats, the sheep are now encouraged to also travel further distances for food (Behnke, 1980; Nicolaisen, 1963; Shahrani, 1979). This mobility prevents sheep from overgrazing areas (Shahrani, 1979). Generally, it has been thought that goats are more intelligent than sheep, and therefore having goats in a flock is necessary since the sheep need to be led, especially when the flock is endangered (French, 1970; Nicolaisen, 1963). When the flock is presented with danger, goats will try to fight off predators, whereas the initial reaction of sheep will be to disperse and flee (Dalman, 1939). However, there is no conclusive proof that goats would be more intelligent, and it has been proved than ewes (adult female sheep) can recognise and respond to their names (Dickson, 1951). It is possible to train sheep to respond to commands, making them suitable to lead a flock (Asad, 1970; Hirsch, 1933). It might seem that keeping goats in a flock with sheep might only have benefits, but there also is a major disadvantage. Goats have a looser flock structure than sheep and will separate more easily and can make a mixed flock more divided in the land-scape. This means a shepherd will have to spend a lot of time keeping the mixed flock together and moving them around (Nicolaisen, 1963).

Differences in physiology between sheep and goats will determine how they react to external factors affecting the flock, particularly temperature extremes, precipitation extremes, and disease (Barth, 1961; Hole, 1978; Irons, 1975; Redding, 1981). How sheep and goat cope with these factors, will decide the proportions of sheep and goat in a flock (Redding, 1981). Sheep tend to fare better at higher altitudes due to their coats, whereas goats are less adept at tolerating cold, damp, and windy weather (Behnke, 1980; French, 1970; Shahrani, 1979; Terrill, 1968).

Furthermore, in snowy weather, goats will not be able to uncover food and will rely on sheep to uncover forage for them (Shahrani, 1979). Goats, however, are well adapted to higher temperatures due to their better response to water stress which means they are less impacted by water loss and heat than sheep (Redding, 1981). Another important advantage in environments with higher temperatures is that goats can graze and browse, whereas sheep only graze. By browsing, goats have access to shrubs and trees, plants which can survive heat for longer than those plants consumed by grazing, for example, grasses and legumes (Behnke, 1980; Redding, 1981). This is confirmed by ethnographic observations which show that in drier and hotter environments, the proportion of goats in a mixed flock is higher compared to sheep. When the environment becomes more rugged, particularly in mountainous areas, goats will also have a higher frequency in a mixed flock (Perevolotsky et al., 1989)

Disease will affect sheep and goat equally, but each species will be susceptible to species-specific diseases, which have the potential to severely impact the population of one species whilst leaving the other intact (Redding, 1981). Sheep are more susceptible to the effects of parasites than goats (Redding, 1981; Williamson and Payne, 1978). Goats are less affected by parasites due to their behaviour in feeding. Sheep are grazers and their food intake comes from low vegetation, which will be home to more parasites. Browsing by goats, however, leads to lesser consumption of such parasites (French, 1944).

2.1. Herding Strategies

The work of Richard Redding is vital to all zooarchaeologists working in south-western Asia. Redding developed a theoretical and methodological framework to investigate the decisions herders make when keeping flocks of sheep and goat in the Levant (Redding, 1993, 1981, 1984). This framework is based on the theory of optimal foraging, which applied to this scenario implies the shepherd has more intricate knowledge than a predator about the animals in his flock (Redding, 1984). Herding strategies can be analysed using three methods: the sheep:goat ratio, mortality profiles, and sexing (Redding, 1984).

The sheep:goat ratio considers three factors: the biological and ecological characteristics of sheep and goat, the environment of the assemblage, and the goal of the shepherd (Redding, 1984). Whereas the first two factors are quite intuitive, the third factor needs more explaining. Shepherds can have several goals for their flocks, and they can optimise for energy offtake, protein offtake, or herd security (Redding, 1984). Redding defines herd security as "the minimization of fluctuations in herd size, particularly those that result in a reduction of annual yields" (Redding, 1984).

Due to the strong relationship between energy and protein, it is not possible to differentiate these two goals. This implies that regardless of whether shepherds choose to optimise for protein or energy, they will automatically optimise for the other goal as well. The sheep:goat ratio will be 5:1 when a suitable environment is present, and the shepherds are not heavily engaged in agricultural activities. However, in hotter and more arid environments, sheep will become less productive than goats, which in extreme cases will cause the sheep:goat ratio to shift to 0:1. When the environment gets colder and wetter, goats will become less productive than goats, meaning the sheep:goat ratio shifts towards 1:0 (Redding, 1984).

When the goal of the shepherd is herd security, they will choose to have a mixed flock which will be more resistant against temperature extremes, species-specific diseases, or droughts than a single species flock. In relatively favourable environments, we will see a sheep:goat ratio between 1:1 and 1.7:1, since goats can recover quicker from losses than sheep. As the environment gets hotter and more arid, goats will have a higher survival rate than sheep, whereas when the environment gets wetter and colder, sheep will have a higher survival rate (Redding, 1984).

2.2. Culling Strategies

The age when ovicaprids (a collective term for sheep and goat) get slaughtered determines the age structure of the herd, which can tell us a lot about what products were valued. Generally, ovicaprids have three products they can provide humans with: meat, milk, skin, and, in the case of sheep, wool. Establishing the age of death in faunal assemblages can be done through epiphyseal bone fusion, tooth wear, and tooth eruption. Payne's (1973) research on this topic is fundamental in interpreting these kill-off patterns.

When herders prioritise meat production, most young males will be slaughtered. These will be slaughtered when they have reached the optimum in weight-gain, the point in their life where most meat is gained for the food given to the animal. This optimum point is usually reached when the animal is two or three years old. A few males will be kept alive in the flock for breeding purposes (Payne, 1973). When milk production is the main goal, this will result in the slaughtering of young animals, once the milk yield is not threatened anymore. Typically, this happens in the first three months of the animal's life (Payne, 1973). Finally, if wool is the most important product, mostly adult animals will be killed, leading to an older age profile. Older animals have a lesser quality of wool, so animals should get slaughtered before this happens (Payne, 1973).

It is important to realise that usually flocks are not kept for producing a single product, and the kill-off patterns above refer to the relative importance of a certain product (Payne, 1973). For example, in an economy which focusses on meat, we need to consider that often lamb meat is considered the highest quality meat and will be more expensive when sold, leading to the potential slaughter of lambs. Female ovicaprids can be slaughtered for meat gain for a range of reasons (e.g., year-round meat consumption) and sick animals will be slaughtered as well to prevent the spread of disease (Payne, 1973). All of this leads to the possibility of some ambiguity regarding the interpretation of kill-off patterns in the archaeological record (Payne, 1973).

Since Payne's work, there have been modifications and alternatives for explaining age structures in flocks. Redding provides alternative exploitation strategies for ovicaprids in his dissertation (Redding, 1981). Similar to his herding strategies, he provides optimising for energy/protein and herd security as possible exploitation patterns (Redding, 1981). Exploitation by optimising energy/protein focusses on obtaining meat and milk. This will be achieved by weaning young animals at two or three months and culling the excess males when they have reached their optimum weight, between two and three years old (Redding, 1981). Exploitation by optimising for herd security will concentrate on minimising the fluctuations in the size of the flock, especially those fluctuations that would cause a reduction of the annual yield from the flock (Redding, 1981). Here half of the young animals will be slaughtered towards the end of their first year, whereas the other half will be slaughtered towards the end of their second year. This ensures that in case there is a less successful lamb/kid crop the following year, some animals from the previous year will be available (Redding, 1981).

Vigne and Helmer (2007) have created new culling profiles for exploitation patterns. Although similar to that of Payne (1973), their system is more detailed. They differentiate between two different classes of meat utilisation. Type A meat is characterised by a system where most lambs are killed off between six months to one year of age, whereas type B meat slaughters animals as subadults, so between one and two years (Vigne and Helmer, 2007). They establish two classes of milk utilisation: type A sees unweaned lambs killed from at birth till three months old, and type B where lambs area weaned and separated from their mother. This results in the killing of animals, mainly females, between two and four years old (Vigne and Helmer, 2007). Finally, they have an exploitation pattern focusses on wool where animals are killed between four and six years old (Vigne and Helmer, 2007).

Unfortunately, research has proven that it is not possible to statistically differentiate between the different mortality profiles, and as such, the different exploitation strategies (Marom and

Bar-Oz, 2009). However, this does not mean these exploitation patterns should be abandoned, instead, they should be re-assessed, specifically the way the data is described (Marom and Bar-Oz, 2009). A possible solution is the binning of age classes. This leads to a simple model, based on that of Payne (1973). When about 80% of the animals are killed as very immature animals, it indicates specialised milk production. When very immature animals, subadults (mostly males), and adults are killed in equal frequencies, the economy focusses on meat production. When the majority of killed animals are adults, about 60%, with a large portion of very immature animals (30%) and a small portion of subadults (10%) killed, the focus is on wool and/or traction production (Marom and Bar-Oz, 2009).

In sum, if suitable mortality profiles and exploitation patterns want to be inferred, certain additional factors should be considered when possible. In addition to mortality profiles, sex and species-specific identifications should be determined as well to use with binned age distribution data (Marom and Bar-Oz, 2009).

Adding to this, I refer to the ethnographic observations by Dalman (1939) during the beginning of the 20th century in the southern Levant. He observed sheep were usually of the fat-tailed breed, the tail weighing up to ten kg. These sheep could produce around two kg of wool yearly, and a mother sheep could produce 40 kg of milk every year. People favoured the meat of sheep over goats and valued wool. Goat meat was not favoured since the meat was lean. Instead, goats were valued for their milk and can produce three litres of milk per day. Dalman observed goats generally outnumbered sheep in flocks, perhaps because finding food for goats since they can browse and graze, as opposed to sheep, who only graze (Dalman, 1939).

Chapter 3: Methods

3.1. Macrofauna

For this dissertation, I analyse macrofauna from two ongoing excavations in the southern Levant: Tell Lachish and Tell el-Burak. I also analyse macrofauna from a third site, Tell Keisan, for which no stratigraphic data is present at time of writing. I define macrofauna as any animal that is similar in size to and bigger than a hare. I also identify specimens belonging to the taxonomic family Testudines. At Tell Lachish, I record the presence of birds, fish, and molluscs but do not identify these to family or genus level since appropriate reference material was not available. At Tell el-Burak I identify birds to family and genus level when possible but do not record fish or molluscs since these are being processed by Canan Çakirlar (University of Groningen) and her team. At both sites, faunal material also is recovered and analysed from the heavy fraction from flotation, screened through a one mm mesh. Specimens from Tell el-Burak that could not be identified in the field, were brought back to the University of Tübingen for identification using the reference collection there.

I measure all animal bones using Von den Driesch (1976) with 0.01 cm precision and weigh all bones with 0.01 gr precision using a digital scale. I identify specimens to skeletal element (e.g., innominate) and the bone portion (e.g., acetabulum), and assign these to the genus and species level when possible, otherwise to body-size class (e.g., medium ungulate) following Stiner (2005). I choose NISP (number of identified specimens) as the primary quantification unit but also calculate MNE (minimum number of elements) and MNI (minimum number of individuals) (Lyman, 2018, 2008). I do not assign articulated faunal remains a NISP value of one but instead comment on articulation. For example, a mandible with two teeth is considered to have a NISP value of three. I evaluate evenness in different assemblages at a site by calculating the reciprocal of Simpson's index (1/D), which is a measure of taxonomic evenness (Simpson, 1949). I use species-specific identifications when calculating the reciprocal of Simpson's index, the exception being sheep and goats. These species are combined into an ovicaprid category since their distinction is challenging even with well-preserved specimens.

I record bone surface modifications (Fisher, 1995) such as burning (Stiner et al., 1995), weathering (Behrensmeyer, 1978), breakage, tooth marks, pathologies (Sapir-Hen et al., 2008; Siegel, 1976), and human modifications (Fernández-Jalvo and Andrews, 2016; Lyman, 1994) for every specimen. I evaluate density-mediated attrition to check for preservation bias by comparing the MNE of the most frequent lower tooth with mandibular MNE (Stiner, 1991). The assumption

is that animal carcasses arrive whole at the site, i.e., the teeth and cranial bones are all present at the site initially and the tooth to bone ratio will be one. However, at archaeological contexts, tooth enamel is more likely to be recovered than bone due to its higher mineral content (Hillson, 1986; Lyman, 1994). This means if there is a tooth to bone ratio that is higher than one, density-mediated attrition most likely affects the assemblage. I examine body part profiles of the major taxa at a site by dividing the body into nine anatomical regions: horn (antler and horn), head (mandible, cranium), neck (atlas, axis), axial column (innominate), upper front limbs (scapula, humerus), lower front limbs (radius, ulna, metacarpal), upper hind limbs (femur), lower hind limbs (tibia, calcaneus, astragalus, metatarsal), and feet (phalanges) (Stiner, 1991). I leave out ribs and vertebrae (cervical, thoracic, lumbar, sacral) here to avoid overrepresentation of certain taxa where these skeletal elements are highly diagnostic. I calculate MAU (minimal animal units) for each of these regions by dividing the observed MNE counts by their expected MNE counts in a complete skeleton. By doing this, I standardise my MNE counts so I can examine the anatomical profiles of major taxa.

Whenever possible, I perform ageing on taxa using epiphyseal fusion, tooth wear and tooth eruption. I use the ages of epiphyseal fusion of all long bones to calculate survivorship for ovicaprids (Moran and O'Connor, 1994) and cattle (Habermehl, 1975), these two taxa being the dominant taxa in the southern Levant and often providing enough ageable bone portions. Survivorship is represented using percentages in a non-cumulative line graph per age group. I use teeth to calculate age at death by using tripolar graphs. Here, I plot the frequencies of deciduous, adult, and old fourth premolars (Greenfield and Arnold, 2008; Steele and Weaver, 2002; Stiner, 1990; Weaver et al., 2011). I consider a fourth premolar which is less than half worn to be an adult, whereas one that is more than half worn old.

Distinguishing sheep from goat is an important topic in southwest Asia since these taxa are usually the most abundant in assemblages and we can deduce herding and economic strategies based on their proportions. I differentiate sheep and goat morphologically when possible (Boessneck, 1969; Zeder and Lapham, 2010; Zeder and Pilaar, 2010). It is also possible to establish the sex of sheep and goat. I used biometric data (usually of the distal breadth of phalanges) to determine bimodality which most likely reflects sexual dimorphism (Monchot et al., 2005). In ovicaprids, males are usually larger than females due to sexual size dimorphism (Davis, 2000).

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3.2. Multivariate Statistics

I customise the methodology outlined in Smith and Munro (2009) which uses multivariate statistics, particularly correspondence analysis, to integrate archaeological botanical and faunal remains. I also use this to investigate developments in animal-based subsistence. The methodology is similar for these two aspects, but when differing, I point this out.

The first step in performing correspondence analysis is to select and prepare the data. To collect my data, I use the criteria outlined in Smith and Munro (2009) for the integrative analysis. This means I only use reports for sites which have both zooarchaeological and archaeobotanical reports available. This criterion is left out when only dealing with archaeological faunal remains. I use published data for reproducibility of my results by other analysts. The quantification units are NISP for faunal remains and seed count for botanical remains. Among quantification units for faunal remains, NISP best reflects seed count, as both represent primary data and reflect counts of observed specimens (Gifford-Gonzalez, 2018; Lyman, 2018, 2008). Besides this, these are the two most common quantitative units reported in archaeological reports. Faunal and botanical archaeological remains have to come from the same chronological period, which means in some cases I reduce the chronological resolution of a sample (e.g., IA IIA to IA II). Data from specialised reports, for example on burials or ritual contexts, were excluded. A novel criterion of my approach is that included reports have to present data for both domesticated and wild taxa (Vermeersch et al., 2021a). The analyses focus on macrofauna and Testudines and leave out fish, molluscs, and birds, since species-specific abundance values for these groups are rarely provided.

The next step is data preparation. A common issue in preparing datasets for correspondence analysis is that different analysts identify taxa to different levels or with varying precision. This can be accounted for by combining taxonomic categories, which are not identified to the same levels by all analysts. For instance, when gazelle specimens are identified to species level in report A (e.g., as *Gazella gazella* and *Gazella subgutturosa*) but only as *Gazella* species in report B, I only use *Gazella* species, in the correspondence analysis. I should note, however, that it is possible to have different levels of taxonomic identifications between different groups of taxa within one analysis. This means it is possible to include specimens identified to family (e.g., Mustelidae), genus (e.g., *Gazella* sp.) and species (e.g., *Bos taurus*) in one correspondence analysis. In a further step I establish a threshold for the presence of faunal and botanical taxa among all sites in the dataset (Gauch, 1982). In my datasets this is a 5% cut-off over all samples to include taxa into the analysis. This threshold is important because rare taxa will introduce a

strong numerically based pattern into the output of the correspondence analysis, resulting in reduced visibility of associations of the better-represented taxa. This means that if rare taxa are kept in the dataset, the patterns would be based on the absence of these taxa in samples rather than on meaningful contextual relationships. Finally, I establish a threshold for the minimum number of total specimens per sample. The botanical samples needed a minimum of ten taxa and a minimum abundance of a 100 seed counts per sample. For faunal remains, there is no recommended threshold for specimen abundance per sample, so I use all samples to increase our sample size for the integrative analysis. For the datasets only containing archaeological faunal remains, I must impose a specimen threshold due to the high number of samples. I systematically check this by analysing several correspondence analyses biplots with several NISP thresholds in 100 NISP increments. This established a threshold of 500 NISP, which eliminates samples with too little data that only obscure patterns, whilst having enough samples to still recognise visible trends in the data (Vermeersch et al., 2021a).

I prepare three datasets for the faunal and the integrative analyses, each using only domesticated taxa, only wild taxa, and a combination of wild and domesticated taxa. The datasets with only domesticated taxa allow to investigate trends in agricultural practices, the datasets with only wild taxa focusses on investigating environmental factors, hunting, arable weeds, and fodder, whereas the datasets containing both wild and domestic taxa allow to look at a combination of environmental and economic factors. I choose three independent parameters to investigate these datasets: relative chronology, mean annual precipitation (MAP), and elevation. I check the distribution of samples within these parameters to see whether samples are evenly represented therein, or whether certain categories such as MAP ranges are overrepresented.

I apply correspondence analysis (CA), detrended correspondence analysis (DCA), and canonical correspondence analysis (CCA) in the integrative analysis and for analysing animal-based subsistence, because these multivariate approaches can recognise patterns and associations in large datasets and have several benefits, as outlined by ter Braak (1996):

- both quantitative (abundance) and binary (presence/absence) data are accepted
- large numbers of taxa are allowed (10 – 500 taxa)
- the dataset can contain many zero values
- it shows a non-linear, unimodal relationship between taxa and quantitative environmental parameters.

CA, DCA, and CCA are visualised by biplots where the first axis (horizontal axis) represents the greatest amount of variance within the dataset, whereas the second axis (vertical axis) represents lesser variance (Leps and Smilauer, 2003). These two axes only present a two-dimensional view of the obtained results, so whenever results are not clear, I check how the data are represented using additional axes (the third and fourth axis). Taxa and samples can be represented together in a biplot or separately, this is a matter of personal preference.

The distribution of samples in a CA biplot can follow the shape of an arch, which is called the 'arch effect' (Jongman et al., 1987). When this happens, it is recommended to run a DCA, which removes the arch by detrending the data. I detrend all data using second-order polynomials.

CCA can recognise patterns against known, independent parameters by constraining the ordination axes to assess the effect they have on the data (ter Braak, 1994). The results of a CCA can be statistically tested for significance against the null hypothesis (here that there are no relationships) by performing a Monte Carlo permutations test (Leps and Smilauer, 2003; ter Braak, 1994). This is an advantage over the CA and DCA, which do not involve a statistical test and rely on a critical, visual assessment of the data.

Chapter 4: Results and Discussion

4.1. Developments in Animal-Based Subsistence at the Studied Sites

4.1.1. Lachish

Before analysing the faunal remains of Lachish, I check for the effect of sample size on species richness in the different assemblages. The relationship between the two is not significant (Pearson's correlation, $r = 0.410$, $p > 0.05$) and individual rarefaction (see SI 2.1. of Vermeersch et al. [2021b]) shows sample size and evenness are independent. This means the observed changes in faunal composition can be attributed to human behaviour and are not caused by differences in sample size. The complete taxonomic composition list for the analysed fauna of Lachish can be found in SI 1 of Vermeersch et al. (2021b). Note, the excavators at Lachish divide the MBA and LBA into subperiods. The sub-periods of relevance here are the MBA III and the LBA II, the MBA III corresponds to 1,650 to 1,550 BCE, and the LBA II corresponds to 1,450 to 1,300 BCE.

4.1.1.1. Species Abundance

The majority of faunal specimens of area S date to the LBA II (see table 2 of Vermeersch et al. [2021b] for taxonomic composition). Ovicaprids are the dominant taxa in the assemblage, goats outnumbering sheep (sheep:goat ratio = 0.34). Cattle are the second most frequent taxa in the assemblage. Suids are present in small numbers, indicating infrequent consumption. The low frequency of wild taxa such as fallow deer or gazelle suggests hunting did not contribute much to subsistence practices.

Most of the faunal specimens of area P date to the MBA III, LBA II, and IA II (see table 3 of Vermeersch et al. [2021b] for taxonomic composition). During the MBA III, ovicaprids are the most common taxon found, sheep and goat almost equally represented (sheep:goat ratio = 0.88). Fish and cattle are an important part of the diet during this time. Suids, wild taxa, bird, and shells are present in small frequencies. During the LBA II, the taxonomic composition is similar to the previous assemblage. Ovicaprids dominate the assemblage but now sheep outnumber goats (sheep:goat ratio = 1.94). Hunting plays a slightly more important role during this time and fish appear in higher frequencies. During the IA II, ovicaprids are the most frequent taxon, goats outnumbering sheep (sheep:goat ratio = 0.70). Cattle are an important part of the diet but opposed to the other assemblages, there are no suids present during the IA II. Hunting plays a minor role in subsistence practices during this time. The evenness for all assemblage in area P

is low, probably due to the high frequencies of ovicaprid (1/D: MBA III = 1.64, LBA II = 2.00, IA II = 1.2).

4.1.1.2. Body Part Representation

The body part profile, also called anatomical profiles, for ovicaprids during the LBA II in area S (see fig. 2.A of Vermeersch et al. [2021b]) shows lower hind limbs, front limbs, and head elements are most represented. Axial, neck, and feet elements are present in low frequencies. The body part profile for cattle during the LBA II in area S (see fig. 2.B of Vermeersch et al. [2021b]) shows they are most represented by hind and front limbs. Just like with the ovicaprids, axial, neck, and feet elements are underrepresented.

Due to sample size, I can only create body part profiles for ovicaprids for the three assemblages in area P, not for cattle (see fig. 3 of Vermeersch et al. [2021b]). It is important to point out the MAU values for these body part profiles are small. During the MBA III, ovicaprids are most represented by head elements, axial elements, and upper front limbs. Feet and lower front limbs are underrepresented. During the LBA II, lower hind limbs, and front limbs are prominent. Axial and feet elements are underrepresented. During the IA II, lower hind limbs, front limbs, and axial elements are most frequent. Feet, neck elements and upper hind limbs are only present in low numbers.

4.1.1.3. Ageing and Sexing

I reconstruct mortality profiles using epiphyseal fusion on ovicaprids dating to the LBA II in area S (see fig. 4.A and table 4 of Vermeersch et al. [2021b]). Most ovicaprids survive to sub-adulthood, followed by a large drop of survival in adulthood. The tripolar graph (see fig. 4.B of Vermeersch et al. [2021b])) confirms this pattern by showing the presence of mostly juvenile ovicaprids. Epiphyseal fusion on cattle from the LBA II in area S (see fig. 5 and table 5 of Vermeersch et al. [2021b]) show most survive the first two years of life, and then the majority are slaughtered at year three.

Due to the small sample size of the assemblages in area P, I can only perform ageing on ovicaprids of the MBA III and LBA II (see fig. 6 and table 6 of Vermeersch et al. [2021b]). During the MBA III, ovicaprids mostly survive to sub-adulthood with a drop in survival during adulthood. During the LBA II, a similar ageing pattern is present, although more individuals survive to adulthood. Due to the small sample sizes, I cannot perform a tripolar graph for ovicaprids or cattle for these assemblages.

I perform sexing of the ovicaprid specimens dating to the LBA II of area S, the other assemblages have too few data. I do this by using the measurements of the distal breadth of the first phalanx following Von den Driesch (1976) to perform mixture analysis. The measurements are normally distributed (Shapiro-Wilk test, W = 0.943, P = 0.1443), and the mixture analysis (N = 27, mean = 11, standard deviation = 2.20, see fig. 7, table 7 of Vermeersch et al. [2021b]). Most specimens belong to the group with the larger mean, which means males outnumber females in this assemblage.

4.1.1.4. Taphonomy

I check for the effect of density-mediated attrition in the assemblages I analyse and find this did not affect them, indicating the changes in subsistence practices reflect choices made by humans (see table 8 of Vermeersch et al. [2021b]). I check the assemblages for recovery bias (see SI 2.5 of Vermeersch et al. [2021b]) by examining the length measurements of the bone specimens of the most common taxon, ovicaprid, and determine this is not an issue for the LBA II sample in areas S and P. I observe a slight bias in the MBA III and IA II assemblages of area P but this should not affect interpretations of the results since the smallest bone fragments measure 20 mm here which is still large enough to retrieve most ovicaprid elements.

Butchery traces in the faunal assemblage at Lachish are rare (see table 9 of Vermeersch et al. [2021b]). In area S, 42 bones show butchery traces, and most of these specimens date to the LBA II. The majority of these cutmarks are on ovicaprids, particularly on the humerus and astragalus. Area P hardly has any traces of butchery, with only five bones showing such traces.

The bone specimens of the Lachish assemblages do not show many traces of burning (see table 10 of Vermeersch et al. [2021b]). Most of the burning in area S (1.1% carbonized, 0.3% calcined) occurs on ovicaprids and medium ungulates on LBA II material. In area P (1.0% carbonized, 0.5% calcined), specimens dating to the MBA III and LBA II show more traces of burning. The MBA III in area P shows most burning on medium mammals and ovicaprids, whereas the LBA II shows most burning on medium mammals and large ungulates.

4.1.1.5. Regional Comparison

Finally, I compare the subsistence patterns of Lachish during the MBA, LBA, and IA II to those of other sites in the Shephelah. I choose to broaden the periods to include more comparative material, but this decision means I lose some chronological resolution. My faunal results are combined with those of previous analyses at Lachish (Croft, 2004). I compare these sites by looking at herding strategies (through the sheep:goat ratio) and economic strategies (through

ovicaprid mortality profiles). A map with the location of the comparative sites and a table containing all reference information ovicaprid abundance counts, and the sheep:goat ratio can be found in figure 8 and table 11, respectively, of Vermeersch et al. (2021b).

During the MBA, the inhabitants of Lachish show a preference for sheep over goats, and they slaughter adult animals more often. Sheep are usually kept into adulthood, for gaining wool, whereas goats are typically slaughtered at a younger age, to obtain milk (Croft, 2004; Vermeersch et al., 2021b). The inhabitants of Tell Miqne/Ekron and Tel Haror also show a preference for sheep over goats (Klenck, 2002; Maher and Hesse, 2016). At Tell Miqne/Ekron, the inhabitants slaughter ovicaprids of all ages indicating a mixed economy focussing on meat, milk and wool (Maher and Hesse, 2016), whereas at Tel Haror young animals are killed more frequently, suggesting a higher focus on obtaining milk and meat (Klenck, 2002). Tell Nagila only has goats attested at the site and no sheep, although the analyst suggests two specimens potentially could be identified as sheep. The goats are slaughtered during sub-adulthood and adulthood, indicating a mixed economy (Ducos, 1968).

During the LBA, the inhabitants of Lachish have mixed flocks of sheep and goat in an almost even proportion, suggesting the primary aim was obtaining herd security. The same herding strategy can be seen at Tel Beth-Shemesh and Timna. The inhabitants of Lachish maintain the same economic strategy as during the MBA, namely, killing ovicaprids during adulthood which suggests a focus on obtaining meat (Croft, 2004; Vermeersch et al., 2021b). The situation is different at Tel Beth-Shemesh (Tamar et al., 2015) and Timna (Lernau, 1988), where the slaughtering of ovicaprids during sub-adulthood and adulthood indicates a focus on meat and secondary products. The inhabitants of Tell Miqne/Ekron show a preference for sheep over goats, and mostly slaughter young and old ovicaprids suggesting a mixed economy (Lev-Tov, 2010, 2000). The people of Tel Burna, on the other hand, show a preference for goats over sheep, but no mortality data is provided to understand the economic strategies at the site (Greenfield et al., 2017).

During the IA II, the occupants of Lachish show a slight preference for sheep over goats, but the economic strategy remains unchanged, i.e., a focus on obtaining meat (Croft, 2004; Vermeersch et al., 2021b). The inhabitants of Tel Halif prefer goats over sheep, and initially, their economic strategy focusses on meat exploitation since they mainly slaughter prime-aged adults. During the eighth century, the occupants slaughter not only prime-aged adults but older animals as well, suggesting a focus on both meat and secondary products. Eventually, animals of all ages are slaughtered, indicating a mixed economy (Sapir-Hen, 2015). The residents of Tell

Miqne/Ekron and Tell el-Hesi prefer sheep over goats. At Tell Miqne/Ekron, they mainly slaughter prime-aged adults but leave enough animals alive to be able to obtain secondary products as well (Lev-Tov, 2010, 2000; Maher and Hesse, 2016). At Tell el-Hesi, occupants mainly slaughter prime-aged adults, suggested a focus on obtaining meat (Peck-Janssen, 2006).

4.1.2. Tell el-Burak

First, I check for the effect of sample size on species richness in the different assemblages of the IA Tell el-Burak material. These correlate for the assemblages, and individual rarefaction (see fig. 5 of Appendix 4) shows particularly the assemblages of area 4 attest to low evenness. This means the results of the assemblages coming from area 4 need to be interpreted carefully. The complete taxonomic composition for the analysed fauna of Tell el-Burak can be found in SI 1 of Appendix 4.

4.1.2.1. Species Abundance

Taxonomic composition remains consistent throughout time in area 3. Ovicaprids are the most frequent taxon found, goats constantly outnumbering sheep (sheep:goat ratio: Early = 0.75, Middle = 0.68, Late = 0.68). Cattle are the second most frequent species, and the ovicaprid to cattle ratio remains similar throughout the different occupational phases (ovicaprid:cattle ratio: Early = 7.18, Middle = 6.43, Late = 7.33). Suids and wild taxa are present in small numbers, the latter indicating hunting only plays a minor role in the diet. Dog specimens are frequent in the Late assemblage due to the conservation of two well-preserved individuals. Evenness is low during the Early and Middle assemblages (1/D: Early = 1.5, Middle = 1.4), and the Late assemblage has a slightly higher evenness (1/D = 2.4).

In all assemblages of area 4, ovicaprids are the most frequent taxon, although there is a change in the sheep:goat ratio through time (sheep;goat ratio: Early = 1.30, Middle = 0.60, Late = 0.76). Sheep are preferred over goats during the Early assemblage, whereas goats are favoured during the Middle and Late assemblage. However, this could be because of a small sample size, which, as I determined earlier, influences richness and evenness. Cattle are the second most frequent taxon present, and the ovicaprid to cattle ratio stays consistent from the Early to the Middle assemblage, but the Late assemblage sees a large increase in ovicaprids (ovicaprid:cattle ratio: Early = 5.78, Middle = 5.83, Late = 8.26). Suids are present in small frequencies during the Early and Middle assemblage but are absent during the Late assemblage. Note, this could be due to the small sample size. Wild taxa are present in low numbers, indicating hunting did not contribute much to the daily diet. Evenness in all assemblages of area 4 is low (1/D: Early = 1.76, Middle = 1.53, Late = 1.73).

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4.1.2.2. Body Part Representation

The anatomical profiles of ovicaprids in area 3 differ slightly through time (see fig. 6 and SI 2 of Appendix 4). All assemblages show a preference for head elements, front limbs, and hind limbs. The Early assemblage also shows a high presence of axial elements. Feet and neck elements are underrepresented throughout the assemblages.

The body part profiles of ovicaprids in area 4 could only be made for the Early and Late assemblages (see fig. 7 of Appendix 4) since there are not enough data to do this for the Middle assemblage. The profiles for the Early and Late assemblages are similar, showing a preference for head elements, front limbs, and lower hind limbs. Feet elements are underrepresented.

4.1.2.3. Aging and Sexing

I use epiphyseal bone fusion to reconstruct mortality profiles for ovicaprids through time in area 3 (see table 4 and fig 8.A of Appendix 4). During the Early assemblage, most ovicaprids are killed when they are sub-adults. The ones which are kept alive, almost all survive into adulthood. During the Middle and Late assemblages, the same pattern appears where most ovicaprids are slaughtered upon sub-adulthood. The epiphyseal bone fusion data is too small to reliably calculate the survivorship upon adulthood for these two assemblages. I also create a tripolar graph (see fig. 8.B. of Appendix 4), which due to small sample sizes is only possible for the Early assemblage, which confirms the results of the epiphyseal bone fusion. It shows the presence of mostly juveniles and adults, with a slightly higher presence of juveniles.

I perform epiphyseal bone fusion to reconstruct ovicaprid mortality profiles through time in area 4 (see table 5 and fig. 9 of Appendix 4). Due to small sample sizes here, I could only do this for the Early assemblage. Most ovicaprids survive into adulthood. Small sample sizes did not allow me to create tripolar graphs for any of the assemblages of area 4.

Sexing was not possible on the material of area 3 or 4 of Tell el-Burak, due to small sample sizes.

4.1.2.4. Taphonomy

I check for the effect of density-mediated attrition in the assemblages of Tell el-Burak and determine this did not affect these assemblages (see table 6 of Appendix 4). This means the observed differences in diet are due to the choices humans made.

Burning does not occur often on the specimens of Tell el-Burak (see table 7 of Appendix 4). Area 3 contains more burned bones than area 4 and contains both carbonised and calcined bones. Area 4 only has carbonised bones.

Butchery appears in small quantities, there are 119 bones with cutmark from area 3 and 111 bones with cutmarks from area 4 (see SI 3 of Appendix 4). Most of these cut marks appear on medium ungulates and ovicaprids. During the Early assemblage of area 3, the majority of cutmarks appear on axial elements, whereas during the Middle assemblage most cutmarks appear on the upper front limbs and hind limbs. In area 4, during the Early assemblage, most cutmarks appear on the front limbs, axial, and feet elements. During the Late assemblage, most appear on the front limbs.

The faunal material of Tell el-Burak shows traces of pathologies, usually related to arthritis. Twelve bones from area 3 and five bones from area 4 show traces of pathologies (see table 8 and SI 4 of Appendix 4). Pathologies in area 3 appear most often on ovicaprids and cattle, those of area 4 on equids and cattle.

4.1.2.5. Regional Comparison

I compare the subsistence patterns during the IA II at Tell el-Burak with other synchronous sites in the region. I look at how the diet differs between Tell el-Burak and other sites for which a predominantly Phoenician identity has been ascribed, and other coastal or synchronous sites in the northern and central Levant, which do not have a mostly Phoenician identity ascribed to them. When using terms which refer to ethnicity, such as Phoenician, caution needs to be taken. The inhabitants of Phoenicia, especially during the IA II, were known for being heavily involved in international trade and establishing trading colonies and settlements in other regions, for example, in Sardinia, Tunisia and Italy. It is, therefore, reasonable to assume the possibility of settlements which are not regarded as being Phoenician, having Phoenician inhabitants or elements of Phoenician culture.

I use CA (fig. 11 of Appendix 4) to compare the taxonomic composition between the sites. A map showing the location of the sites used for comparison, along with some key sites in the region, can be found in fig. 4 of Appendix 4. The references for the faunal reports used for this comparison, along with abundance data and ratios, can be found in table 9 of Appendix 4. Note that I combined the faunal data I analysed with those analysed by Canan Çakirlar (University of Groningen) (Çakırlar et al., 2013).

Most sites cluster together on the negative side of the first axis and along the second axis. These sites are associated with ovicaprids, cattle, gazelle, and mustelids. The outlier to this group is Tell Jemmeh, which is caused by its low taxonomic diversity. Tell el-Burak and Tell Nebi Mend cluster together on the positive side of the first and second axis. They are characterised by their frequencies of cat and camelids. Tell Afis also plots on the positive side

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of the first and second axis but is an outlier to this group. It is characterised by its high frequencies of fox and horse. Tell el-Burak, Tell Nebi Mend, and Tell Afis all are associated with high frequencies of donkey. Finally, two sites which are located in present-day Turkey, Tell Tayinat and Kinet Hoyuk, plot on the positive side of the first axis and the negative part of the second axis. These sites are characterised by their frequencies of boar, roe deer, Testudines, and red deer. Roe deer only appears in these two samples.

4.1.3. Discussion

4.1.3.1. Lachish

At Lachish, ovicaprids are the most frequent taxa throughout all assemblages, although there are changes in the sheep:goat ratio which could be caused by different preferences between households or the two areas. Sheep and goat are represented almost equally during the MBA III assemblage of area P, suggesting inhabitants aim for herd security during this time. During the LBA II in area S, inhabitants prefer goats over sheep, and they slaughter more male than female ovicaprids. However, the LBA II in area P shows inhabitants of this palace area prefer sheep over goats. During the IA II, occupants show a slight preference for goat over sheep. Economic strategies at Lachish do not change much over time, inhabitants mostly slaughter adult ovicaprids during the MBA III and LBA II. Cattle are an important taxon for subsistence at Lachish, but their frequency drops during the IA II. Fish have a large contribution to the diet, particularly during the MBA III and the LBA II in area P. Suids and wild animals such as fallow deer and gazelles appear only in small numbers. The low frequency of wild animals suggests hunting did not play a big role in subsistence practices at the site.

A comparison with other sites in the Shephelah, allows me to investigate how well Lachish fits within its regional framework. During the MBA, similar economic strategies regarding ovicaprids are practised by the inhabitants of the sites in this region. Generally, there is a preference for sheep over goats, and a mixed economy is practised. Such a mixed economy would have exploited ovicaprids to gain meat and secondary products, without a focus on a single product. During the LBA, the inhabitants of Lachish practice similar herding strategies as those of Timna and Tel Beth-Shemesh, by focussing on herd security. At these sites, there is an almost even representation of sheep and goat. The choice for such a herding strategy coincides with the drier climate during the end of the LBA (Drori and Horowitz, 1989; Langgut et al., 2015; A. M. Rosen, 1986). The occupants of Tell Miqne/Ekron, on the other hand, prefer sheep over goats. The people of Tell Burna show the opposite and prefer goats over sheep. The occupants of these sites practise a mixed economy. During this time, it could be that Tel Burna participated in

regional politics, as is suggested by the large size of the tell. As such, it is possible that Tel Burna and Lachish would have had political and economic interactions, especially considering the distance between the two sites is only about ten km. During the IA, the inhabitants of Lachish practice different economic strategies than other sites in the Shephelah. Their economy focusses mainly on obtaining secondary products, whereas the occupants of the other sites now focus on obtaining meat, which could hint at specialised production and trading activities. The inhabitants of most IA II sites show a preference of sheep over goats. The popularity of sheep, which fare well in humid conditions and have higher water requirements, correlates well with the archaeological botanical evidence of the region. High frequencies of grape pips dating to the IA II have been found at Tel es-Safi (Mahler-Slasky and Kislev, 2012) and many flax remains have been identified at Tel Burna (Orendi, 2020). Both these taxa are good indicators of the presence of high water availability, which is supported by stable carbon isotope analysis of barley grains dating to this time and from this region (Riehl and Shai, 2015). The requirement of having more sheep during the IA II can also be related to the effect of the Neo-Assyrian Empire, who would transport and tax wool to improve their economy (Ben-Shlomo, 2014; Finkelstein, 1999; Postgate, 1974). The exception to preferring sheep in flocks is Tel Halif, where there is a strong preference for goats. This preference for goats could be attributed to the geographical location of Tel Halif, namely, close to the northern Negev regions, where goats would fare better than sheep due to the aridity.

4.1.3.2. Tell el-Burak

The subsistence practices at Tell el-Burak are consistent through time and no major differences can be observed between areas 3 and 4 of the site. I should note that the minor changes observed particularly in area 4 could be related to the effect of small sample sizes on diversity and evenness.

Throughout all assemblages from both areas, ovicaprids are the most frequent taxon. Goats outnumber sheep in flocks, except during the Early assemblage of area 4. This suggests the inhabitants were optimising for protein and energy intake and their preference for goats suggest a warm and relatively dry environment. During the Early assemblage of both areas, occupants of the site slaughter ovicaprids of all ages, suggesting a mixed economy where they did not specialise in obtaining a single product such as meat or secondary products. During the Middle and Late assemblage, I only could calculate mortality profiles for the ovicaprids in area 3. These show that most ovicaprids were slaughtered a sub-adults. Unfortunately, the mortality data for calculating survivorship as adults is too small to make reliable conclusions, so I cannot deter-

mine the economic strategies employed during these occupation phases. Cattle are the second most frequent taxon through all assemblages in both areas. The ovicaprid to cattle ratio indicates ovicaprids heavily outnumbered cattle, particularly during the Late assemblage in area 4. Keeping cattle at the settlement might not have been worth the effort for the inhabitants since cattle have higher food and water requirements than ovicaprids (Sasson, 2016; Tchernov and Horwitz, 1990). The main advantage of cattle is that they can be used for labour, but perhaps this position was already filled by another labour animal, for example, donkeys. Suids are only present in small numbers through time in both assemblages, as are wild taxa. This shows suids and hunting did not contribute significantly to the diet of the occupants of Tell el-Burak.

The higher frequencies of dog remains during the Late assemblages of both areas should be noted, especially since these remains only represent a few individuals. Earlier research at Tell el-Burak uncovered two dog burials without grave goods dating to the Persian periods (Çakırlar et al., 2013). It seems the practice of dog burials during the Persian period was widespread in the southern Levant, especially in the coastal regions. The dogs are buried in so-called grave pits, which is a characteristic of dog burials during the Persian period in the southern Levant. The dog burials typically appear in clusters within settlements, as is the case for the dog burials at Tell el-Burak. The symbolic or social role of these dog burials is difficult to assess at this moment since more detailed faunal analyses need to be performed on the dog specimens of these burials (Çakırlar et al., 2013).

Finally, I compare the taxonomic abundance between Tell el-Burak and regional sites through CA. Although it is not possible to identify a diet characteristic of the Phoenicians, common subsistence strategies can be discerned for sites located in the southern Levant during the IA II. Tell el-Burak, Tell Nebi Mend, and Tell Afis plot further away from this main group of southern Levantine sites. These three sites are associated with higher frequencies of fox, donkey, cat, and camelid. A clear difference can be seen between the southern Levantine sites and those in present-day Turkey (i.e., Tell Tayinat and Kinet Hoyuk). The sites in present-day Turkey are associated with higher proportions of wild taxa such as boar, roe deer, Testudines, and red deer, with roe deer only being attested at these sites. Their different subsistence strategy does not relate to chronology, MAP, or elevation, so I suggest the causes are cultural choices and a stronger reliance on hunted game. Tell Tayinat and Kinet Hoyuk are thought to be associated with the Hittite empire and future comparisons with more sites in present-day Turkey can hopefully shed more light on these intriguing patterns.

4.2. Regional Developments in Animal-Based Subsistence

The faunal dataset consists of 48 sites represented by 76 samples, resulting in a total of 242,786 specimens (fig. 3). I do not include taxa which could contain both domesticated and wild taxa in the CA, for example, Canidae or Equidae. I also leave out samples with mixed or very broad time periods, for example, IA I–IA II or BA. I check how evenly the independent parameters (relative chronology, MAP, and elevation) are distributed among the faunal dataset (table 2). The parameter chronology is evenly distributed between the BA and IA, but the parameters of MAP and elevation are not. Table 3 gives a list of references for the faunal reports I use to establish developments in animal-based subsistence.

Table 2: Distribution of the three independent parameters (chronology, MAP, elevation) used in correspondence analyses of the faunal dataset.

Chronology	# samples	MAP (mm)	# samples	Elevation (m)	# samples
EBA I	8	200-300	8	Below sea level	9
EBA II	3	300-400	16	0-100	22
EBA III	6	400-500	17	100-200	11
MBA	9	500-600	27	200-300	8
LBA	11	600-700	3	300-400	4
IA I	13	700-800	4	400-500	2
IA II	26			500-600	3
				600-700	2
				700-800	7
				900-1000	6

Fig. 3: Map of the southern Levant showing the location of the sites used for establishing developments in subsistence through the faunal dataset.

Table 3: Sites used for analysing developments in animal-based subsistence.

Site	Reference
Aphek	(Hellwing, 2000; Horwitz, 2009)
Arad	(Lernau, 1978)
Aroer	(Motro, 2011)
Ashdod	(Hakker-Orion and Nahshoni, 2013; Maher, 2005)
Ashkelon	(Hesse et al., 2011)
Bet-Shean	(Horwitz, 2006)
Bet-Shemesh	(Hesse et al., 2016; Tamar et al., 2015)
Bethsaida	(Fischer, 2015; Fisher, 2014)
Dan	(Greer, 2013; Wapnish et al., 1977)
Dor	(Bartosiewicz and Lisk, 2018; Raban-Gerstel et al., 2008; Sapir-Hen et al., 2014)
Ekron	(Lev-Tov, 2010, 2006, 2000; Maher and Hesse, 2017, 2016)
Hazor	(Lev-Tov, 2012a; Marom, 2012; Marom et al., 2017; Marom and Zuckerman, 2012)
Hirbet el-Mudeyine el-'Aliye	(Lev-Tov et al., 2011; Popkin, 2009)
Horvat 'Illin Tahtit	(Allentuck, 2013)
Horvat 'Uzza	(Sade, 2007a, 2007b)
'Izbet Sartah	(Hellwing and Adjeman, 1986)
Jawa	(Popkin, 2009)
Jerusalem	(Horwitz, 2000, 1996; Horwitz and Lernau, 2018; Sapir-Hen et al., 2016)
Kabri	(Dayan and Horwitz, 1999; Horwitz, 2002; Marom et al., 2015)
Kamid el-Loz	(Bökönyi, 1990)
Kinneret	(Ziegler and Boessneck, 1990)
Lachish	(Croft, 2004; Lernau, 1975)
Manahat	(Horwitz, 1998)
Megiddo	(Sasson, 2013; Wapnish and Hesse, 2000)
Mount Ebal	(Horwitz, 1987)
Nahal Tillah	(Levy et al., 1997)
Pella	(Köhler-Rollefson, 1992)
Qiryat 'Ata	(Agha, 2014; Horwitz, 2013, 2003; Maher, 2014; Sadeh, 2000)
Shiloh	(Hellwing et al., 1993)
Sidon	(Vila, 2006)
Tel Dalit	(Horwitz et al., 1996)
Tel Halif	(Sapir-Hen, 2015; Seger, 1983; Seger et al., 1990)
Tel Harasim	(Maher, 1999)
Tel 'Ira	(Dayan and Horwitz, 1999)
Tel Lod	(van den Brink et al., 2015)
Tel Malhata	(Sade, 2015)
Tel Michal	(Hellwing and Feig, 1989; Sade, 2006)
Tel Moza	(Sade, 2009; Sapir-Hen et al., 2016)
Tel Yaqush	(Hesse and Wapnish, 2001)
Tel Yarmuth	(Davis, 1988; Salavert, 2008)
Tel Yoqne'am	(Horwitz et al., 2005)
Tell el-Burak	(Çakırlar et al., 2013)
Tell el-'Umeri	(Harrison, 1995; London, 2011)
Tell es-Safi	(Kehati et al., 2018; Lev-Tov, 2012b)
Tell es-Sakan	(de Miroschedji et al., 2001)
Tell es-Seba'	(Hellwing, 1984)
Tell Hesban	(Ray, 2001a, 2001b; Von Den Driesch, 1995)
Tell Zira'a	(Benecke, 2019)

4.2.1. Chronology

In a first step I test whether changes in subsistence patterns through time are caused by political or social changes. I check this by using multivariate statistics on a dataset containing all faunal taxa, only domesticated taxa, and only wild taxa against the parameter of relative chronology.

The CCA based on all taxa against relative chronology confirms there are changes in taxa composition throughout time (pseudo-F = 1.6, P = 0.002). The CA of the dataset containing all taxa with the parameter of relative chronology (Fig. 4.A) shows a trend where taxa composition is different between the EBA and the IA. The EBA samples mainly plot on the positive side of the first axis and along the second axis. These sites are associated with a high abundance of wild taxa. The MBA and especially the LBA samples plot heterogeneously and are not particularly associated with any taxa. The IA I and IA II samples predominantly plot on the negative side of the first axis and along the second axis. These samples are associated with zebu and camelids. Zebus only occur at IA II samples. Camelids predominantly occur in the IA, with only a few records in the LBA and only one EBA sample. Furthermore, the IA samples are characterised by a negative association of wild taxa, i.e., a trend towards fewer wild taxa.

The CCA with only domesticated taxa against relative chronology states there are no differences in the composition of domestic taxa through time (pseudo-F = 1.3, P = 0.09). A visual inspection of the CA with only domesticated taxa and the parameter relative chronology (fig. 4.B) shows that although trends are similar to those of the dataset containing all taxa, they are weaker. EBA and MBA samples mainly plot along the first axis and in the negative part of the second axis. These samples are associated with mule, horse, and onager. The LBA samples plot heterogeneously. IA samples mainly plot in the negative part of the first axis and along the second axis. These samples are characterised by the presence of camelids.

Finally, the CCA with only wild taxa against relative chronology shows there is a difference in wild taxa composition through time (pseudo-F = 1.7, P = 0.004). The observed trends in the DCA with only wild taxa and the parameter of relative chronology (fig. 4.C) are following those seen in the DCA of all taxa against the parameter of relative chronology. EBA samples plot along the first axis and are mainly in the positive part of the second axis. They are associated with hippopotamus, roe deer, and aurochs. The MBA and LBA samples plot heterogeneously. The IA samples mainly plot on the positive side of the first axis and along the second axis. These samples are associated with marbled polecat and gazelle.
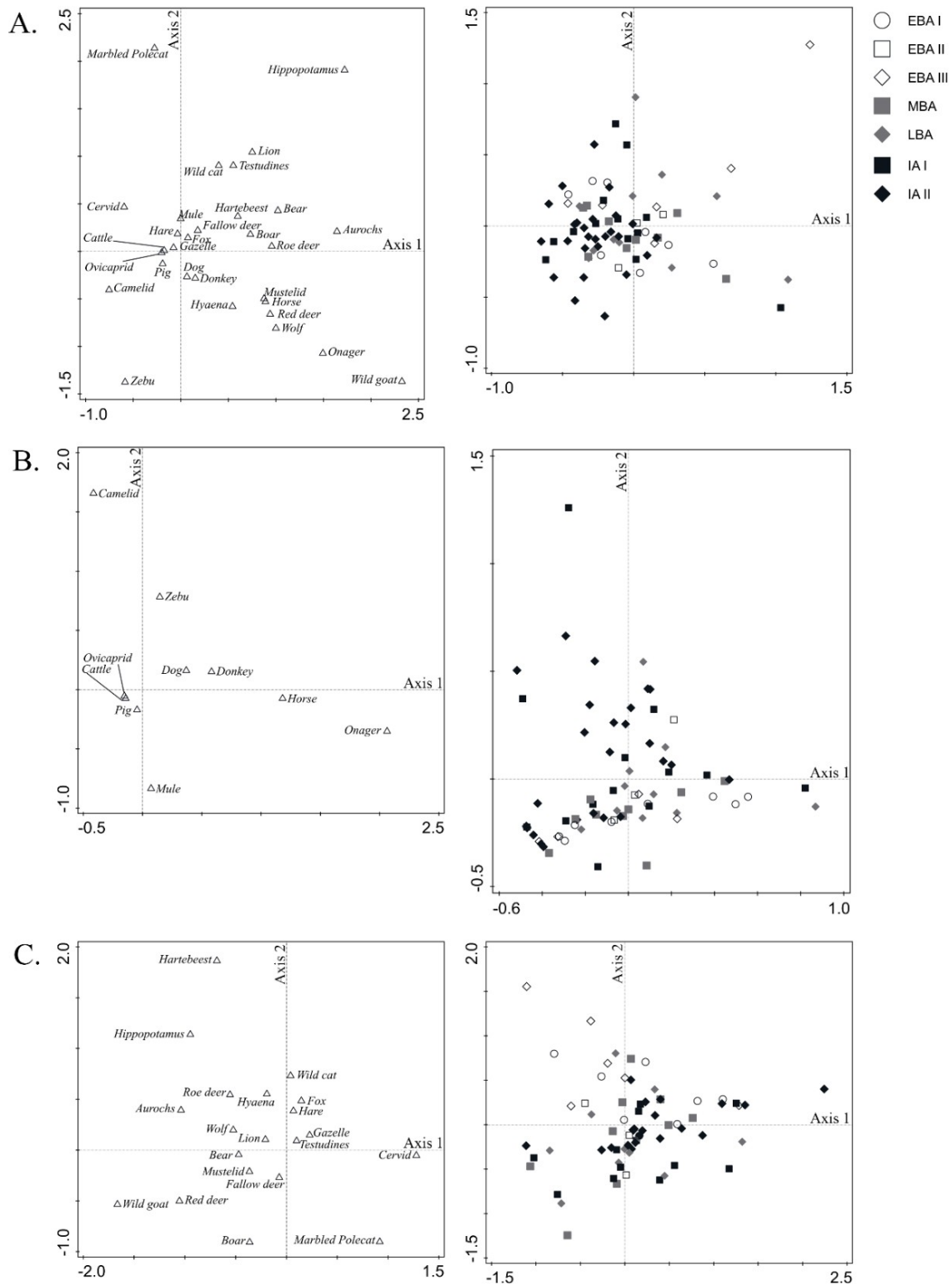
Fig. 4: A: CA containing all faunal taxa against relative chronology. Cumulative explained variation for axis 1 = 14.56%, and for axis 2 = 23.94%. Eigenvalues are 0.1686 and 0.1085 for axis 1 and 2, respectively. **B:** CA containing domesticated taxa against relative chronology. Cumulative explained variation for axis 1 = 21.65%, and for axis 2 = 39.15%. Eigenvalues are 0.0990 and 0.0800 for axis 1 and 2, respectively. **C:** DCA containing wild taxa against relative chronology. Cumulative explained variation for axis 1 = 15.11%, and for axis 2 = 25.52%. Eigenvalues are 0.3245 and 0.2234 for axis 1 and 2, respectively.

Additional attribute plots investigate the distribution of the frequency of some key taxa. Such attribute plots are intuitive to understand, the bigger the symbol, the higher the frequency of the taxon. First, I look at how the frequency of pigs is distributed through time (Fig. 5.A). Pigs are most abundant from the EBA I through the MBA. However, one sample dating to the IA I shows a large abundance of pigs, this sample is from Tel Miqne/Ekron which is a Philistine site. Pig remains are quite numerous at Philistine sites during the IA I but their numbers decline during the IA II (Faust, 2018; Hesse, 1990, 1986). However, it remains ambiguous whether the frequency of pig remains at a site can be used to determine the ethnicity of the inhabitants of a settlement. Some scholars argue the consumption of pork became a cultural and ethnic marker, once it became associated with people identifying as Philistine (Faust, 2018). Other scholars argue pigs cannot be used as an ethnic marker, since, although the occupants of urban Philistine sites consume pigs during the IA I, people of rural Philistine sites do not (Sapir-Hen, 2019). The correct answer will only be obtained once the faunal remains of more Philistine sites are published. Second, I look at the distribution of camelids through time (Fig. 5.B). The attribute plots show one attestation of camelids at an EBA II sample from Arad. These remains probably belong to a wild camelid (Lernau, 1978). Camelids appear in higher numbers starting from the LBA and are especially frequent during the IA II, as indicated by the greater size of the symbols. This is supported by new faunal evidence, which suggests the first widespread occurrence of camelids developed during the IA II in the Aravah Valley (Sapir-Hen and Ben-Yosef, 2013).
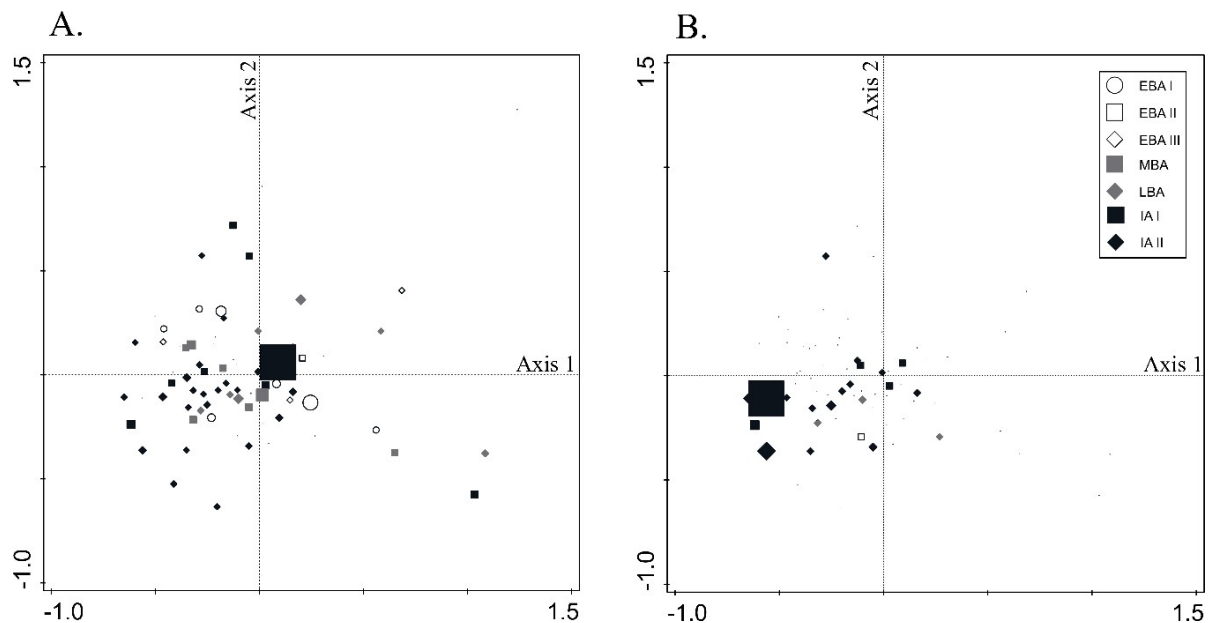

Fig. 5: A: Attribute plot of pigs through time, **B:** attribute plot of camelids through time. Cumulative explained variation for axis 1 = 14.56%, and for axis 2 = 23.94%. Eigenvalues are 0.1686 and 0.1085 for axis 1 and 2, respectively

4.2.2. Mean Annual Precipitation

Next, I look at whether there are changes in the diet of people living in settlements at different MAP zones. I check this using multivariate statistics on datasets containing all faunal taxa, only domesticated taxa, and only wild taxa against the parameter of MAP. Note, the MAP zone of 700 – 800 mm consists of three samples belonging to one site, Kamid el-Loz. This means conclusions drawn from this MAP zone are not to be extrapolated to make general statements on this MAP zone.

The CCA of all taxa against MAP shows there are significant changes in taxonomic composition between sites in different MAP zones, particularly between sites at low and high MAP zones (pseudo-F = 2.9, P = 0.002). In the corresponding CA (fig. 6.A), four clusters of MAP zones can be discerned, which, however, also greatly overlap. Sites located at MAP zones between 200 – 400 mm mostly group towards the negative ends of the first and second axes. They are associated with pig, camelid, zebu and cervid. Sites located in the MAP zone of 400 – 600 mm cluster on the negative side of the first axis and along the second axis. These sites show higher numbers of cervid, marbled polecat, pig, camelid, and zebu. Sites at a MAP zone of 600 – 700 mm plot close to the origin and one outlier plots in the positive part of the first and second axis. The sites near the origin, Tell Kabri and Tell el-Burak, cannot be used to discriminate them from other sites since their taxonomic composition has too much in common with all the other sites. Sidon, however, is characterised by the high frequency of hippopotamus. Finally, samples of sites located at a MAP zone of 700 – 800 mm group on the positive side of the first axis and the negative part of the second axis. These are characterised by their frequencies of mustelid, hyena, horse, red deer, wolf, onager, and wild goat.

The CCA of only domesticated taxa against MAP also shows significant changes in taxonomic composition between sites in different MAP zones (pseudo-F = 2.2, P = 0.006). The CA confirms these differences (fig. 6.B). Sites located in a MAP zone of 200 – 300 mm plot along the first axis and mainly in the positive part of the second axis. These are mainly associated with camelids, zebu, dogs, and donkey. Settlements located in MAP zones between 300 – 400 mm plot heterogeneously and are not characterised by any specific taxa. Sites situated in MAP zones of 400 – 500 mm are mainly situated along the first axis and mainly in the negative part of the second axis. These sites are associated by their frequencies of pig, mule, horse, and onager. Sites at MAP zones between 500 – 700 mm plot mainly in the negative part of the first axis and along the second axis. They are characterised by their frequencies of pig and camelid. Finally, sites located at MAP zones between 700 – 800 mm group in the positive part of the first axis

and the negative part of the second axis. These are mainly associated with high frequencies of onager and horse.

The CCA of only wild taxa against MAP also shows significant changes in taxonomic composition between sites in different MAP zones (pseudo-F = 3.1, P = 0.002). The DCA shows a separation between sites located in zones with higher and lower MAP (fig. 6.C). Samples of sites located in MAP zones between 200 – 300 mm mainly group on the positive side of the first and second axis. These samples are associated with gazelle, fox, hare, and Testudines. Samples located in MAP zones between 300 – 400 mm group heterogeneously, mostly along the second axis. Those situated in MAP zones between 400 – 600 mm group mostly along the first axis. They are associated with a variety of wild taxa. Samples belonging to sites located in MAP zones of 600 – 700 mm are located close to the origin, and one sample, Sidon, plots on the negative side of the first axis and the positive side of the second axis. It is characterised by wild taxa such as aurochs and lion. The three samples of one site, Kamid el-Loz, represent a site in a MAP zone of 700 – 800 mm and are located on the negative part of the first and second axis. They are associated with high frequencies of wild goat, red deer, and bear.

Fig. 6: A: CA containing all faunal taxa against MAP. Cumulative explained variation for axis 1 = 14.56%, and for axis 2 = 23.94%. Eigenvalues are 0.1686 and 0.1085 for axis 1 and 2, respectively. **B:** CA containing domesticated taxa against MAP. Cumulative explained variation for axis 1 = 21.65%, and for axis 2 = 39.15%. Eigenvalues are 0.0990 and 0.0800 for axis 1 and 2, respectively. **C:** DCA containing wild taxa against MAP. Cumulative explained variation for axis 1 = 15.11%, and for axis 2 = 25.52%. Eigenvalues are 0.3245 and 0.2234 for axis 1 and 2, respectively.

Figure 7 expresses the proportion of the taxon over the different MAP zones as pie diagrams. Mules, pigs, ovicaprids, cattle, and zebu all appear in settlements located in zones with low MAP (200 – 400 mm) and have high occurrences at sites in zones of 400 – 500 mm MAP. This seems to contradict the notion that taxa such at cattle and pig should appear at sites with higher MAP since they have high water requirements (Tchernov and Horwitz, 1990). Camelids, usually associated with drier environments, appear most commonly in MAP zones of 500 – 600 mm. Horse and onager appear mostly in zones of higher MAP, 700 – 800 mm. Dogs and donkeys appear in equal proportions in the different MAP zones.
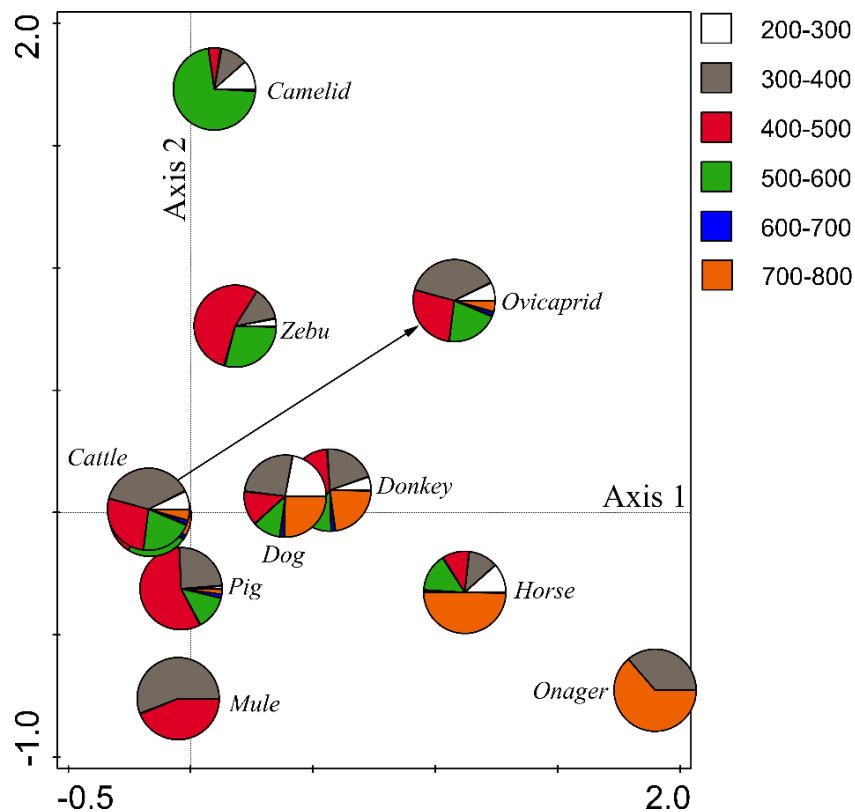
Fig. 7: Representation of the domesticated taxa as pie diagrams, representing the occurrence of the taxa in the different MAP zones. Note that the location of pie diagram for ovicaprids was changed to make it visible. Cumulative explained variation for axis 1 = 21.65%, and for axis 2 = 39.15%. Eigenvalues are 0.0990 and 0.0800 for axis 1 and 2, respectively.

4.2.3. Elevation

Finally, I investigate whether there are changes in the diet of people living in settlements at different elevations. I check this using multivariate statistics on a dataset containing all faunal taxa, only domesticated taxa, and only wild taxa against the parameter of elevation. Note, the two samples at 600 – 700 m elevation belong to one site, Jerusalem, and as such are not representative for this elevation range.

The CCA of all taxa against elevation shows significant changes in taxonomic composition between sites at different elevations (pseudo-F = 1.7, P = 0.004). The CA confirms these changes (fig. 8.A). Sites located at an elevation below sea level mainly plot on the negative part of the first and second axis. These are associated with an abundance of camelid and zebu. Sites at an elevation of 0 – 400 m and 600 – 700 m mainly group on the negative side of the first axis and along the second axis. They are characterised by their frequencies of zebu, camelid, marbled polecat and cervids. There are only two samples belonging to two sites, Nahal Tillah and Tel Halif, at an elevation of 400 – 500 m. Tel Halif plots on the negative part of the first axis and on the second axis and is not characterised by any specific taxa. Tel Halif plots on the positive part of the first axis and the negative part of the second axis. It is associated by its frequencies of gazelle as the only wild taxon. Sites at an elevation of 500 – 600 m and 700 – 800 m mainly group on the negative part of the first and second axis and are associated by their abundance of zebu, camelid, and pig. The sites at an elevation of 900 – 1000 m group on the positive side of the first axis and the negative part of the second axis. These are characterised by their frequencies of wild goat, onager, wolf, red deer, mustelid, and horse.

The CCA of only domesticated taxa against MAP also shows significant changes in taxonomic composition between sites at different elevations (pseudo-F = 1.9, P = 0.004), visible in the corresponding CA biplot (fig. 8.B). Sites at an elevation below sea level plot heterogeneously. Samples of sites at an elevation of 0 – 400 m mainly group along the first axis and on the negative part of the second axis. They are associated by their frequencies of pig, mule, horse, and onager. Two samples of two sites, Nahal Tillah and Tel Halif, are at an elevation of 400 – 500 m. Nahal Tillah plots on the negative side of the first axis and on the second axis, it is not associated with any particular taxa. Tel Halif plots on the positive part of the first axis and on the negative part of the second axis. It is characterised by only having ovicaprids and cattle as domestic taxa, no pigs, suids, or camelids are present. Sites at an elevation of 500 – 600 m plot mainly on the positive side of the first and second axis. These are characterised by their frequencies of camelid and zebu. Sites at an elevation of 600 – 800 m mainly plot on the negative

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part of the first axis and along the second axis. They group due to their frequencies of mule and pig. Sites at an elevation of 900 – 1000 m cluster on the negative side of the first and second axis. They are associated by the presence of horse and onager.

The CCA of only wild taxa against MAP also shows significant changes in taxonomic composition between sites at different elevations (pseudo-F = 1.8, P = 0.002). This is visible in the DCA biplot (fig. 8.C). Sites located below sea level group in the negative part of the first axis and close to the second axis. This does not seem to be driven by the frequency of a specific wild taxon. Samples of sites at an elevation between 0 – 100 m, 400 – 500 m, 700 – 800 m, and 900 – 1000 m plot heterogeneously. Sites at an elevation of 100 – 400 m group mainly on the positive side of the first and second axis. These are characterised by their frequencies of Testudines, gazelle, and cervids. Samples of sites at 500 – 600 m mainly plot on the positive part of the first axis and the negative part of the second axis. These are associated by frequencies of marbled polecat and cervid. Sites at an elevation of 600 – 700 m are located mostly on the positive side of the first and second axis. These are only represented by one site, Jerusalem, and as such is not representative.
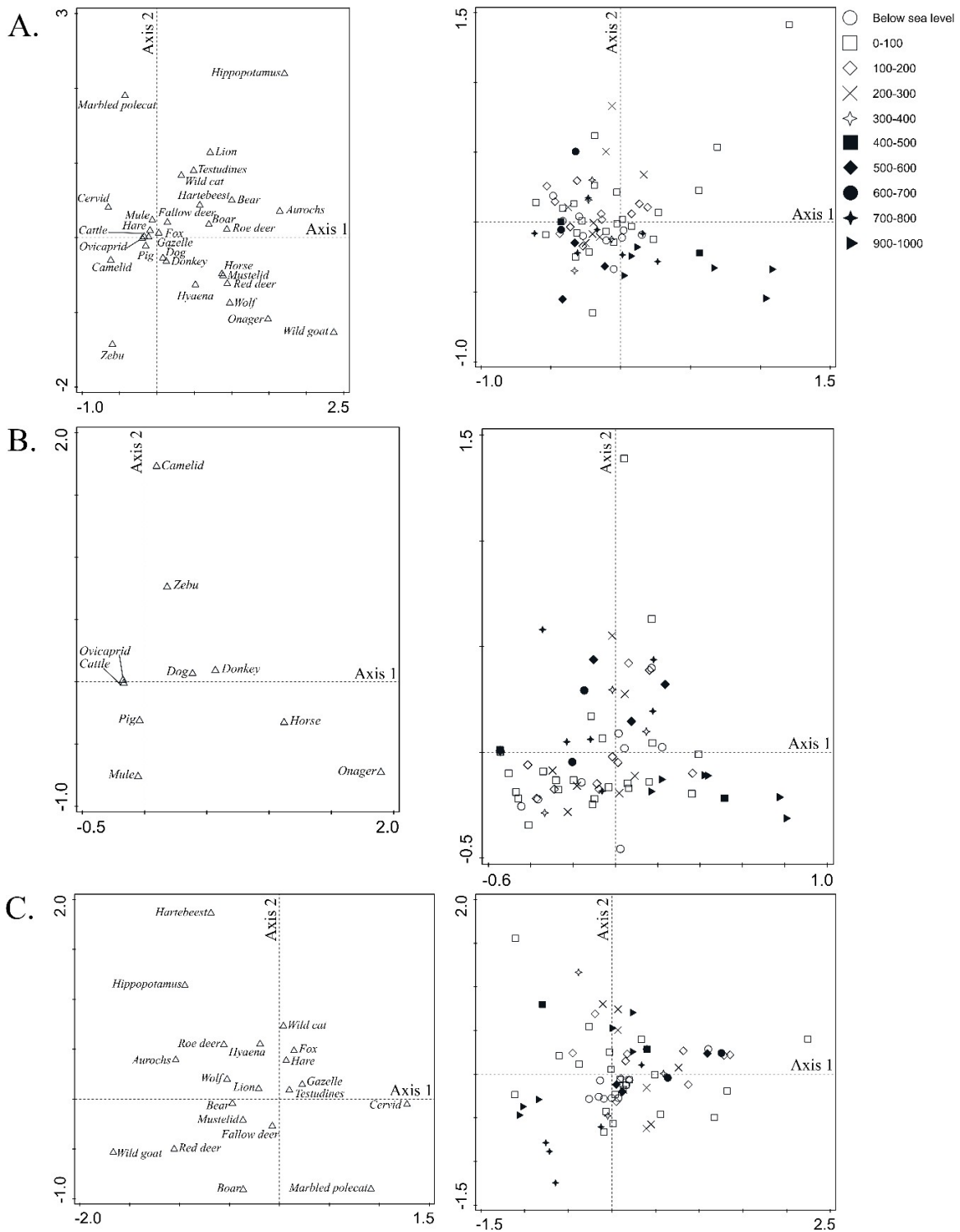
Fig. 8: A: CA containing all faunal taxa against elevation. Cumulative explained variation for axis 1 = 14.56%, and for axis 2 = 23.94%. Eigenvalues are 0.1686 and 0.1085 for axis 1 and 2, respectively. **B:** CA containing domesticated taxa against elevation. Cumulative explained variation for axis 1 = 21.65%, and for axis 2 = 39.15%. Eigenvalues are 0.0990 and 0.0800 for axis 1 and 2, respectively. **C:** DCA containing wild taxa against elevation. Cumulative explained variation for axis 1 = 15.11%, and for axis 2 = 25.52%. Eigenvalues are 0.3245 and 0.2234 for axis 1 and 2, respectively.

4.2.4. Discussion

My results show differences in subsistence composition through time, specifically between the EBA and IA. The EBA samples are associated with a higher occurrence of wild taxa and tend to have higher frequencies of pig. Pig consumption occurs in the southern Levant, but through time their frequency in the animal record decreases, particularly from the LBA onward (Redding, 2015; Sapir-Hen, 2019). Nonetheless, a rise in pork consumption is seen during the IA I which can be attributed to the diet of inhabitants in Philistine urban centres but is largely absent in other sites in the southern Levant (Faust, 2019; Sapir-Hen, 2019). This trend is confirmed by the attribute plots representing the frequency of pig through time. The IA samples are characterised by the presence of zebu cattle and camelids. Camelids and specifically dromedaries (*Camelus dromedarius)* were introduced in the southern Levant towards the end of the tenth century BCE but became more common starting in the IA II (Sapir-Hen and Ben-Yosef, 2013). This is reflected in the attribute plots showing the abundance of camelids through time. Generally, the IA samples tend to have a lower frequency of wild taxa than the BA samples. Note the main domesticates (i.e., ovicaprids, cattle, and pigs) tend to plot close to the origin of the biplot. These taxa, especially ovicaprids, appear in all samples and their frequencies do not differ enough between samples to be a discriminating factor. However, faunal analyses have noticed a diachronic change in the ovicaprid to cattle ratio (Gaastra et al., 2020; Sapir-Hen, et al., 2014; Sasson, 2016, 2008; Tchernov and Horwitz, 1990), so why is this not visible in the CA? The changes in ovicaprid to cattle ratio are probably too small or/and too inconsistent to be picked up by the CA and CCA biplots. Another study showed the difference between consumption patterns between rural and urban settlement from the EBA through the MBA by looking at mortality profiles of ovicaprids (Gaastra et al., 2020). This highlights benefits of exploring diachronic changes in animal-based subsistence by combining several methods.

Analysing the taxonomic composition of sites at different MAP zones recognises differences between sites located in lower and higher MAP zones. The diet of the people at sites in lower MAP zones (200 – 400 mm) are associated with pig, camelid, zebu, fox, hare, and cervids. Although taxa such as camelid and fox are well-adapted to arid environments, especially taxa such as pig are thought to have high water requirements (Tchernov and Horwitz, 1990). Indeed, the representation of the domesticated taxa as pie diagrams, showing the distribution of the domesticates over the various MAP zones confirms this. Mules, pigs, ovicaprids, zebu, and cattle all are common in these lower MAP zones. During the BA and IA people inhabiting the southern Levant would have used irrigation, aquifers, and other water sources to fulfil their water needs and those of their animals (Pustovoytov and Riehl, 2016; Vermeersch et al., 2021a).

The diet of occupants at sites in a higher MAP zone (600 – 800 mm) is characterised by their frequencies of, among others, horse, onager, and many wild taxa including boar, red deer, and bear. These wild taxa typically inhabit forests, wetlands, and grasslands and as such have higher water requirements (Boitani et al., 2010; Keuling and Leus, 2019; Lovari et al., 2019). The pie diagrams show that although camelids are associated with low MAP zones, they appear most frequently in MAP zones of 500 – 600 mm. This can be explained by the fact that camelids were frequently used as pack animals, for agricultural practices, and in trade starting from the IA I (Sapir-Hen and Ben-Yosef, 2013), which would have brought them far outside their natural habitat. The sample where the frequency of camelids is highest, the IA I sample of 'Izbet Sartah, is situated in a MAP zone of 500 – 600 mm. The faunal report said most of these camelids, which are represented by domestic dromedary, would have died of natural causes and were not slaughtered (Hellwing and Adjeman, 1986). Instead, they would have been used as a beast of burden, and to plough fields (B. Rosen, 1986). Horses and onagers appear most frequently at sites in higher zones of MAP (700 – 800 mm), although for what reason is not clear. Animals such as dogs and donkeys appear in almost equal frequencies throughout the different MAP zones, which is unsurprising, since pictorial and literary sources attest to that the donkey was used means of transportation in the southern Levant, and to the importance of donkey caravans for trade (Grigson, 2012). The discrepancies at times between the water requirements of animals and the sites at where they appear most frequently, shows the importance of not only considering environmental factors when trying to explain changes in subsistence strategies but also to take the socio-economic background into account.

Finally, I examine whether diet changes between sites at different elevations and see a difference between the taxonomic composition of sites located at lower and higher elevations in general, although this difference is not as clear as the differences through time or in different MAP zones. The diet of people at sites on a lower elevation (below sea level – 400 m) tend to be associated with ovicaprids, cattle, pig, horse, camelid, zebu, marbled polecat and cervids. Sites at a higher elevation (900 – 1000 m) are typically associated with wild goat, onager, wolf, red deer, mustelid, and horse. Taxa which have higher water requirements, such as cattle, pig, and horse, appear at lower elevation ranges since these will be closer to water sources. But besides this, it is hard to explain why taxonomic abundance changes through different elevation. Probably because there are more factors at play here than can be understood by merely looking at elevation. In the future, stable strontium isotope analysis or detailed GIS studies should allow for a better understanding for this phenomenon.

4.3. Developments in Animal- and Plant-Based Subsistence

The integrative dataset consists of 15 sites represented by 24 samples, having a total of 21 faunal taxa (36,626 specimens) and 111 botanical taxa (199,669 specimens). I use the criteria outlined in section '3.2. Multivariate Statistics' to create the dataset. Unlike the faunal dataset, I do not apply a specimen threshold for the faunal specimens here to obtain a higher sample size for integration nor do I restrict the samples to unmixed time periods. The references for these samples, along with the distribution of the parameters can be found in Vermeersch et al. (2021a), table 1 and 3, respectively. A map showing the location of sites used for integration can be found in figure 9.

The results and discussion for the integrative analysis have been published in-depth in Vermeersch et al. (2021a). In this dissertation, I will discuss the major trends which were observed but refer to this paper for a more in-depth discussion.

4.3.1. Chronology

The CCA of all taxa against relative chronology indicates no chronological differences in subsistence composition (pseudo-F = 0.9, P = 0.666). A visual inspection of the corresponding CA, however, does show some diachronic trends (see SI 2.8 of Vermeersch et al. [2021a]). EBA and MBA samples mainly plot on the positive side of the first and second axis. These samples are associated with high frequencies of the main livestock species (pig, cattle, and ovicaprid) but also gazelle, donkey, dog, and roe deer. The botanical taxa characteristic for these samples include garden pea, glume wheat, lentil, and wild pistachio. LBA samples plot heterogeneously. IA samples are mainly found in the positive part of the first axis and the negative part of the second axis. These IA samples are associated with red deer, boar, felids, fallow deer, free-threshing wheat, flax, pomegranate, grape, and bitter vetch. Samples from multi-period sites group per site.

The CCA of only domesticated taxa against relative chronology indicates no clear chronological differences in subsistence composition (pseudo-F = 0.8, P = 0.782). Yet, the CA (see fig. 10 of Vermeersch et al. [2021a]) shows similar trends like the integrative dataset containing all taxa, with EBA and MBA samples plotting separately from LBA and IA samples. The EBA and MBA samples are associated with cattle, pig, ovicaprid, donkey, dog, and glume wheat. The LBA and IA samples are characterised by higher frequencies of horse, free-threshing wheat, pomegranate, flax, broad bean, bitter vetch, and grape.

Fig. 9: Map of the southern Levant showing the sites used for integrating archaeological botanical and faunal remains.

The CCA of only wild taxa against relative chronology indicates no clear chronological differences in subsistence composition (pseudo-F = 0.9, P = 0.602). The DCA of wild taxa against relative chronology (see SI 2.9 of Vermeersch et al. [2021a]) shows the weakest trends of all integrative datasets with chronology but once again a similar pattern can be seen. EBA and MBA samples are associated by their proportions of gazelle, leporids, and roe deer. The IA samples are characterised by *Scirpus* spp., Cyperaceae, *Rumex* sp., *Phalaris* sp., and some halophytes.

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4.3.2. Mean Annual Precipitation

The CCA of all taxa against MAP shows there are differences in taxa composition in different zones of MAP (pseudo-F = 2.0, P = 0.002). The CA (see fig. 11 of Vermeersch et al. [2021a]) of all taxa against MAP shows three clusters: 200 – 400 mm, 400 – 600 mm, and 600 – 700 mm. Samples of the sites belonging to the MAP zone of 200 – 400 mm are associated with horse, gazelle, donkey, roe deer, dromedary, barley, and olive. Samples in this MAP zone dating to the EBA are also characterised by glume wheat. Samples in a MAP zone of 400 – 600 mm are associated with similar faunal taxa, gazelle, donkey, roe deer, fallow deer, red deer, boar, and dromedary. These sites also show higher frequencies of broad bean, free-threshing wheat, pomegranate and grape. Only one sample is in the MAP zone of 600 – 700 mm, Sidon, which has a low diversity and low seed counts, so this should not be considered a representative sample for this MAP zone.

The CCA of only domesticated taxa against MAP shows there are no differences in domesticated taxa composition in different zones of MAP (pseudo-F = 1.3, P = 0.1). The corresponding CA does not show clear trends (see SI 2.10 of Vermeersch et al. [2021a]). It is possible to see a weak trend in the samples of the 500 – 600 mm MAP zone. Here, samples are divided into two groups, one consisting of four samples from Megiddo, the other consisting of two samples from Shiloh and three samples from Aphek. The first group is associated with donkey, dog, dromedary, and wheat. The latter group is characterised by free-threshing wheat, barley, and grape.

The CCA of only wild taxa against MAP shows there are significant differences in taxa composition in different zones of MAP (pseudo-F = 2.2, P = 0.002). The DCA of wild taxa against MAP (see SI 2.12 of Vermeersch et al. [2021a]) shows similar trends to the CA of all taxa against MAP, although not as clear. Samples of sites in MAP zone of 200 – 400 mm plot separately from those between 400 – 600 mm. It is possible to see two groups within the 500 – 600 mm MAP zone, as it appeared in the dataset containing only domesticated taxa. Only one sample of one site lies in a MAP zone of 600 – 700 mm and is not representative.

4.3.3. Elevation

The CCA of all taxa against elevation shows there are differences in subsistence composition between different elevation ranges (pseudo-F = 1.7, P = 0.002). The CA of all taxa against elevation (see fig. 12 of Vermeersch et al. [2021a]]) shows samples of sites at an elevation of 100 – 200 m and 700 – 800 m group together and are associated by the main domesticates,

gazelle, dog, dromedary, Testudines, and red deer. The sites at 700 – 800 m are characterised by grape and olive.

The CCA of only domesticated taxa against the parameter of elevation shows there are differences in subsistence composition between different elevation ranges (pseudo-F = 2.0, P = 0.002). The CA of domesticated taxa against elevation (see SI 2.13 of Vermeersch et al. [2021a]) shows samples of site at an elevation of 0 – 100 m plotting on the positive side of the first axis and the negative side of the second axis. These samples are associated with cultivated plants which need higher precipitation. Animals such as cattle and pig, which have higher water requirements, are closely linked to these elevations. The second group of samples are those belonging to sites at an elevation of 500 – 600 m, plotting on the positive side of the first and second axis. These samples are characterised by botanical taxa such as einkorn and emmer.

The CCA of only wild taxa against elevation shows there are differences in subsistence composition between different elevation ranges (pseudo-F = 1.4, P = 0.042). The DCA of wild taxa against elevation (see SI 2.14 of Vermeersch et al. [2021a]) shows similar trends like the previous datasets concerning elevation. Samples of sites at an elevation of 0 – 100 m are characterised by fox, Asparagaceae, halophytes, *Plantago* sp., *Ranunculus* sp., and chaste tree. Samples of sites at an elevation of 500 – 600 m are characterised by Fabaceae and Poaceae.

The representation of domesticated taxa as pie diagrams expressing MAP zones shows additional trends, especially regarding botanical taxa (see fig. SI 2.11 of Vermeersch et al. [2021a]). Here, free-threshing wheat appears almost only at sites in the 500 – 600 mm MAP zone, whereas pomegranate and grass pea are most frequent at settlements in the 400 – 500 mm MAP zone. Glume wheats appear in drier zones and are most frequent at settlements in the 300 – 400 mm MAP zone.

4.3.4. Discussion

It is possible to see diachronic differences in subsistence composition, especially between the samples of the EBA and MBA, and the IA samples. The LBA samples plot heterogeneously in the CA but tend to plot closer to the IA samples. These differences correspond to the social and economic changes occurring during these periods. The EBA and MBA samples are associated with the main domesticates, gazelle, donkey, glume wheat, emmer, lentil, and garden pea. The presence of such taxonomic diversity is characteristic of the mixed agropastoral economy which would have prevailed during these periods. The frequency of pig and emmer is highest in these earlier periods as well and indicate distinct culinary choices of these societies. As already noted in '4.1.4. Discussion' of the faunal dataset, pigs appear in higher numbers during the EBA and MBA and lose their importance in local diets from the LBA onward. The frequency of grape is highest during the LBA, which coincides with the dominance of Ancient Egypt in the region during this time. Egyptian rule is also reflected by agricultural surplus production due to the Egyptian tribute system and the export of wine to Egypt. The IA samples are characterised by free-threshing wheat, bitter vetch, flax, fig, and pomegranate, suggesting the importance of fruit cultivation. The shift to free-threshing wheat from emmer in the IA is important to note, although emmer is still cultivated in small quantities during this time, most likely to export to Ancient Egypt where emmer was an important staple for beer and bread production. In the dataset against the parameter chronology, there is a trend where samples belonging to multi-period sites group per site, but these too show a difference between EBA/MBA samples and LBA/IA samples.

Some differences can be seen between the different MAP zones, especially between MAP zones of higher and lower precipitation. Animal taxa that are arid-resistant such as ovicaprid and camelids and water-dependent taxa such as cattle and pig appear together at many samples, suggesting their presence at sites is not only dependent on environmental factors as already discussed in section 4.2.4.

There is a difference between sites located at a different elevation, specifically between sites at a higher (500 – 600 m) and lower (0 – 100 m) elevation. Animal and plant taxa that need more moisture tend to be found at lower elevations. This makes sense since lower elevations will have more access to water sources. At present, it is not possible to explain the differences between the taxonomic composition of sites at different elevations by just looking at the abundance data of taxa. To understand this difference, other analyses are necessary, as discussed in section 4.2.4.

I should note that integrating archaeological faunal and botanical remains does not come without its issues (Vermeersch et al., 2021a). A basic problem lies within the very nature of the remains themselves. NISP is the measure of abundance I use for the faunal remains and represents animal bone fragments, which in turn represent fragments of a particular skeletal element of an animal. Due to this, it is possible to reconstruct MNI (Grayson, 1984; Lyman, 2008). However, although seed count is also a measure of abundance, these botanical remains only represent specific parts of reproduction units of an unknown entity. This means it is not possible to reconstruct a minimum number of plant individuals based on seed count. For seed counts to be completely analogous to NISP, this difference would need to be addressed and solved, for example, by creating a conversion factor to calculate the minimum number of plants represented by seed count (Jacomet et al., 1989). The next issue lies in what the faunal and botanical remains represent of the archaeological record. Faunal and botanical remains usually represent cooking or household refuse, and botanical remains can be found in storage contexts. However, botanical remains, as opposed to faunal remains, usually do not reflect foodstuffs that went through the human digestive system, unless in rare preservation contexts of faeces or gut contents. Another, inherent issue of the disciplines, is the completeness of taxonomic representation. Reports of botanical remains from archaeological sites will usually entail all wild and domesticated taxa found at the site. Faunal remains of a site are often published in several reports, some concentrating on the macrofauna, whilst others report specifically on the marine fauna, the microfauna, or the avifauna. Besides this, quite often fish and bird remains are not published, because excavators did not screen to obtain these remains. Since botanical remains will include higher frequencies of diverse wild plant taxa, the botanical remains will be able to provide a stronger signal for environmental effects. Finally, the datasets showed samples of multi-period sites grouped per site, which calls for caution. Sometimes, such grouping can be introduced by excavators or analysts. Excavators could have had difficulties interpreting the stratigraphy of the site of analysts could have dealt with challenges in the laboratory process.

Finally, I want to emphasise that the integrative analyses confirm the trends observed in the dataset containing only faunal remains. This validates that the trends in the faunal dataset match general agricultural developments. Due to the smaller sample size, and the mutually exclusive factors of the different data types represented by faunal and botanical remains, the observed trends are weaker in the integrated dataset. However, the integrative analyses have the merit of proving that animal and crop husbandry strategies are equally influenced by parameters such as precipitation and socio-cultural developments, allowing us to arrive at more holistic conclusions about past farming systems.

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Chapter 5: Conclusion

My dissertation seeks to study the developments in subsistence from the EBA through the IA, during which many socio-economic, political, and environmental changes happen. I accomplish this in three steps: 1) traditional zooarchaeological analysis of Tell Lachish and Tell el-Burak, 2) establishing a reference database consisting of faunal abundance data from the EBA through the IA in the southern Levant, and 3) using multivariate statistics to explore trends in animal-based subsistence and to integrate faunal and botanical remains to study developments in subsistence from the EBA through the IA in the southern Levant. These analyses show clear trends in subsistence practices and diet due to socio-cultural and environmental changes in the southern Levant from the EBA through the IA.

During the EBA and MBA, animal-based subsistence is associated with higher numbers of pig and wild taxa, whereas diet during the LBA and IA is characterised by the higher frequencies of zebu and camelids. Pigs are consumed in larger quantities during these earlier periods and starting from the LBA their importance to the diet of people in the southern Levant diminishes. There are exceptions to this, for example, during the IA I pigs are consumed frequently in urban Philistine sites, whereas pig consumption is avoided in most other settlement. A higher presence of camelids during the LBA and IA can be explained by their introduction to the southern Levant during the end of the tenth century BCE. The abundance of ovicaprid and cattle at sites is not a good criterion to recognise large-scale changes in the diet through time. This needs to be done through other measures, such as mortality profiles. However, there is a lot of inconsistency in establishing mortality profiles between faunal analysts, so establishing such a review would require further study and standardisation of these data. The mortality profiles I constructed for ovicaprids at Tell Lachish, show inhabitants engaged in an economy focussing on secondary products during the IA II, with flocks consisted of more sheep than goats. The climate during the IA II would have been moister, and a higher water availability is suggested by stable carbon isotope analysis performed on botanical remains and the presence of many grape pip and flax remains at sites in the regions. During this time, the Neo-Assyrian Empire dominated the region, and they took sheep as a tax commodity from the local people, which could have spiked the increase in sheep compared to goats in these regions. On the other hand, the inhabitants of Tell el-Burak practiced a mixed economy, and flocks contained more goats than sheep. However, it is suggested the Neo-Assyrians allowed the Phoenicians to continue their trade without too many restrictions, since they profited more from taxing the trade. I also see differences between

lower and higher zones of MAP. The diet of people at sites located in lower MAP zones are associated with mules, pigs, ovicaprids, cattle, and zebu. Although most of these taxa are usually associated with having high water requirements, the use of water sources, irrigation, and aquifers would have allowed people to keep these animals in less ideal environments. Camelids appear most frequently in a MAP zone of 500 – 600 mm, probably due to the rise in using these animals for labour and in trade. Horses and onagers occur most often in higher MAP zones, but the reason for this is not clear. Dogs and donkeys appear in all MAP zones, the latter being important as an animal of transportation and labour throughout time, as attested by donkey caravans. My analysis of taxonomic abundance in different zones of MAP highlights the importance of investigating changes in subsistence by not only looking at environmental factors, but also by considering the socio-economic and political background. I see a different in diet of people at sites at lower and higher elevations. Taxa appearing most frequently at sites at lower elevations, such as ovicaprids, cattle, pig, and horse, can be explained by the proximity of water sources at lower elevations. Otherwise, the changes in subsistence between different elevations is difficult to explain and will require further study which uses different methods, such as stable isotope analysis and detailed GIS studies.

The trends seen in the integrated dataset confirm those of the individual faunal analyses and allow for a more holistic view of subsistence and agricultural practices from the EBA through the IA II in the southern Levant. Once again, differences in diet through time can be observed. During the EBA and MBA, a large taxonomic diversity can be seen in the diet, indicative of a mixed agropastoral economy. The diet of people during this time is associated with high frequencies of pig, gazelle, donkey, glume wheat, lentil, and garden pea. During the LBA, there is a high abundance of grape caused by the influence of Ancient Egypt in this region. Besides an interest in Levantine wine, Ancient Egypt also caused agricultural surplus in the region to keep up with the tribute system. The subsistence practices of people during the IA is associated with large numbers of camelids, free-threshing wheat, bitter vetch, grass pea, broad bean, flax, fig, and pomegranate. An important development here is the shift from emmer, which was most common during the EBA, to free-threshing wheat in the IA. Emmer still is cultivated in small quantities during the IA, probably to export to Ancient Egypt where emmer was an important staple for beer and bread production. There are differences between the diet at higher and lower MAP zones. Aridity-adapted and water-dependent faunal and botanical taxa appear together at most sites, suggesting irrigation practices, trade, or pastoral mobility uncouple many resources from their original habitats. The diet of people at lower and higher elevation ranges also differs,

with moisture-dependent taxa being more frequent at sites on a lower elevation since these will be closer to water sources.

My dissertation shows it is possible to determine trends in subsistence through time in the southern Levant. I demonstrate the merit of using multivariate statistics for integrative analysis, especially when considering known, independent variables such as chronology, MAP, and elevation. My integrative analyses allow a holistic reconstruction of subsistence patterns and consider animal and crop husbandry as equally important and interlinked aspects of past farming societies. My results clearly show that subsistence developments are determined by multiple factors including politics, economy, environment, and culture. These changes take place in a dynamic environment consisting of regional and supra-regional relationships, expressed by trade and exchange of ideas. This dissertation provides a first large-scale and integrative synthesis of the entanglements of economic developments and dietary choices with major political and social processes from the EBA through the IA in the southern Levant.

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Appendix 1

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Developments in subsistence during the Early Bronze Age through the Iron Age in the southern and central Levant: Integration of faunal and botanical remains using multivariate statistics.

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Abstract:

Subsistence patterns during the Early Bronze Age I through the Iron Age II (3,600-586 BCE) are the topic of many archaeobotanical and zooarchaeological studies. The results of these two disciplines are usually published separately, depriving us of an all-encompassing view of subsistence and agriculture during this time period since people did not solely make use of animal or plant products. In this paper, our goal is to integrate faunal and botanical lines of evidence and study developments in subsistence using multivariate statistics. By analysing individual and integrated datasets of botanical and faunal remains, we aim to better understand the role of diverse variables, such as chronology, mean annual precipitation, and elevation within the composition of our datasets. We see chronological differences, a distinction between sites at higher (400-600mm) and lower (200-400mm) precipitation ranges and differences between sites at different elevations (0-100m and 500-600m). We also highlight methodological issues intrinsic to differences in genesis and quantification of archaeobotanical and zooarchaeological datasets. We conclude that to obtain a complete understanding of subsistence during the Bronze and Iron Age in the Southern Levant, archaeobotanists and zooarchaeologists need to work on integrating their data on a site-specific level. This will allow us to obtain a holistic understanding of subsistence and agricultural practices on both a site and regional level and allow us to develop a stronger framework for understanding social and political developments that occurred during these time periods.

Keywords: Holocene, Near East, Levant, Bronze Age, Iron Age, subsistence

1. Introduction

Understanding the cultural and natural foundations of subsistence strategies during the Bronze and Iron Ages (3,600-586 BCE) in the southern and central Levant is of major interest to archaeologists, making archaeobotanical and zooarchaeological studies essential. Specifically, researchers are interested in topics such as animal husbandry practices (e.g. Allentuck, 2013; Gaastra et al., 2020; Horwitz, 1989; Redding, 1984; Sasson, 2010, 2008), crop cultivation practices (e.g. Orendi and Deckers, 2018; Weiss and Kislev, 2004), the relationship between important domesticates and environmental circumstances (Gaastra et al., 2019; Riehl, 2009a, 2012; Sapir-Hen, et al., 2014), and more specific questions such as the origins of the pig taboo and the consumption of pigs and by whom (e.g. Faust, 2018; Hesse, 1990; Price and Evin, 2019; Redding, 2015; Sapir-Hen, 2019a; Sapir-Hen et al., 2013). Not only do such studies help us gain knowledge of past subsistence practices, they are also considered an important factor for social and political developments (Fall et al., 1998; Zeder, 1988). Individual faunal or botanical reports provide us with in-depth knowledge on the developments in subsistence within a site, and sometimes these results are placed against a regional background. Occasionally, we find syntheses concentrating on the diachronic developments within animal husbandry (Gaastra et al., 2020; Sapir-Hen, et al., 2014; Sasson, 2008), but archaeobotanical works on the diachronic development of crop cultivation are virtually non-existent for the Levant and can only be conducted by comparing site-specific analyses. Although reports on either plant or faunal remains advance our knowledge in the individual fields, they only provide a one-sided picture of subsistence practices. After all, applied to socio-cultural developments, the separation between animal husbandry and crop cultivation in the archaeological record is arbitrary and based on methodological aspects in the different scientific disciplines, rather than on historical subsistence practices. Subsistence implies a strong link between plants and animals, and only by studying them both together can we truly gain a deeper understanding of past economies. Fortunately, in

recent years, scholars have undertaken some work to develop methods to integrate zooarchaeological and archaeobotanical data (VanDerwarker and Peres, 2010). Several reports have used different methods ranging from ubiquity data to multivariate analyses to gain a more complete view of subsistence strategies (e.g. Miller et al., 2009; Smith and Munro, 2009; Twiss et al., 2009), demonstrating the merit of a truly interdisciplinary approach.

In this study, we investigate developments in subsistence from the Early Bronze Age I through Iron Age II in the southern and central Levant. We do this by analysing archaeological and environmental variables using multivariate statistics. By analysing botanical and faunal datasets in isolation and as an integrated unit, we hope to see patterns that are reflective of real changes in subsistence practices that we might overlook by considering the data separately. We explore the data using several variables: chronology, mean annual precipitation, and elevation.

1.2. Background to research

During the Bronze and Iron Ages in the southern and central Levant, major socio-economic and cultural changes occur, often related to agriculture and animal husbandry. Among these changes we see the first development of complex urban-based settlements (de Miroschedji, 2014; Genz, 2014; Richard, 2014), of which agriculture was of key importance (Butzer, 1996). Agriculture consists of crop cultivation and animal husbandry; these two activities are not only complementary, but also interdependent (Bogaard, 2005; Butzer, 1996) and affect social and political developments (Butzer, 1997; Fall et al., 1998; Zeder, 1988).

Towards the end of a long and multifaceted process during the Early Bronze Age I (EBA I; 3,600-3,000BCE) we see the appearance of large, fortified settlements, and the development of a complex and hierarchised society. This continues to evolve through the EBA II and III (3,000-2,400BCE), when settlements show the development of monumental architecture, and the mobility of people increases. We see a mixed agropastoral economy which is based on agriculture, horticulture, and animal husbandry (Kamlah and Riehl, 2020). The plough is probably introduced around this time as a pivotal agricultural innovation which facilitated urban development. During the EBA I, we see a strong Egyptian presence in the southwestern part of the southern Levant making use of the rich agricultural resources in this region. On a smaller scale the Egyptian presence here continues during the EBA II-III. The EBA IV (2,400-2,000BCE) witnesses a return to regionalism (Kamlah, 2001), which can be seen, for example, by small-scale family-based production (de Miroschedji, 2014; Falconer and Fall, 2019; Prag, 2014; Richard, 2020, 2003, 1987).

The beginning of the Middle Bronze Age (MBA; 2,000-1,550BCE) is characterized by a wave of re-urbanisation, which is accompanied by the reappearance of massive fortification systems, palaces, and public structures. Re-urbanisation occurs with a strong intensification of non-local influences, especially from Syria and the northern Levant. However, the profound cultural changes in the central and southern Levant cannot be explained by mono-causal theories based on population change (Burke, 2014; Cohen, 2014). With the foundation of the new cities, new patterns of interaction between urban and rural sites develop (Cohen, 2014). Faunal research shows that once regional hierarchies and institutions are present, there is a difference in domesticate composition between rural and urban settlements during the EBA and MBA (Gaastra et al., 2020). Urban sites tend to have a greater proportion of cattle relative to rural sites, and we see a difference in mortality profiles between urban and rural sites, the former mainly containing subadult ovicaprids and the latter adults. Besides this, we also see a relationship between the urban-consumer sites and the rural-producer sites (Gaastra et al., 2020).

During the Late Bronze Age (LBA; 1,550-1,200BCE) the region is under Egyptian dominance, and the city-states of the central and southern Levant belong to the Egyptian provinces 'Canaan' and 'Upe' (Mumford, 2014; Panitz-Cohen, 2014). Even if details of the Egyptian tribute systems remain unknown, we can hypothesize that agricultural products constituted an important part of the tributes retrieved by Egypt. In general, the LBA is a period of strong inter-regional exchange. The prosperity of the region increases during the MBA and continues in the first half of the LBA. In contrast, the final phase of the LBA is a period of gradual decline, and its end which is seen as a sudden 'collapse' by traditional scholarship is part of a far-reaching and large-scale transition (Knapp and Manning, 2016; Millek, 2019).

As part of the transition, and to a small extent as a result of migration processes, the formation of new identities evolves during the Iron Age I (IA I; 1,200-975BCE), among which are the Phoenicians, Philistines, Israelites, Arameans, Ammonites, Moabites and Edomites. During this period, the Egyptian hegemony ends, which, together

with the end of the Hittite Empire, provides space for new developments (Killebrew, 2014; Levy and Holl, 2002). Most noticeably, a new rural village culture, characterized by small-scale and family-based subsistence agriculture, arises in the inland hill countries of the southern Levant.

Finally, the Iron Age II (IA II; 975-586BCE) witnesses the creation of a new political order in the southern Levant: kingships with a royal residence city and with a certain territory, (i.e., the so-called monarchic territorial states). Southern Levantine kingships, among them the Israelite and the Judean monarchy, are relatively small, and their economy depended on a tax income consisting mainly of agricultural products. These kingdoms therefore demanded an agricultural surplus production from their population, although as far as we can see it was not extensive. In contrast to the new territorial states, the old Levantine city state system continues to exist in Philistia and Phoenicia during the IA II. The Phoenician cities along the coast in the central Levant establish maritime networks of trade and extend their cultural influence in the neighbouring areas (among them the kingdom of Israel) as well as in the Mediterranean. During the IA II, the Neo-Assyrian empire gradually dominates the area and conquers parts of it. The Assyrians influence the agricultural production of the southern Levant for the benefit of their own economy. Examples of this are olive oil production (Ben-Shlomo, 2014) and animal husbandry practices with the aim of keeping sheep for secondary products which could be transported and taxed (Finkelstein, 1999; Postgate, 1974).

In addition to the economic aspects of agriculture, cultural and religious aspects are relevant for animal husbandry. The LBA and IA are at the centre for the discussion on the association of the consumption/avoidance of pigs with regard to cultural identity (Faust, 2018; Sapir-Hen et al., 2015; Sapir-Hen, 2019a), and the origins of the pig taboo (Harris, 2012; Hesse, 1990; Miller, 1990; Redding, 2015; Sapir-Hen et al., 2013; van Wyk, 2014).

1.3 Holistic research

Examples of holistic research on plant and faunal remains in the central and southern Levant are rare (Smith and Munro, 2009), which is probably due to the methodological issues that come when integrating different lines of evidence (VanDerwarker and Peres, 2010). Understanding how faunal and botanical remains interplay will not only lead to a better understanding of past subsistence and agriculture, but will allow us to provide a better framework in which the sociocultural and political developments took place in the southern and central Levant.

Our analysis focuses on three variables: chronology, mean annual precipitation and elevation. Considering the many discussions about the chronology of different phases in the region (Finkelstein and Piasetzky, 2011; Mazar, 2005; Regev et al., 2014), we follow Kamlah and Riehl (in press), which is based on the chronological summary by Sharon (2014). By looking at our data chronologically, we want to see whether there are diachronic differences from the EBA through the IA, and what historical or environmental factors cause these differences. To date, most faunal syntheses have focused on sheep:goat or ovicaprid:cattle ratios, along with the presence of pig (Gaastra et al., 2020; Sapir-Hen, et al., 2014; Sasson, 2008; Tchernov and Horwitz, 1990), and very seldom are other taxa taken into account (Smith and Munro, 2009). By including other taxa, we hope to see to what extent hunting played a role in the diet, and whether hunting patterns change throughout time. As mentioned previously, agricultural syntheses regarding the botanical material are not available for the southern and central Levant.

In addition to chronology, we chose to analyse mean annual precipitation and elevation due to the highly diverse climatological and topographical conditions present in the southern and central Levant, which supposedly influenced agricultural strategies on a local and regional level. Climate (and by default precipitation) tends to be raised as a possible determinant when considering what could have caused periods of reduction of settlement sizes or abandonment in the southern and central Levant, although scholars have not reached a consensus on this topic (Finkelstein and Langgut, 2014; Issar and Zohar, 2007; Langgut et al., 2013). Typically, during periods of profound change, we see a return to regionalism and more family-based production (Drake, 2012; Finkelstein and Langgut, 2014; Kaniewski et al., 2019; Langgut et al., 2013).

Finally, we investigate elevation to see whether there are differences in taxonomic composition since certain taxa are better suited to different elevation ranges than others. For example, farmers keep pigs differently than ovicaprids, which are often herded on a seasonal basis (Bartosiewicz, 1999; Levy, 1983). Higher elevation settlements might also have different levels of accessibility, so we might expect them to have lower species diversity if they are not well-connected to other regions through active trade networks.

2. Methods

2.1. Data selection and preparation

To obtain our data, we reviewed the zooarchaeological and archaeobotanical literature on EBA through IA sites situated in the southern and central Levant published through the end of 2019. Our final dataset contains 73 sites represented by 158 samples. We use the term sample as all the botanical or faunal remains dating to one time period of one site, for example, all the faunal remains dating to the IA I from Aphek represent one sample. We created three datasets for our analyses: 1) all botanical remains, 2) all faunal remains, and 3) integrated data, which combines botanical and faunal remains. The faunal dataset contains 53 sites represented by 87 samples and 271,846 specimens and the botanical dataset contains 36 sites represented by 71 samples and 1,384,291 specimens (see table 1). We only use published reports with abundance values. When a site has several contexts published separately or multiple reports published for the same time period, we merge these. Besides this, different analysts identify specimens to different taxonomic levels or use different names to identify the same species. We attempt to minimise this effect by broadening taxonomic categories, for example we categorize *Gazella gazella*, *Gazella dorcas* and *Gazella subgutturosa* as *Gazella* species. For both the botanical and faunal data we impose a 5% threshold for the presence of species in all samples (Gauch, 1982) since rare species can make the biplot difficult to interpret. For the faunal material, we only include mammals, except for Chelonia (turtles, tortoises, and terrapins), since fish, molluscs, amphibians, microfauna and birds have not always been consistently retrieved and recorded. We merge sheep (*Ovis aries*) and goat (*Capra hircus*) into one taxon: ovicaprid. Although the ratio between sheep and goat is important for understanding animal husbandry practices, not all faunal analysts distinguish between the two (24 of our 87 faunal samples do not differentiate between sheep and goat). For the dataset containing all faunal remains, we analyse several CA plots with different NISP thresholds in 100 NISP increments. We find that a threshold of 500 NISP eliminates samples with too little data, while still maintaining visible trends in the data. We modify the dataset containing botanical remains by only using samples with at least ten different taxa and reaching an abundance in seed records of at least 100.

Table 1: Sites used for our analyses with an indication of presence for archaeobotanical (AB) and zooarchaeological (ZA) remains, and references we used to establish our dataset.

Site	AB	ZA	Reference
'Afule	X		(Melamed, 1996; Zaitschek, 1955)
Aphek	X	X	(Hellwing, 2000; Horwitz, 2009; Liphsschitz, 1989)
Arad	X	X	(Hopf, 1978; Lernau, 1978)
Aroer		X	(Motro, 2011)
Ashdod	X	X	(Hakker-Orion and Nahshoni, 2013; Maher, 2005; Melamed, 2013)
Ashkelon	X	X	(Hesse et al., 2011; Weiss et al., 2011a)
Bab ed-Dra'	X		(McCreery, 1981)
Bet-Shean	X	X	(Horwitz, 2006; Liphschitz, 1989)
Bet-Shemesh		X	(Hesse et al., 2016, p. 20; Tamar et al., 2013)
Dan		X	(Greer, 2013; Wapnish et al., 1977)
Dor		X	(Bartosiewicz and Lisk, 2018; Raban-Gerstel et al., 2008; Sapir-Hen et al., 2014)
Ekron		X	(Lev-Tov, 2010, 2006, 2000; Maher and Hesse, 2016a, 2016b)
Hazor		X	(Lev-Tov, 2012a; Marom, 2012; Marom et al., 2017; Marom and Zuckerman, 2012)
Hirbet Hamra Ifdan		X	(Muniz, 2007)
Hirbet el-Mudeyine el-'Aliye	X	X	(Farahani et al., 2016; Lev-Tov et al., 2011; Popkin, 2009)
Hirbet el-Minsahlat		X	(Chesson et al., 2005; Makarewicz, 2005)
Hirbet en-Nahas		X	(Muniz and Levy, 2014)
Hirbet er-Rasm	X		(Weiss, 2011)

Hirbet ez-Zeraqon	X	X	(Dechert, 1994; Riehl, 2004)
Horvat 'Illin Tahtit		X	(Allentuck, 2013)
Horvat Rosh Zayit	X		(Kislev and Melamed, 2000)
Horvat 'Uzza		X	(Sade, 2007a, 2007b)
'Izbet Sartah		X	(Hellwing and Adjeman, 1986)
Jaffa	X		Orendi unpublished data
Jawa		X	(Popkin, 2009)
Jericho	X		(Bar-Yosef, 1986; Cecilia Western, 1971; Hopf, 1983)
Jerusalem		X	(Horwitz, 2000, 1996; Horwitz and Lernau, 2018; Sapir-Hen et al., 2016)
Kabri		X	(Dayan and Horwitz, 1999; Horwitz, 2002; Marom et al., 2015)
Kamid el-Loz		X	(Bökönyi, 1990)
Kinneret		X	(Ziegler and Boessneck, 1990)
Lachish		X	(Croft, 2004; Lernau, 1975)
Manahat	X	X	(Horwitz, 1998; Kislev, 1987)
Megiddo	X	X	(Borojevic, 2006; Liphschitz et al., 2006; Sasson, 2013; Wapnish and Hesse, 2000)
Mount Ebal		X	(Horwitz, 1987)
Nahal Tillah		X	(Levy et al., 1997)
Pella		X	(Köhler-Rollefson, 1992)
Qiryat 'Ata		X	(Agha, 2014; Horwitz, 2013, 2003; Maher, 2014; Sadeh, 2000)
Qubur el-Waleyide	X		(Maher, 2010; Riehl, 2010), Orendi unpublished data
Ras en-Numera	X		(White et al., 2014)
Rukes	X		http://perso.wanadoo.fr/g.willcox/
Shiloh	X	X	(Hellwing et al., 1993; Kislev et al., 1993; Liphschitz, 1993)
Sidon	X	X	(de Moulins and Marsh, 2011; Vila, 2006)
Tel Burna	X		(Greenfield et al., 2017; Shai and Uziel, 2014), Orendi unpublished data
Tel Dalit		X	(Horwitz et al., 1996)
Tel Hadar	X		(Kislev, 2015)
Tel Harasim		X	(Maher, 1999)
Tel 'Ira		X	(Dayan and Horwitz, 1999)
Tel Lod		X	(van den Brink et al., 2015)
Tel Malhata		X	(Sade, 2015)
Tel Michal		X	(Hellwing and Feig, 1989; Sade, 2006)
Tel Moza		X	(Sade, 2009; Sapir-Hen et al., 2016)
Tel Rehov		X	(Marom et al., 2009)
Tel Yaqush		X	(Hesse and Wapnish, 2001)
Tel Yarmuth	X	X	(Davis, 1988; Salavert, 2008)
Tel Yoqne'am		X	(Horwitz et al., 2005)
Tell Abu Haraz	X		(Holden, 1994)
Tell Der 'Alla	X		(Van Zeist and Heeres, 1973)
Tell el-Burak	X	X	(Çakırlar et al., 2013; Orendi, 2020; Orendi and Deckers, 2018)
Tell el-Far'a (South)	X		Orendi unpublished data
Tell el-Hayyat		X	(Falconer et al., 1984)
Tell el-Ifshar	X		(Chernoff, 1988; Chernoff and Paley, 1998)
Tell el-Qasile	X		(Kislev and Hopf, 1985)

Tell el-'Umeri	X	X	(Harrison, 1995; London, 2011; Ramsay and Mueller, 2016)
Tell esh-Shune	X		(Holden, 1999)
Tell es-Safi	X	X	(Kehati et al., 2018; Lev-Tov, 2012b; Mahler-Slasky and Kislev, 2012)
Tell es-Sakan		X	(de Miroschedji et al., 2001)
Tell es-Seba'		X	(Hellwing, 1984)
Tell Fadous-Kfarabida		X	(Badreshany et al., 2005; Genz et al., 2009)
Tell Hesban	X	X	(Gilliland, 1986; Ray, 2001a, 2001b; Von Den Driesch, 1995)
Tell Qiri		X	(Davis, 1987)
Tell Zira'a		X	(Benecke, 2019)
Timna	X		(Kislev et al., 2006)
Wadi Fidan	X		(Colledge, 1994; Meadows, 1996)

To increase potential common samples for our integrated dataset, we did not use the NISP threshold we established for faunal specimens since the samples used for integration would be too few. We merge data into the broader time period when, for example, faunal results are divided into subperiods, and botanical results are presented as a broader time period. To establish our integrated dataset, we use the same criteria we did for the botanical and faunal dataset, but we add a criterion following Smith and Munro (2009): reports had to deal with general subsistence (i.e., we exclude specialised reports focussing on ritual aspects, specific species, burials, etc.). We add the additional criterion of reports including both domesticated and wild taxa. We choose NISP to quantify faunal data, since as an observational unit it represents primary data, and NISP has been established as a good method to quantify taxonomic abundances (Gifford-Gonzalez, 2018; Lyman, 2018, 2008), whereas MNI (minimum number of individuals) as secondary data is preferred for other analytical analyses such as reconstructing biomass or skeletal part frequencies (Gifford-Gonzalez, 2018; Lyman, 2018, 2019, 2008). Analysis of our metadata shows NISP is the unit most often provided in faunal reports, followed by MNI, whereas weight data are not as frequently provided for taxonomic abundance. Besides this, we believe NISP is the most appropriate counterpart to seed count in that both are primary and observational data, but a more in-depth discussion on this can be found in part 4.3. In the end, only 16 sites fulfil our criteria, represented by 24 samples spanning a time period from Early Bronze Age I to Iron Age II (fig. 1) (3,600-586 BCE). These samples consist of 21 faunal taxa (36,626 specimens) and 111 botanical taxa (199,669 specimens).

Figure 1: Map of the southern and central Levant showing the sites used for our integrated dataset.

First, we analyse the botanical and faunal datasets separately for trends and check to what extent they are similar, then we analyse the integrated dataset and compare the trends found here with the trends found in the separate botanical and faunal datasets (table 2). We analyse datasets by dividing them into three subsets: all available taxa,

domestic taxa, and wild taxa. The first subset will allow us to investigate subsistence practices in their entirety, the second subset will provide a deeper insight into agricultural practices, and the last subset will give us a look into the environment and the role of hunting and what wild plants accompanied crops or were consumed by animals. Mean annual precipitation and elevation values for modern-day data are from WorldClim 2 (Fick and Hijmans, 2017). We chose to use modern data, since using paleoenvironmental data do not come without their own challenges and are unavailable on the local level. One of the main issues is the distribution of the paleoenvironmental records throughout the southern and central Levant, their dating, and their resolution (Rambeau, 2010). This is important to consider, since the environment and climate in the southern and central Levant can change drastically over a small area (Zohary, 1962).

Table 2: The different datasets with the total number of sites and samples per subset.

Dataset/Subset		All taxa	Domesticates	Wild taxa
Faunal dataset	No. sites	53	53	53
	No. samples	87	87	87
Botanical dataset	No. sites	36	31	29
	No. samples	71	61	49
Integrated dataset	No. sites	16	16	16
	No. samples	24	24	24

We check how well the different ranges of these three variables are represented, and saw that although chronology is well represented, mean annual precipitation and elevation do not have all ranges well represented (see table 3).

Table 3: The three variables with their most-occurring ranges in the faunal, botanical, and integrated dataset – when applicable. DS stands for dataset.

Variable	Fauna DS	Botanical DS	Integrative DS
Chronology	All time periods represented well	All time periods represented well	All time periods represented well
Mean annual precipitation	300-600mm	200-600mm	400-600mm
Elevation	0-100m	Below sea level and 0-100m	0-200m

2.2. Statistical methods

We use multivariate statistics to explore the subsistence patterns of the EBA I through the IA II in the southern and central Levant. We apply correspondence analysis (CA), detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA), which have been applied so far mainly in archaeobotanical works (e.g. Colledge, 1998; Jones, 1991). With a large dataset, CA provides several benefits: the ability to work with binary (presence/absence) or quantitative (abundance) data, even when the latter contains many zero values, being able to deal with a large number of species (10 – 500), and the ability to show non-linear, unimodal relationship between species and quantitative environmental variables (ter Braak, 1996). We present the results graphically in biplots, where the horizontal axis represents the greatest amount of variance within the data, and the vertical axis represents lesser variance (Šmilauer and Lepš, 2014). The closer a sample or taxon plots to the origin, the more common it is. For example, since ovicaprids appear in all samples, they will plot close to the origin. The biplot also shows the likelihood of species appearing together at a site, for example ovicaprids and cattle will typically plot close together and towards the origin, and plots sites with a similar relative taxonomic composition will plot close to each other. Sometimes, CA can suffer from the 'arch effect', where the points in the biplot are scattered in an arch shape This happens when the second axis is an arched function of the first axis (Jongman et al., 1987). Detrended correspondence analysis removes this problem, either by polynomials or by segments (ter Braak and Smilauer, 2012). In our analyses, we apply detrending by second-order polynomials. Finally, we use canonical correspondence analysis, where we have known variables (e.g., precipitation, elevation, time periods) constraining the ordination axes to assess their effect (Ter Braak, 1994), for example, faunal taxa and precipitation ranges would

both be represented in a CCA, as opposed to the individual samples represented in CA. The results of a CCA can be tested for the statistical significance of the null hypothesis by performing Monte Carlo permutation test (Šmilauer and Lepš, 2014). We use the CANOCO 5 programme to perform CA, DCA and CCA.

3. Results

3.1. Zooarchaeology dataset

We do not use the NISP threshold for the subsets containing only domesticates and only wild taxa, as is done for the botanical data. This is because faunal assemblages have relatively low wild taxonomic diversity and NISP counts, so a high threshold would result in an extreme reduction of zooarchaeological samples.

3.1.1 Chronology

The CA plot of the faunal subset containing all taxa does not show clear chronological patterns. In all subsets, however, multi-period sites have the BA and IA samples plotting separately, indicating some small (though not significant) differences in faunal composition, for example Ashkelon, Bet-Shemesh and Megiddo.

The CA of the subset containing only domesticates (fig. 2), however, shows weak clustering of the EBA and MBA samples mainly on the left of the first axis and in the negative part of the second axis. This pattern is probably caused by the presence of pig at the older sites. The IA samples cluster weakly on the right of the first axis and the positive part of the second axis, due to more dromedary in the samples.
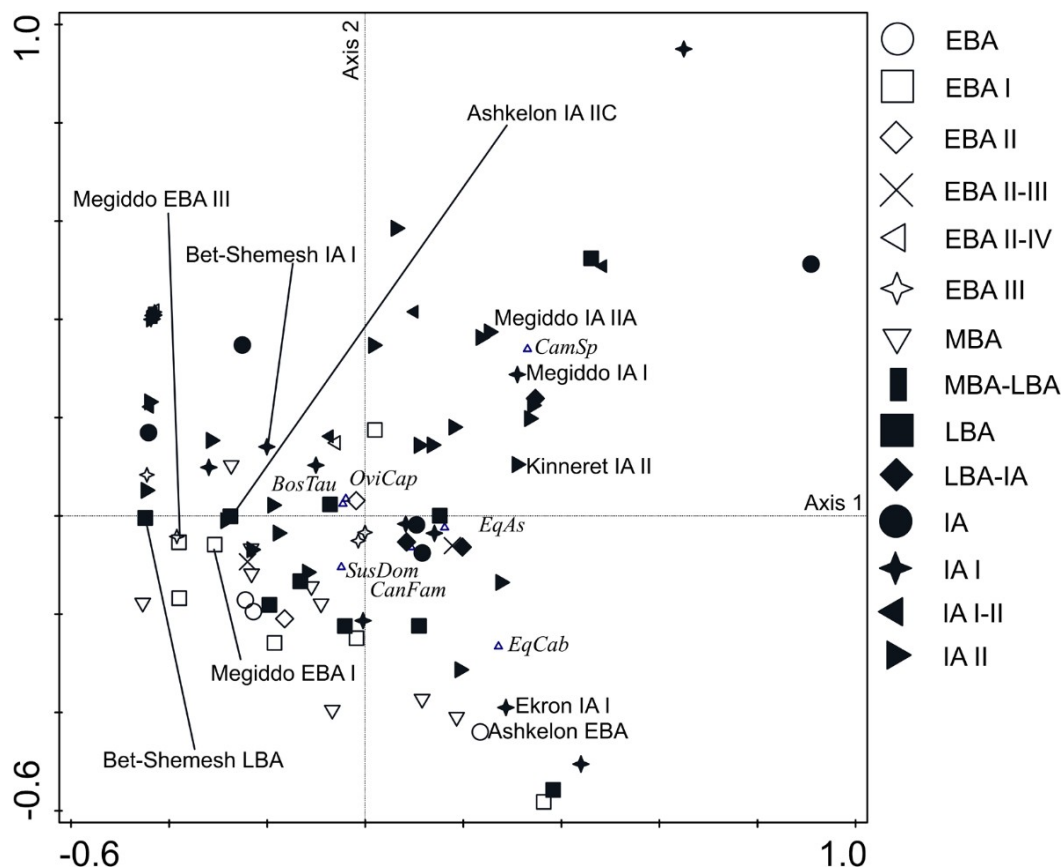
Fig. 2: CA biplot of domesticated fauna against chronology, showing an explained variation (cumulative) of 33.31% on axis 1 and 58.57% on axis 2. The eigenvalues of axis 1 and 2 are 0.9873 and 0.0738, respectively.

The DCA plot of the subset containing only wild species does not provide patterns with regards to chronology.

3.1.2. Precipitation

When we look at the subset containing all taxa (fig. 3), we see a gradient from lower to higher precipitation ranges along the first axis. Sites with precipitation lower than 600mm generally plot separately from sites with

precipitation range between 600-1000mm. The lower precipitation range shows taxa such as Canidae (dogs, wolves, and foxes), Leporidae (hares and rabbits), and dromedary are typically more represented, whereas samples with higher precipitation are associated with taxa such as Felidae (lions, leopards, cheetahs, domestic cats, etc.), Mustelidae (weasel, badgers, otters, etc.), Chelonia, wild boar, brown bear, red deer, roe deer and horse. Fallow deer occurs most frequently in the precipitation range of 300-400mm, with the highest presence during the IA II of Kinneret. Ovicaprid, gazelle, pig, and cattle plot near the origin of the CA, indicating that these taxa occur in most samples in similar proportions. These patterns are confirmed in the CCA (Monte Carlo permutations test, F=3.2, p=0.002) and when we plot the taxa as pie diagrams against precipitation (SI2.1).
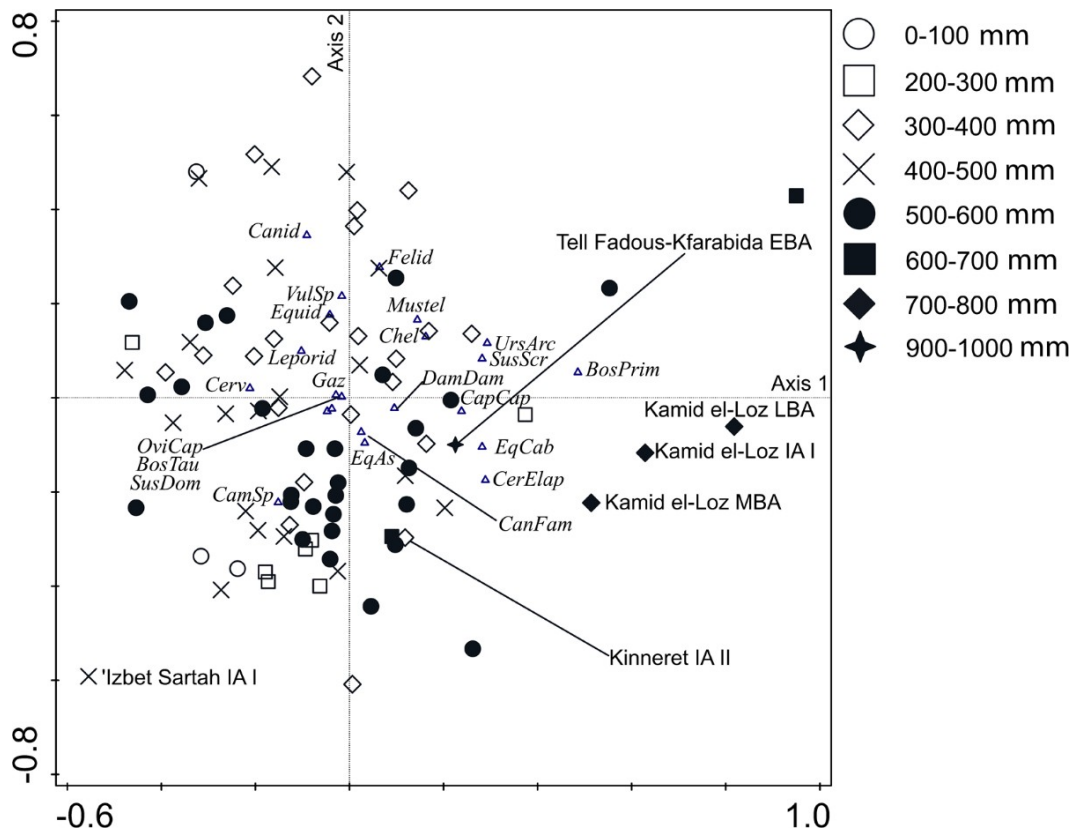
Fig. 3: CA biplot of fauna-all-taxa against precipitation, showing an explained variation (cumulative) of 15.29% on axis 1 and 27.35% on axis 2. The eigenvalues of axis 1 and 2 are 0.1277 and 0.1007, respectively.

The subset containing only domesticates (SI2.2) does not contain a clear pattern. We see a slight gradient from sites with a precipitation range between 0-300mm to 300-700mm. Sites with a precipitation range between 0-300mm show a higher presence of dromedary, whereas sites between 300-700mm plot heterogeneously. The three samples between 700-800mm are represented by one site, Kamid el-Loz and are defined by the presence of horse. One sample, Tell Fadous-Kfarabida, represents precipitation of 900-1000mm and stands out due to its presence of pig. Since both these precipitation ranges are represented by only one site, we cannot determine whether it is the taxonomic composition or the precipitation range that defines these samples. We should note that the sample of IA I at 'Izbet Sartah stands out since it has the highest proportion of dromedary in the raw data. This is noteworthy since it has annual precipitation of 500-600mm.

The DCA for the subset containing only wild taxa (SI2.3) shows the gradient from lower to higher precipitation ranges more clearly, probably because wild taxa are more dependent on their natural environment. Sites with a precipitation range of 200-600mm are associated with Leporidae, fox, aurochs, boar, brown bear, red deer, and roe deer. Sites below this precipitation range stand out due to their presence of Leporidae and fox, whereas sites above this precipitation range have a similar taxonomic composition, with the addition of fallow deer.

3.1.3. Elevation

We leave out the 400-500m elevation range in our discussion, because this is only represented by one sample from one site, Nahal Tillah. In the subset containing all taxa, sites at an elevation of 300-400m and 500-900m mainly plot on the left side of the first axis and in the negative part of the second axis (Fig. 4). These sites cluster due to similar proportions of dromedary, deer, leporids, horse/donkey and canids. Sites between 100-200m cluster together due to the proportion of fox, dromedary and leporids. The other elevations (below sea level, 0-100, 200-300 and 900-1000) are distributed heterogeneously, suggesting the faunal composition at these sites is independent of elevation. When we look at the distribution of dromedaries, horse, donkey, and equid, we can see a division (SI2.4). Dromedaries appear frequently on samples with an elevation of 0-100m, whereas horse appears mostly in areas at an elevation of 900-1000m. Donkeys plot near the centre of the graph, indicating their presence in wide range of sites at different elevations. Equids, a group that comes from specimens where more specific identifications are unavailable, plot separately from the other categories, probably since this group contains several taxa which reflect different patterns.
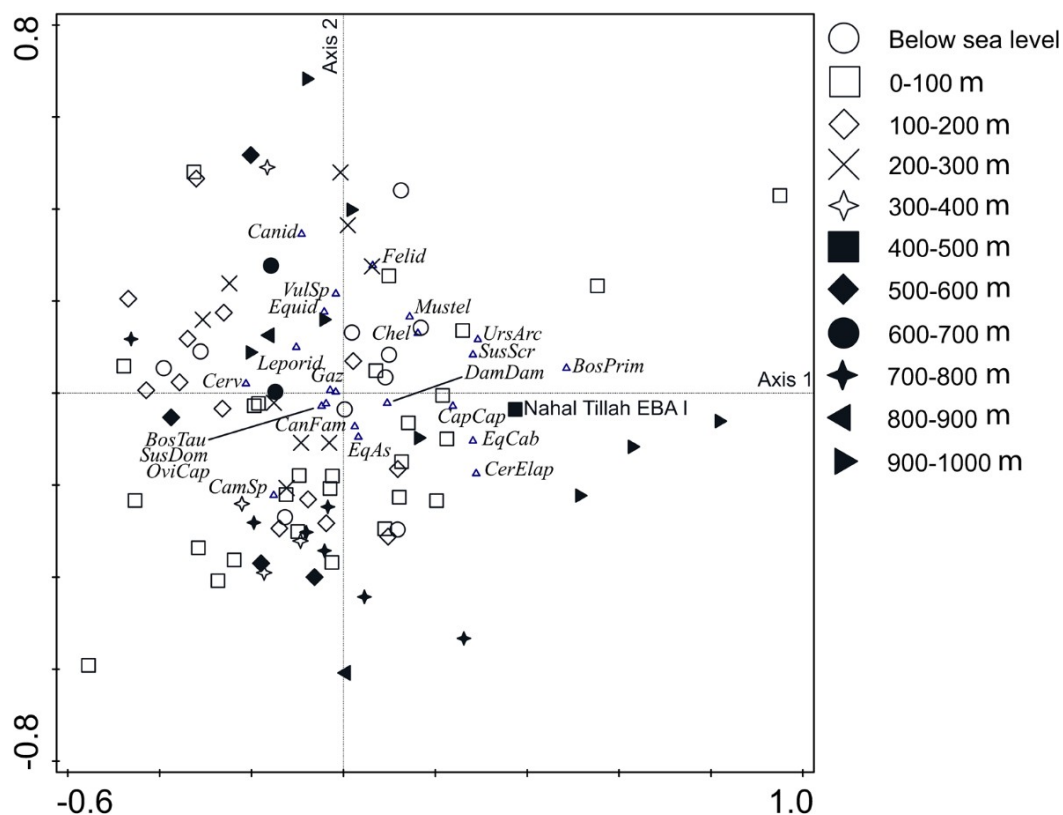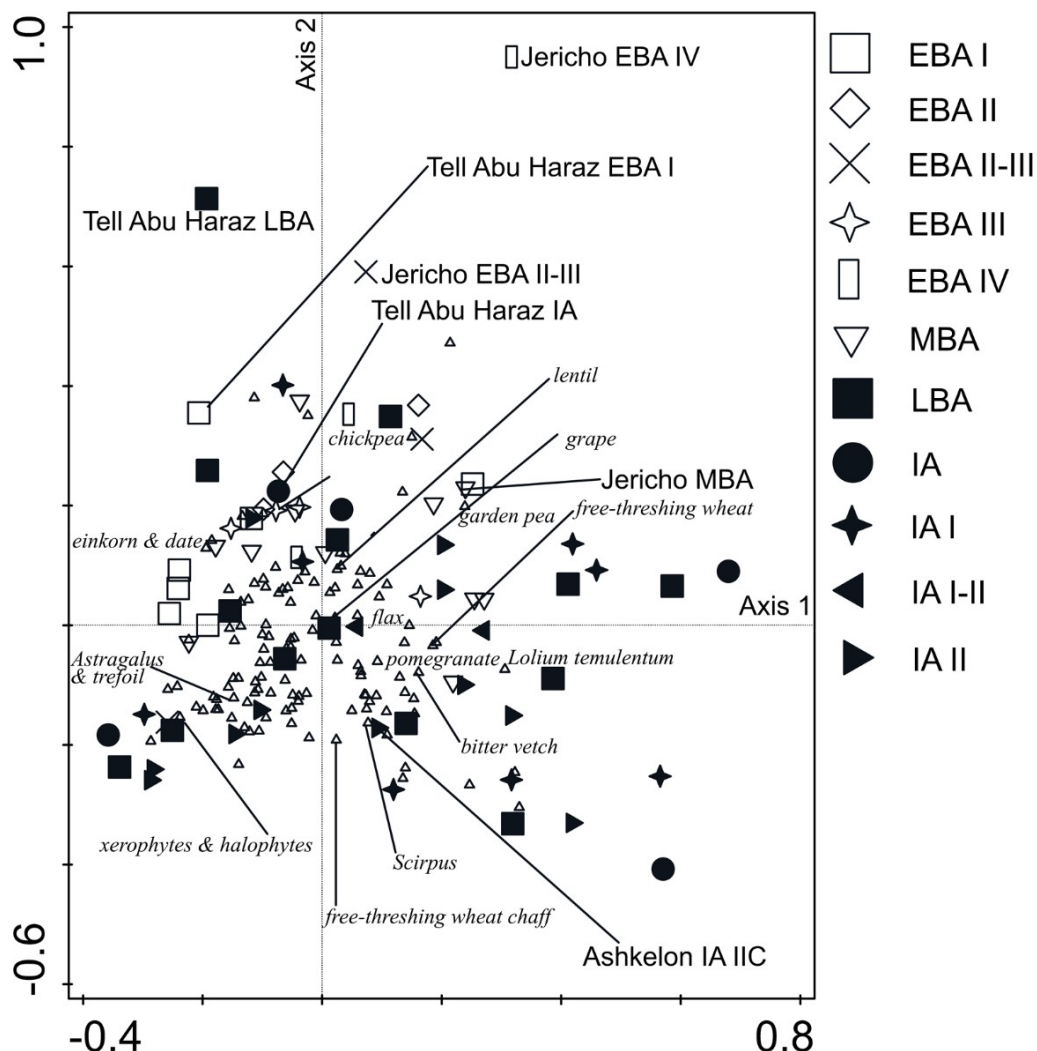

Fig. 4: CA biplot of fauna-all-taxa against elevation, showing an explained variation (cumulative) of 15.29% on axis 1 and 27.35% on axis 2. The eigenvalues of axis 1 and 2 are 0.1277 and 0.1007, respectively.

The subset with only the domesticates (SI2.5) shows clustering of sites at an elevation of 900-1000m on the right of the first axis and in the negative part of the second axis. Horse, donkey, and dog seem to occur more frequently at this elevation. Sites between 0-300m mainly plot on the left of the first axis and along the second axis and are associated with more pigs. There are no patterns for samples from sites below sea level, 300-400m and 500-900m.

The DCA plot of the subset with only the wild species (SI2.6) shows some clustering although not as clear as the other subsets. Sites below sea level and between 500-700m mainly plot along the first axis and the positive part of the second axis and are associated with Leporidae and fox. Sites in regions of 700-900m elevation are also along the first axis but are in the negative part of the second axis and are determined by the presence of fallow deer, boar, brown bear, aurochs, roe deer and red deer. Samples between 900-1000m mainly plot to the left of the first axis. This group is divided into one cluster on the positive part of the second axis, and the other in the negative part. The samples in the positive part all date to the EBA, whereas the samples in the negative part mainly date to the MBA and IA. Samples between 0-200m and 300-400m plot heterogeneously.

3.2. Archaeobotany dataset

When splitting the dataset with all taxa into separate sets of crop remains and wild taxa, they require control of the thresholds, due to considerable changes in the number of taxa and records. This leads to the exclusion of some samples, which consequently again leads to changes in the overall taxa ubiquity, resulting in a need to control the taxa thresholds. Therefore, the dataset of the crop taxa contains 61 samples and 17 crop taxa (without chaff remains, which cannot be discerned as independent units from grains, i.e., they either belong to a grain already represented by one or more grains or may have arrived in the assemblage as additional by-products), the dataset of the wild taxa is composed of 84 taxa and 49 samples.

3.2.1 Chronology

In contrast to the zooarchaeological data the CA of the archaeobotanical data (fig. 5) clearly shows a chronological pattern, in that the IA II samples are drawn away from the EBA and MBA samples along the positive part of the first axis and the negative part of the second axis., whereas the LBA and IA I samples are spread over the complete plot, indicating a certain distinctiveness of the EBA and MBA sites in contrast to IA II sites, whereas the LBA and IA I sites appear with very diversified taxonomic compositions.

Fig. 5: CA biplot of botany-all-taxa against chronology, showing an explained variation (cumulative) of 8.79% on axis 1 and 15.53% on axis 2. The eigenvalues of axis 1 and 2 are 0.2516 and 0.1932, respectively.

Looking at the somewhat sample-reduced dataset of the crop taxa, the trend becomes slightly diluted in that only the IA II samples appear to be relatively consistent in taxa representation, indicated by plotting on the negative side of the first axis. Most of the LBA sites show the same trend, whereas the samples of all other periods are

distributed over the whole diagram. This pattern appears to be caused by several crop species that are particularly prominent in IA sites, such as pomegranate, flax, but also grape and free-threshing wheat. Einkorn wheat, which may never have been a major crop in the region, seems to be responsible for the relative disorder of the crop plot, pulling out some of the few multi-period sites, Tell Abu Haraz and Jericho, respectively. However, the CCA of the same data shows a clear patterning with the EBA samples separated from the rest of the samples.

The dataset containing wild taxa does not show clear trends.

3.2.2. Precipitation

The CA plot containing all taxa shows some clustering of sites 0-400mm precipitation in the negative sector of both axes, but this is inconsistent, and generally, we see an inhomogeneous distribution of sites with all different precipitation ranges over the whole area of plot, except the sites at ranges between 0-100mm, which all plot on the negative part of the first axis. This is also explained by the relatively low cumulative variation of 25,75% for all four axes. It is however interesting to note that when looking at the attribute plots some of the aridity indicators, such as xerophytes and halophytes, show high abundance with the low precipitation sites in the negative sector. The CCA (Monte Carlo permutations test: F=1.9, P=0.002) has higher consistency in that the five different ranges used for classifying the sites do not show extremely contradictory patterns (i.e., precipitation ranges close to each other are plotted in the same sectors), and the ranges between 0-400mm and 400-700mm are separated along the first axis.

The cumulative explained variation of all four axes for the CA of the crop species (Fig. 6) is with almost 54% much better than for the complete dataset. This is visible in the output plot by a cluster of sites all located in areas with mean annual precipitation of 400-600mm, all together plotting on the left side along the second axis, and most of the sites with 200-300mm precipitation plotting on the negative part of the second axis. While the higher precipitation range is associated with the fruit trees, including pomegranate, grape and olive, the lower precipitation ranges are linked to a number of pulse crops and the cereal species, except free-threshing wheat and flax, which also appears with the higher precipitation ranges. As may be expected, these patterns are strongly supported in the CCA output (Monte Carlo permutations test, F=2.3, P=0.002).
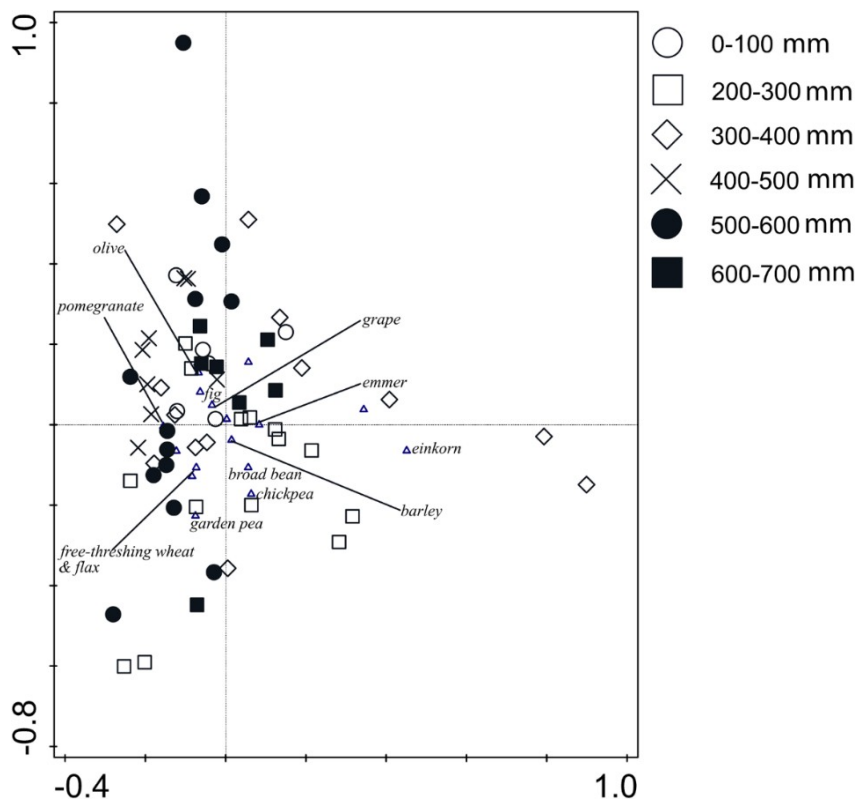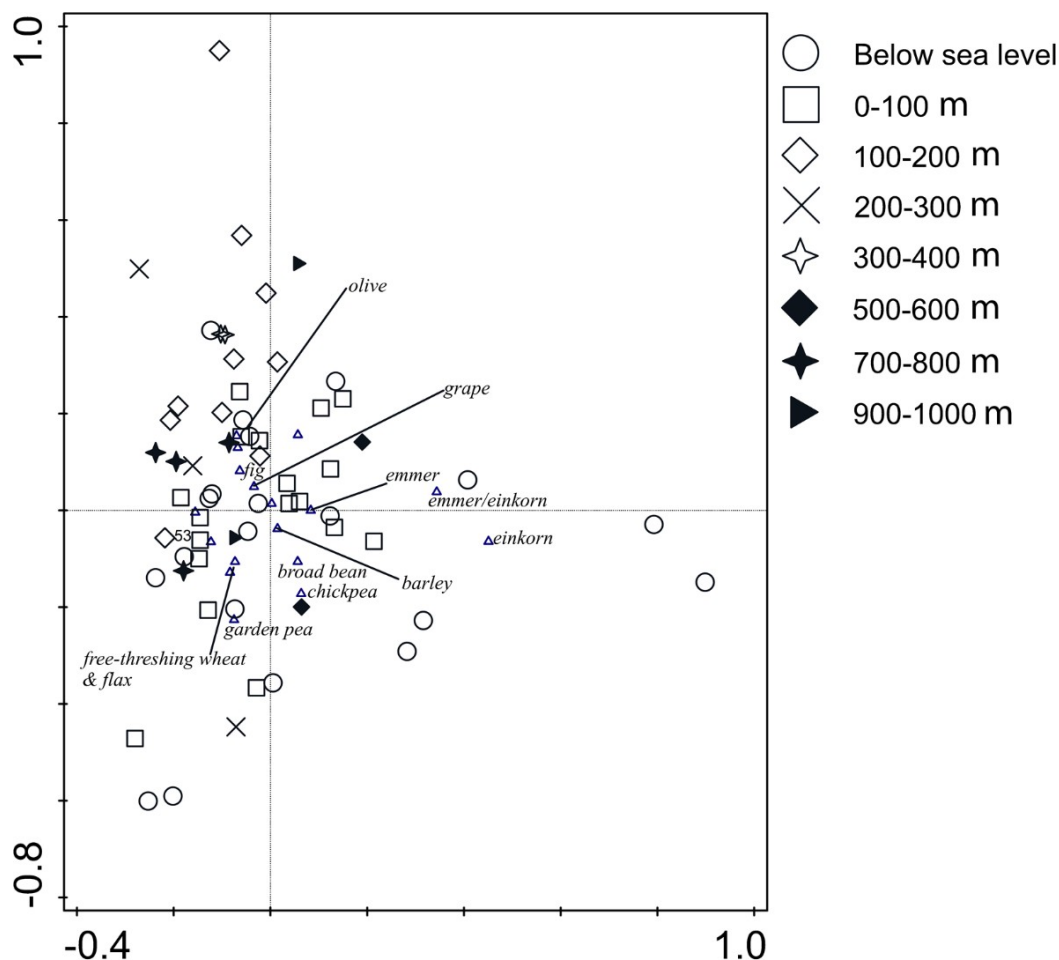

Fig. 6: CA biplot of domesticated crop species against precipitation, showing an explained variation (cumulative) of 20.61% on axis 1 and 35.30% on axis 2. The eigenvalues of axis 1 and 2 are 0.2282 and 0.1626, respectively.

The CA of the 84 wild plant taxa indicates a cumulative explained variation of 30.5% for all four axes, and this translates into an inhomogeneous distribution of precipitation ranges, except the cluster of sites with ranges between 0-400mm, which were already visible when looking at the complete dataset, and are among others associated with taxa of higher drought tolerance, such as *Androsace* sp., xerophytes and halophytes. Again, the CCA (Monte Carlo permutations test, F=1.9, P=0.002) shows a consistent pattern, in terms of the distribution of the variables to specific sectors of the plot, ranges of 400-700mm plot on the positive side of the first axis, and are separated from the lower ranges on the negative side of the first axis. However, it should be noted here that the crop taxa reflect moisture availability better in the plots than the wild taxa do, which may be related also to the fact that only a few of the 84 wild species have environmental indicator qualities.

Plotting only the 30 best-fitting taxa for their representation in different precipitation ranges clearly shows precipitation-related patterns (fig.7). Wild taxa, many of them crop weeds, that have their best representation in sites with 0-300mm precipitation are accumulating along the positive part of the second axis and contain several typical cereal weeds and wild grasses, respectively. Those taxa, many of which belong to small grasses and pulses, and with high contribution to the 300-400mm range are in the negative part of the second axis, and those that predominate sites within higher ranges of precipitation are plotting along the positive part of the first axis.
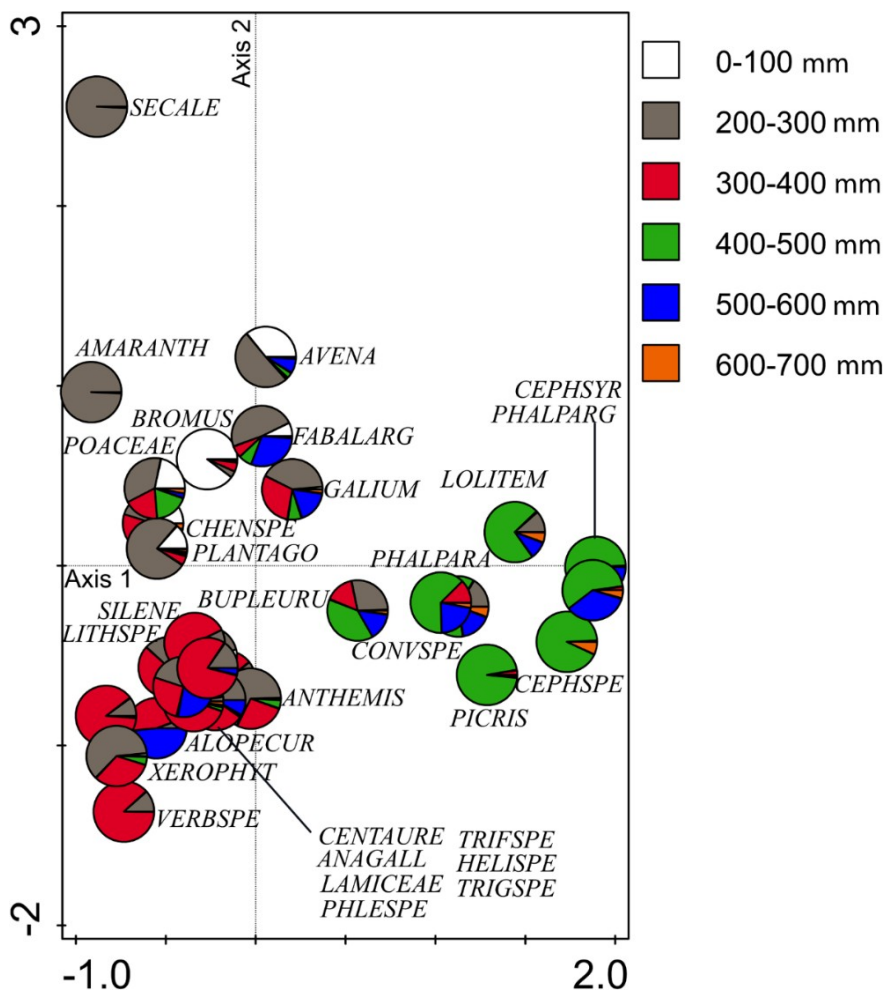
Fig.7: Wild plant taxa representation within site-specific precipitation ranges (30 best-fitting of 84 taxa, showing an explained variation (cumulative) of 11.02% on axis 1 and 19.02% on axis 2. The eigenvalues of axis 1 and 2 are 0.3175 and 0.2303, respectively.

3.2.3. Elevation

In contrast to the faunal data, the patterns produced by the CA analysis appear much weaker for elevation ranges in the botanical dataset. This may also relate to the uneven distribution of elevation ranges to the set of samples, with 38 samples attributed to elevations from below sea level to 200m, but only nine samples falling into the wide range of 200-1000m.

In the dataset containing all taxa (SI2.7) most of the sites below sea level are accumulated on the positive side of the second axis, but except date palm do not indicate particular Sudanian phytogeographic elements. All other sites are more or less distributed over the whole space, which suggests the layout of plant assemblages at sites above sea level to be more or less independent from elevation.

The crop data (fig. 8) set shows a weak clustering of samples and sites at elevations of 100-400m on the negative side of the first axis. There is also a trend of olive and fig, but in particular grape occurring with lower amounts in sites below sea level. However, it should be noted that for elevation 300-400m there is only one site (i.e., representativeness of this elevation range is questionable). Another observation comparing elevation ranges of the faunal and plant domesticates is that in both cases sites at 0-100m elevation are widely spread over the complete space, so they appear very diverse in assemblage compositions.

Fig. 8: CA biplot of domesticated crop taxa against elevation, showing an explained variation (cumulative) of 20.61% on axis 1 and 35.30% on axis 2. The eigenvalues of axis 1 and 2 are 0.2282 and 0.1626, respectively.

The wild taxa dataset reflects a pattern very similar to the one visible in the full dataset, with most of the sites below sea level accumulating on the positive side of the second axis. Additionally, a weak cluster is formed on the negative side of the first axis by sites at an elevation between 300-600m. However, also here it should be noted that these elevations are only represented by three different sites.

3.3. Integrated dataset

Cereal chaff is included to compensate for a loss of too many samples due to threshold settings. Once again, we divide our dataset into three subsets: all taxa, only domesticates, and only wild taxa. In the subset of only wild taxa, Sidon repeatedly is an outlier due to the presence of aurochs and brown bear. The legend attributing the numbers to botanical and faunal samples along with the abundance data can be found in SI1.

3.3.1 Chronology

When we depict the proportions of wild and domesticated fauna NISP/botany seed count of a sample as a pie diagram (fig. 9), we see that samples with a higher abundance of faunal remains plot separately from those where plant remains dominate. The faunal remains are dominated by domesticated taxa, the exception being the EBA II-III of Sidon (23) where wild taxa slightly outnumber domesticates. Similarly, the botanical remains usually consists of more domesticates than wild taxa. Samples with more wild botanical taxa than domesticates plot separately.
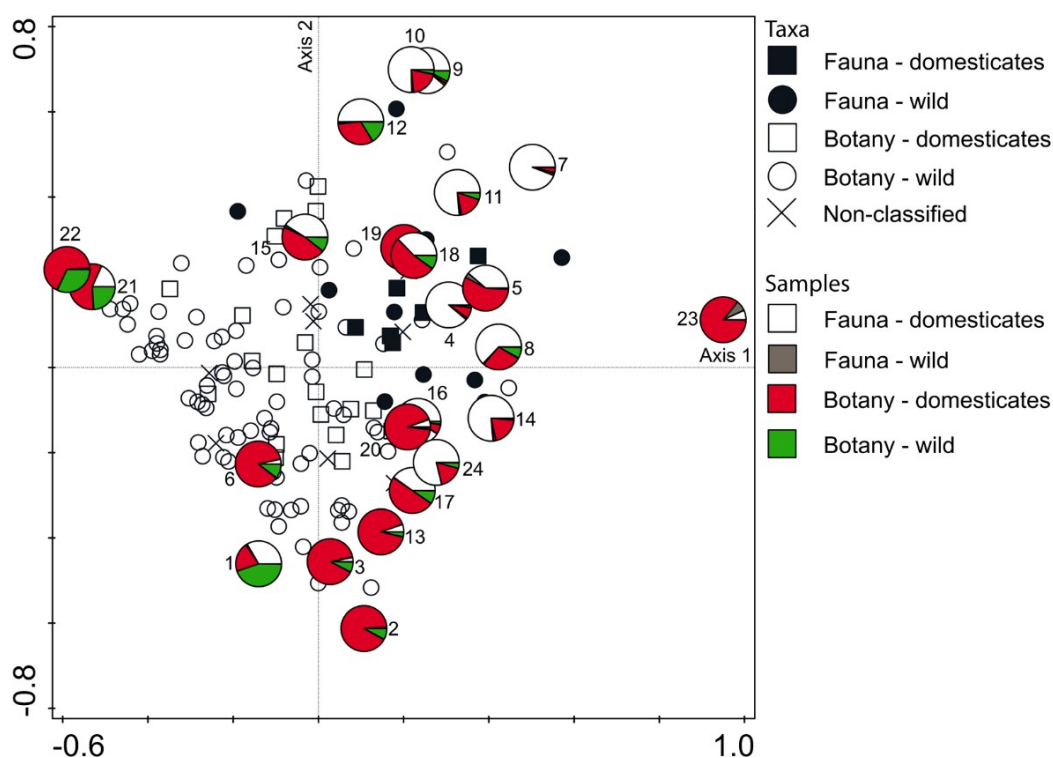
Fig. 9: Integrated samples expressed in pie-diagrams showing the distribution of archaeobiological material, expressing an explained variation (cumulative) of 14.28% on axis 1 and 26.40% on axis 2. The eigenvalues of axis 1 and 2 are 0.3001 and 0.2549, respectively.

Despite a pattern of samples from multiple-period sites clustering per site (e.g., Megiddo [9, 10, 11, 12], Tell es-Safi [16, 17, 24] and Aphek [1, 2, 3]), the integrated dataset containing all taxa shows some chronological trends indicated by the explained cumulative variation of four axes of 44.11% (SI 2.8). Samples belonging to the EBA and MBA period plot mostly on the right of the first axis, and the positive part of the second axis due to large amounts of pig, cattle, ovicaprid, but among others also by gazelle, donkey, dog, roe deer. As attribute plots indicate, among the crops garden pea is particularly associated with EBA samples, but also the glume wheats, lentil, and wild pistachio seem to determine the cluster of EBA and MBA samples. Two EBA II-III samples deviate from these clusters, Hirbet ez-Zeraqon (21) and Sidon (23). The outlying position of the latter is likely caused by a relatively small taxonomic diversity with comparatively low counts, and a general low representation of faunal data (fig.9). The presence of aurochs and brown bear also causes this sample to plot separately, while barley and free-threshing wheat are the main cereal crops. Hirbet ez-Zeraqon, in contrast, has a very broad taxonomic diversity and has large numbers of wild botanical taxa, fox, Equidae and emmer chaff. We can also see two temporal outliers in this quadrant: one IA I sample (Megiddo [11]) and one IA II sample (Hirbet el-Mudeyne el-'Aliye [7]), both

dominated by faunal data. Samples belonging to the LBA spread heterogeneously, indicating diverse taxonomic compositions. Samples belonging to the IA mainly plot in the negative part of the second axis and are mostly on the right of the first axis. They mostly contain red deer, boar, felids and fallow deer. Among the crops free-threshing wheat, flax, pomegranate, grape and bitter vetch are abundant, all being well-known for their preponderance in sites dating to the Iron Age II.
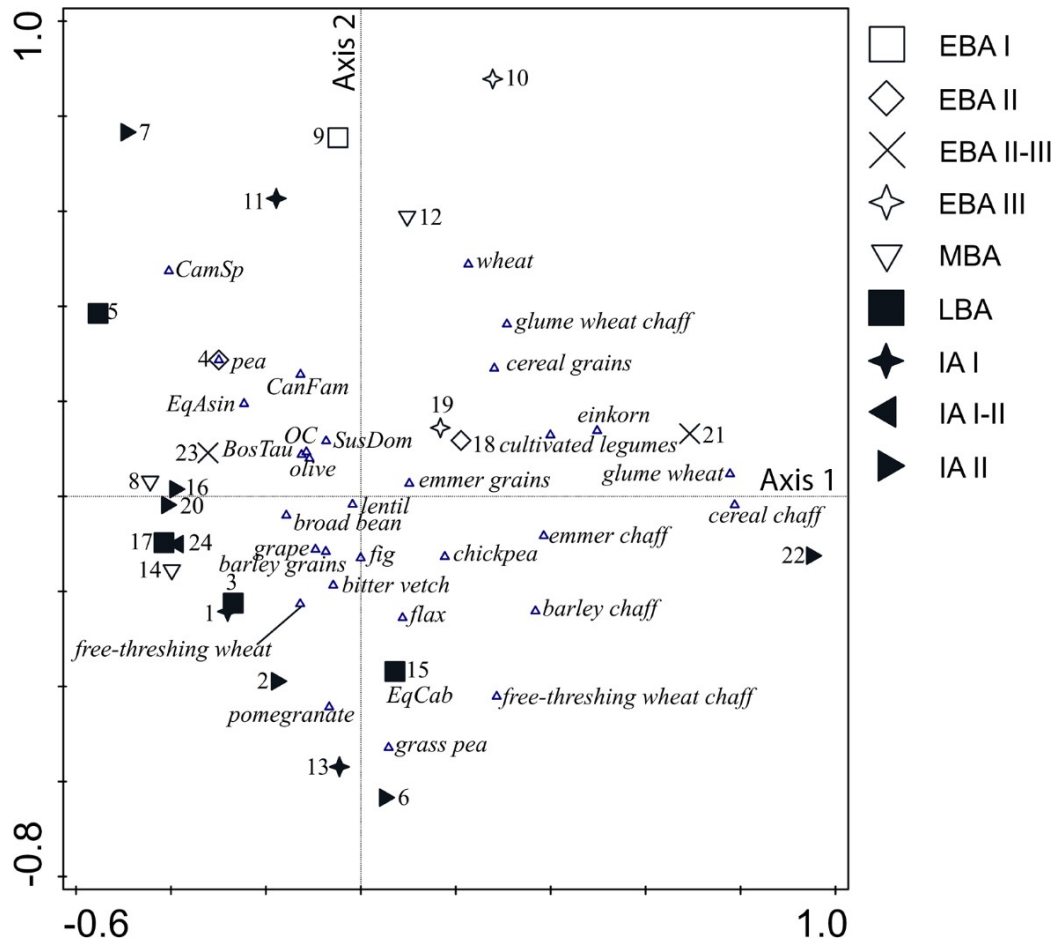
Fig. 10: CA biplot of integration-only domesticates against chronology, showing an explained variation (cumulative) of 19.40% on axis 1 and 35.73% on axis 2. The eigenvalues of axis 1 and 2 are 0.2310 and 0.1945, respectively.

We see a similar chronological pattern in the CA of the integrated dataset containing only domesticates (fig. 10). The cumulative explained variation for the four axes is 58.71%. The EBA and MBA samples plot separately from the LBA and IA samples. The EBA and MBA samples have large numbers of cattle, ovicaprid, but also donkey, dog as well as by the glume wheats. The LBA and IA samples contain higher proportions of horse, free-threshing wheat, pomegranate, flax, broad bean, bitter vetch, and grape. Whereas the EBA II-III of Sidon (23) is an outlier in the CA of the integrated dataset containing all taxa, this is not the case here, because when subtracting the wild taxa, the sample is dominated by barley and has a high number of ovicaprids and cattle, ubiquitous taxa that cluster the site along with many others. We also see that pigs are more common in EBA samples, the exception being the IA II sample of Tell es-Safi (16).

The DCA of the integrated dataset containing only wild taxa (SI2.9) is not as explanatory as the other subsets, but shows largely the same pattern, the four axes explain a cumulative variation of 38.37%. Most of the EBA and MBA samples cluster together due to high proportions of gazelle, leporids, and roe deer. Most of the LBA and IA samples cluster separately, although it should be noted that the EBA II-III of Sidon (23) is a clear outlier, due to its high amount of wild fauna. The presence of wild taxa such as brown bear and aurochs move it away from the other EBA samples. Apart from this, several wild plant taxa, such as *Scirpus* spp. and other Cyperaceae, *Rumex* sp. *Phalaris* sp. and some halophytes (indicative of moister, potentially irrigated habitats) are closely associated

with the Iron Age sites, as well as being an indicator species of overgrazing, such as different geophytes or *Euphorbia* spp. Commonly hunted taxa such as gazelle and fallow deer are most abundant in the LBA and IA.

3.3.2. Precipitation

We can see weak patterns related to ranges in modern mean annual precipitation when looking at the CA plot for the integrated dataset containing all taxa (fig. 11). Sites with precipitation between 200-400mm contain higher proportions of fox, horse, pig, cattle, ovicaprid, gazelle, donkey, roe deer, and dromedary. They have low amounts of seed records which are often dominated by barley, to a lesser extent olive, and in EBA sites by glume wheats. Sites with precipitation between 400-600mm cluster and generally contain pig, cattle, ovicaprid, gazelle, donkey, roe deer, dromedary, boar, red deer, and fallow deer. Among the crop taxa broad bean, and to a minor degree free-threshing wheat, pomegranate and grape are associated with sites of these higher precipitation ranges. The only sample in the 600-700mm range is Sidon (23) and is the main outlier due to its peculiar sample composition and generally a narrow diversity of taxa and low seed counts. The CCA plot confirms these results (Monte Carlo permutations test, F=2.0, P=0.002).
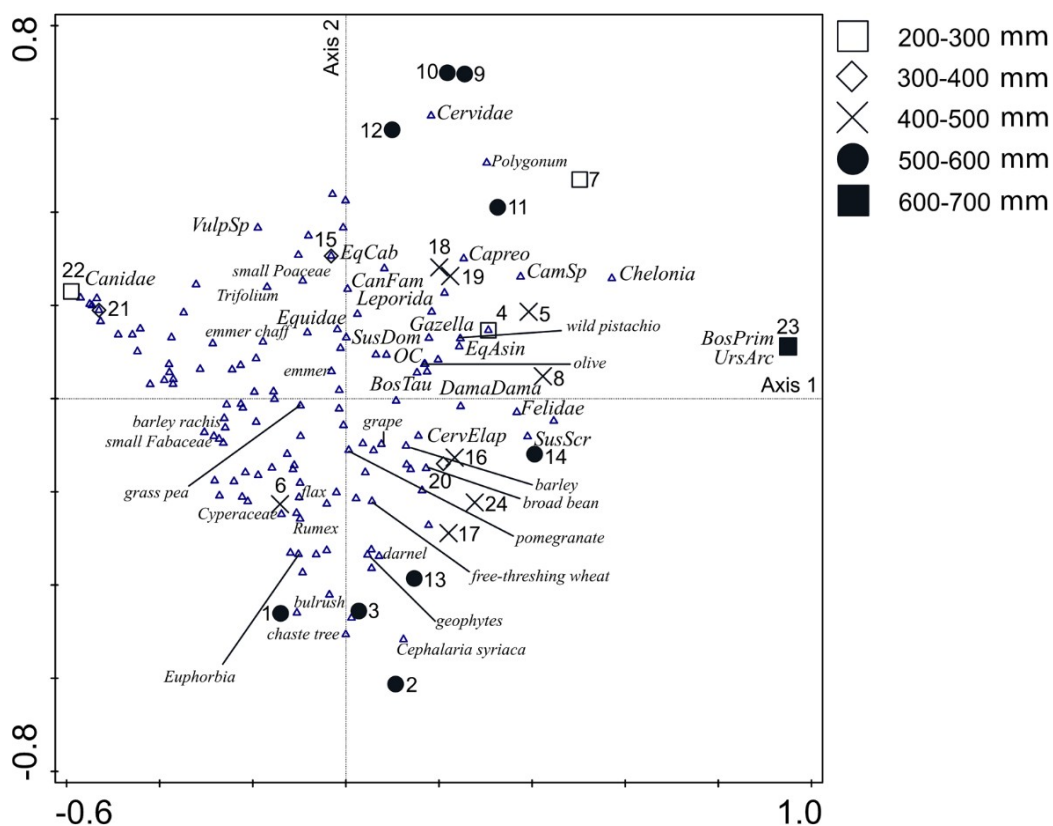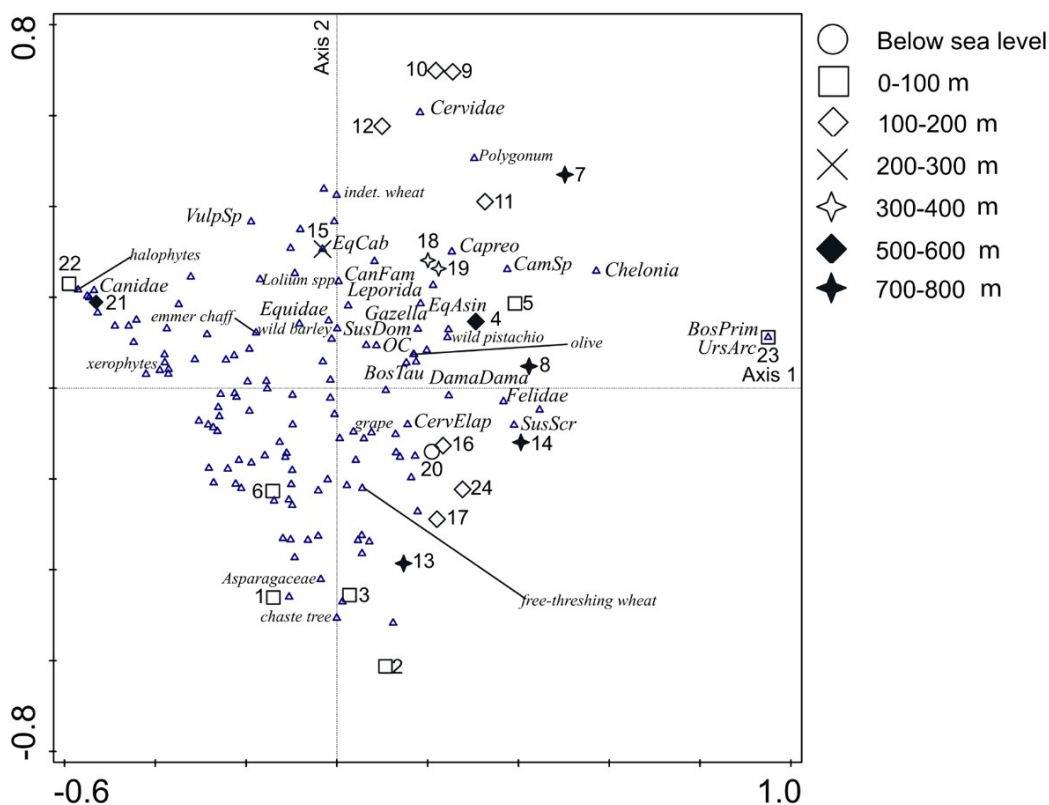

Fig. 11: CA biplot of integration-all taxa against precipitation, showing an explained variation (cumulative) of 14.28% on axis 1 and 26.40% on axis 2. The eigenvalues of axis 1 and 2 are 0.3001 and 0.2549, respectively.

The CA of the integrated dataset containing domesticates (SI2.10) does not show any clear patterns and has close internal clustering of multi-period sites. The precipitation ranges plot heterogeneously. However, we see a small trend within the 500-600mm range where samples are divided into two groups: one group consisting of four Megiddo samples (9, 10, 11, 12) with higher proportions of donkey, dog, and dromedary, and unidentified wheat, the latter of which may be considered an artefact of sampling strategy. The other group consists of two Shiloh (13, 14) and three Aphek (1,2, 3) samples caused by botanical taxa such as free-threshing wheat, barley, and grape.

We find further trends of dominating associations of crops in particular precipitation ranges by creating a pie diagram for each domesticated taxon (SI2.11). For example, free-threshing wheat is almost limited to sites in the 500-600mm precipitation range, pomegranate and grass pea are particularly numerous in sites with precipitation of 400-500mm, while glume wheats predominate at 300-400mm and canids are typical at sites with a precipitation of 200-300mm. Considering these four major classes, the 200-400mm ranges tend to appear in quadrants 1, 2 and

4, whereas the 400-600mm ranges dominate quadrant 3. The main faunal domesticates (ovicaprid, cattle, pig), plot close to the origin, as many of the crop species do, and seem to indicate these taxa are not particularly related to precipitation.

The DCA of the integrated dataset containing wild taxa (SI2.12) shows patterns, although not as clearly as the integrated dataset with all taxa. Sites between 200-400mm cluster separately from sites between 400-600mm. Within the 500-600mm group we can again see two groups, the one in the positive part of the second axis consisting of Megiddo samples (9, 10, 11, 12), which appear to be caused by a higher amount of wild plant taxa thriving mainly in open and weedy habitats, and the group in the negative part of the second axis containing Shiloh (13, 14) and Aphek (1, 2, 3) samples showing a higher contribution of shrubland species, but also indicating habitats of higher moisture or even irrigated plots. The exception here is the one sample in the 600-700mm range, represented by EBA II-III of Sidon (23) that is an outlier, which is related to a very narrow taxonomic diversity of only four taxa in very low counts.

3.3.3. Elevation

The integrated dataset containing all taxa (fig. 12) shows sites at an elevation of 100-200m and 700-800m clustering due to similar proportions in ovicaprid, cattle, pig, gazelle, dog, dromedary, Chelonia and red deer. The sites within the 700-800m range are associated with grape, and to a minor extent by olive and IA Shiloh (13) also by free-threshing wheat. The sites of the 100-200m range are dominated by grape and free-threshing wheat in the case of Tell es-Safi (16, 17, 24), and at Megiddo (9, 10, 11, 12) by an unidentified wheat species. Note the separation of the samples in the 100-200m range between Megiddo and Tell es-Safi. The former plots in the positive part of the second axis and the latter in the negative part. Samples between 0-100m plot heterogeneously.

Fig. 12: CA biplot of integration-all taxa against elevation, showing an explained variation (cumulative) of 14.28% on axis 1 and 26.40% on axis 2. The eigenvalues of axis 1 and 2 are 0.3001 and 0.2549, respectively.

The integrated dataset containing only domesticates shows a similar picture to that of the previous subset. Sites at an elevation between 0-200m and 700-800m cluster together. Within the 100-200m range, we can see a divide between samples belonging to EBA, MBA and IA Megiddo (9, 10, 11, 12) and LBA and IA Tell es-Safi (16, 17, 24). The former plot closer to the second axis, the latter closer to the first axis. They are caused by the main

domestic species, but also donkey, dog, and dromedary. Sites at an elevation between 500-600m plot heterogeneously.

When we plot the domestic taxa as pie diagrams representing their occurrence at a different elevation (SI2.13), we can see more clearly that elevation plays a certain role in the occurrences of the different taxa. Taxa predominating at 0-100m elevation plot on the left of the first axis and in the negative part of the second axis. They mostly consist of cultivated plants that need higher precipitation, which makes sense since lower elevations tend to occur near the coastal regions or other water bodies. Olive and barley are also frequent in sites below sea level (i.e., the Jordan Rift Valley). Animals with higher water requirements such as cattle and pig occur mostly at an elevation of 100-200m, at elevations that have more water sources. We also see taxa which occur mostly at 500-600m on the right of the first axis and the positive part of the second axis. These are represented by several drought-resistant botanical taxa, examples being einkorn and emmer, which is not explained by the relatively high precipitation, and might indicate possible climate shifts in the past. We note that horse only occurs on an elevation of 200-300m, and dogs occur mostly at 700-800m.

The integrated dataset containing wild taxa (SI2.14) shows similar results as the other subsets. Sites at an elevation of 0-100m cluster together due to high numbers of fox, and several plant taxa typical for open habitats on coastal plains, namely Asparagaceae, halophytes, *Plantago* sp., *Ranunculus* sp. and chaste tree. Sites at an elevation of 0-200m cluster, but it should be noted that all the samples belonging to Megiddo (9, 10, 11, 12) plot on the left of the first axis and in the negative part of the second axis, whereas the samples belonging to Tell es-Safi (16, 17, 24) plot on the left part of the first axis and in the positive part of the second axis. Sites at an elevation of 700-800m cluster together, with IA II Hirbet el-Mudeyne el-'Aliye (7) in the negative part of the second axis, having only six wild plant taxa and being dominated by gazelle and fallow deer. Sites at an elevation between 500-600m plot heterogeneously and are characterised by some small-seeded Fabaceae and Poaceae taxa but are only represented by two EBA sites.

4. Discussion

4.1 Trends in the individual datasets

The botanical dataset reflects diachronic changes slightly better than the faunal dataset, in that differences between IA II and EBA sites are clearer. Both datasets reflect these diachronic patterns also in multi-period sites, where EBA/MBA are plotted separately from LBA/IA samples. The samples of the faunal dataset are always dominated by ovicaprids and cattle, whereas wild species are minimally present (the exception being Sidon). This is in contrast to the botanical dataset where the diversity of wild plant taxa can be comparatively high, and some crop species appear with much higher counts in some periods than in others, such as free-threshing wheat, flax and pomegranate in most of the IA II sites, which were together with grape and olive also important trade goods, and not always produced at the sites, where they were found (Faust and Weiss, 2005; Simchoni and Kislev, 2006). A very significant difference in cereal cultivation is the fast replacement of dominant emmer cultivation in the EBA by free-threshing wheat in the Iron Age, which was in concordance with similar but earlier developments in northern Mesopotamia, where emmer was no longer cultivated already in the MBA (Riehl, 2009b). In the southern Levant it remains a minor crop through the Iron Age, which may be related to the Egyptian presence there, and their requirements in emmer for beer and bread production.

Although we know from faunal analyses the ovicaprid:cattle ratio changes throughout time (Gaastra et al., 2020; Sapir-Hen, et al., 2014; Sasson, 2016; Tchernov and Horwitz, 1990), this is not strong or consistent enough to lead to trends in the CA and CCA plots. The faunal dataset shows some patterns in differentiating the EBA and MBA samples from IA samples. The EBA and MBA samples have more pig, whereas the IA samples contain dromedary. Pigs were part of the diet in the southern Levant throughout history, but their number started declining drastically from the LBA (Redding, 2015; Sapir-Hen, 2019b). However, during the IA I, pork consumption increased in Philistine urban centres but were still largely absent in other sites (Faust, 2018; Sapir-Hen, 2019b), which we see, for example, in the IA I of Ekron, which has the highest presence of pig in the entire dataset. Ekron is also well-known for being the largest production centre for olive oil during the seventh century BC, however, no botanical data have been published for Ekron yet. We cannot generalise these results since we did not find other samples for Philistine sites adhering to our selection criteria.

Dromedaries were introduced towards the end of the tenth century BC in the southern Levant but are present in higher numbers from the IA II onwards (Sapir-Hen and Ben-Yosef, 2013). Wild animal taxa do not show any diachronic trends, and their representation is always low. The botanical dataset of the wild taxa is in agreement with the crop plant data, confirming the distinctiveness of the EBA and IA II assemblages, with a higher contribution of xerophytic components and in some cases also with high amount of halophytic and moisture indicating components in the IA sites, which indicates intensified agricultural production, increased irrigation of some crop species, and some of the negative consequences. At the same time the Iron Age started with increased humidity after the end of the LBA, and then continuously reverted to drier conditions, with ongoing fluctuations (Bar-Matthews and Ayalon, 2011, 1998). This should have set the background for a surplus production oriented at agriculture and may have forced farmers to irrigate some of these crop species. These trends are also indicated in the pollen diagrams from this region, which also outline an increased olive cultivation with the beginning of Iron Age I, reaching almost the same extent as during the moister EBA (Langgut et al., 2015; Neumann et al., 2010). The diachronic similarities in the abundance of this important crop species may also influence the association of some EBA and IA sites in the CA plot (fig. 10).

Our diachronic results contribute and partly confirm the patterns of social and economic development we outlined in '1.2. Background to Research'. The EBA samples, a period characterised by the first complex urban-based societies and a mixed agropastoral economy, group together with the MBA samples, which is a period of re-urbanisation with differences in subsistence between rural and urban settlements. These periods are defined by higher frequencies of emmer and pig in our data. We cannot see a difference between rural and urban sites in our quantitative data, possibly because the most distinguishing factor between the two site types is more older and mor younger animals, respectively, and our analysis did not take that into account. This underlines the importance of considering mortality profiles for faunal remains to gain more in-depth knowledge. The LBA, defined by a strong Egyptian influence and internationalism, groups with the IA, a period characterised by the genesis and development of new identities within new political structures. Both periods show trends of surplus production. It seems that during the LBA trans-regional exchange and the Egyptian hegemony over the Southern Levant were the background for surplus production. In contrast, during the IA the needs of the newly formed territorial states as well as duties towards the Neo-Assyrian Empire during the later IA seemed to have led to surplus production strategies. Emphasising this trend, are the intensified crop cultivation and increased irrigation practices happening during the IA, probably to create surpluses.

Both the faunal and botanical datasets show differences between sites in high and low mean annual precipitation areas. In the faunal dataset, these differences can be seen in all the subsets, whereas in the botanical dataset patterns are much better recognizable in the domestic and wild subsets. The fauna of the sites in lower precipitation areas is characterised by taxa such as leporids, canids and dromedary. Dromedaries would have been used as pack animals, in agricultural practices and for trade (Sapir-Hen and Ben-Yosef, 2013), and they are well-suited for drought conditions (Naumann, 1999). Sites in areas with higher precipitation are associated with taxa such as boar, red deer, roe deer and brown bear, which inhabit forests, wetlands, and grasslands (Boitani et al., 2010; Keuling and Leus, 2019; Lovari et al., 2019, 2016). Taxa such as ovicaprids, cattle, pig and gazelle are always found near the origin of the plot, indicating these animals occur in most samples and have a broader tolerance to cope with different levels of precipitation. This shows that animal husbandry was perhaps not as dependent on the environment as previously thought (Tchernov and Horwitz, 1990) and supports the idea that changes in animal husbandry practices should be understood in their historical context (Sapir-Hen, et al., 2014)

Since crop species are usually specific in their agronomic requirements (soil characteristics, moisture availability and temperature), they can be expected to indicate this conditionality within the CA plots to some degree (Riehl, 2009a). For example, crop species with a larger tolerance range for rainfall like fig and olive are more likely to be found evenly distributed in all sorts of different precipitation ranges, whereas species with a smaller tolerance appear more closely related to specific precipitation ranges, for example, emmer wheat is particularly numerous in sites with 200-300mm precipitation ranges. However, two important limitations in the explanatory power of precipitation values determining crop species need to be considered. First, the extremely diverse topographical and climatological conditions of the Levant with the associated short-distance succession of isohyets ranging from 0-700mm precipitation, which contrasts strongly from inland regions such as northern Mesopotamia, allows the cultivation of a broad range of species within a relatively narrow geographic area. Second, economically important crop species with higher water requirements, such as free-threshing wheat, are probably more often irrigated than

species with minor economic value (e.g. figs), which diminishes the possible association of species with higher water requirements and sites with higher precipitation. Furthermore, singular cities, particularly of the later periods, may have imported crops from elsewhere, if their environmental conditions would not have allowed their cultivation, for example Beth-Schean (Simchoni and Kislev, 2006).

Despite such limitations, we see a good explanatory power of precipitation ranges in CA plots for individual crop taxa, with grape and broad bean occurring in high amounts particularly at sites with precipitation ranges of 400-600mm. This is in contrast to emmer wheat, which is most numerous at sites with precipitation below 400mm. Crop taxa that are relatively sensitive to drought (free-threshing wheat, flax, garden pea), but occur in both high and low precipitation samples, may have been irrigated at least occasionally at the sites which fall into the lower precipitation ranges. Furthermore, when only considering archaeobotanical assemblages a pattern of annual versus fruit tree cultivars arises, with fruit trees closer related to sites with mean annual precipitation of 400-600 mm and annual crop species related to either 200-300 mm or higher. This may be since annuals are easier to irrigate which could explain preferably cultivation of fruit trees in areas with generally higher mean annual precipitation.

When using only the 30 best-fitting wild plant taxa out of 84, their relation to certain precipitation ranges is quite clear (fig.7), even though only a few of them can be unambiguously classified according to their ecological characteristics. It is however visible the typical weedy grasses that occur as weeds in the cereal fields (e.g., *Bromus* spp., *Avena* sp., etc.) are best represented in lower precipitation ranges (< 300 mm), while those wild taxa that mostly occur under conditions of higher water availability (e.g. *Phalaris* spp., *Cephalaria syriaca*, etc.) are best represented in sites above 400 mm.

Like in the case of diachronic similarities in the abundance of particular crop species that may cause association of sites in different cultural periods, as described above for olive cultivation, sites in regions with higher precipitation regions can plot in our CA biplots near a cluster of samples of sites in lower precipitation regions. In this case it can be related to either irrigation practices (e.g., through the dominance of a crop with high water requirements in a site within a low range of precipitation), the import of crop taxa from other environments, or pastoral mobility. Of course, precipitation and sophisticated irrigation technologies are not the only way of obtaining water in any landscape. The presence of differently productive aquifers also plays a role in the water supply (Pustovoytov and Riehl, 2016), as does the distance between settlements and a water source. These are variables we could not explore in this exploratory study but should be considered in future research.

Elevation data shows some trends, but they should be treated carefully. The fauna clusters into three elevation ranges: 0-300m, 300-900m and 900-1000m. Sites at an elevation of 0-300m are mostly characterised by fox, dromedary and Leporidae, but when we focus on just domesticates, also pigs. Sites at an elevation of 300-900m are the most diverse, showing a wide range of adaptability and indicating the taxonomic composition is independent from the elevation. Sites between 900-1000m are mainly due to the presence of horse, donkey, and dog. Donkeys, which were important in their role as pack animals and for transportation (Grigson, 2012; Shai et al., 2016), are present at all elevations, showing they are independent of this variable. Dromedaries and horses only became more commonly used in the IA (Grigson, 2012; Shai et al., 2016). The botanical data also show a weak relationship between the elevation of sites and dominating taxa, and the only visible pattern is a clear underrepresentation of grape in sites at elevations below sea level, possibly because this species may have left its traces there mainly as an import. In the botanical dataset a certain clustering of the sites below sea level could be observed. Given the fact that this region of the Jordan rift valley is phytogeographically home of Sudanian elements one may assume that this could be a characterizing variable in the clustering of samples (Shmida and Aronson, 1986). However, only date palm could be outlined as an associated taxon for this region, while other taxa of dry to hyper arid environments are not closely associated to the sites below sea level. This suggests that irrigation and cultivation in oases probably played an important role in some of these sites. We also need to consider the impact of pastoralism, trade, and the range of movement of both people and animals. Pastoralism is difficult to explore in the faunal record since it is usually detected by looking at the sheep:goat ratio. It should be analysed further using other methods such as isotope ratio analysis (Arnold et al., 2018; Makarewicz and Sealy, 2015).

4.2 Trends in the integrated dataset

Despite the strongly reduced number of samples, the integrated dataset shows similar trends to those of the separate datasets, but they are weaker due to mutually exclusive factors of the different data types (see below) and due to a smaller sample size, which affect the representation of the three parameters, chronology, precipitation and elevation.

We see diachronic differences between the EBA/MBA samples and IA. LBA samples plot heterogeneously but tend to plot closer to the IA samples. The EBA and MBA samples are mainly characterised by ovicaprids, cattle, pig, gazelle, and donkey. Glume wheat, lentil and garden pea define these earlier sites, whereas free-threshing wheat, bitter vetch, grass pea, broad bean, flax, fig, and pomegranate dominate IA sites. As an exception, emmer wheat occurs in comparatively high amounts in IA IIC Ashkelon (6). Although its large abundance is relativized by the generally high abundance of plant finds at the site, it can be interpreted here as a major crop, which is unusual, because emmer cultivation was no longer practiced in noteworthy scale from the 12th cent. BCE onward, and remained to be important only in Egypt until about 300 BCE, where it was of major importance for bread baking and beer brewing (Nesbitt and Samuel, 1996). Weiss et al. (2011b) suggest that emmer at Ashkelon was used as food at the site, but may have been imported from inland sites (Faust and Weiss, 2005). Grape reaches its highest numbers in the LBA sites. This can be understood in connection with the Egyptian hegemony over Canaan during the period. The archaeology of sites like Aphek (1, 2, 3) and Qubur el-Waleyide (22) point to an agricultural surplus production within the frame of the Egyptian tribute system and to wine deliveries from Canaan to Egypt. Concerning the fauna, the IA samples are mainly associated with wild taxa such as red deer, fallow deer, and felids. In the integrated dataset, felids are only represented by lion. This could be an indication of either prestige hunting, hunting for their fur or defensive kills. When we combine the results of the CA with attribute plots of individual taxa, we see LBA and IA samples tend to have a higher abundance of wild animal taxa. For the wild plant taxa, a meaningful diachronic clustering is difficult to interpret. For those IA samples that plot closely with the LBA samples a developed weed flora (including *Lolium temulentum*) and riparian grassland-dominated zones (e.g. *Rumex* spp., *Bupleurum* sp., *Phalaris* spp.), including taxa of overgrazed habitats (Asparagaceae, *Bellevalia* sp.) define the wild assemblages, whereas the cluster of IA II and EBA II-III samples are dominated by plant taxa characteristic of drier sediments (including xerophytes and halophytes, the latter of which may also derive from heavily irrigated plots). However, although these clusters are in good agreement with the environmental and agricultural developments in the Near East (Bar-Matthews and Ayalon, 2011; Cline, 2014; Langgut et al., 2015; Meller et al., 2015), they are not identical and merely represent trends.

Samples of multi-period sites follow the diachronic clustering mentioned above, further confirming a difference in taxonomic composition between EBA/MBA samples and LBA/IA samples. This is the case for Aphek (1, 2, 3), Tell es-Safi (16, 17, 24), Tel Yarmuth (18, 19), Shiloh (13, 14), and Megiddo (9, 10, 11, 12). Two samples plot further away from the other samples, the IA II from Qubur el-Waleyide (22) and the EBA II-III from Hirbet ez-Zeraqon (21). Hirbet ez-Zeraqon stands out from the other samples due to a high number of equids and by far the richest wild plant assemblage. Qubur el-Waleyide also has a high presence of taxa such as *Trifolium* and Xerophytes. Both taxa are not readily identified in other samples.

The diachronic patterns established through our integrated data are consistent with those from the individual fauna and botany datasets. Once again, we see that EBA and MBA samples are characterised by a wide variety of taxa in accordance with the mixed agropastoral economy at the time. Pigs and emmer are present in higher frequencies during these early periods. During the IA emmer is replaced by free-threshing wheat, and we see higher frequencies of wild animal taxa. The IA IIC Ashkelon sample is an exception where emmer is still abundant. We also see LBA and IA samples where the production of surpluses is indicated, corresponding to the increased trading relations during these periods.

Patterns in precipitation are weaker in the integrated dataset than in the separate datasets. However, we see some clustering of samples between 400-600mm, but we see generally better clusters for taxa than for samples. It is noticeable that typically arid-resistant animal taxa (e.g. ovicaprid and dromedary) and water-dependent taxa (e.g. cattle and pig) appear close to each other in the CA plots, confirming the trend we see in the separate dataset. Crop taxa, aside from their chrono-cultural association are also strongly linked with climatic and environmental factors. Because certain taxa, such as ovicaprids and cereals were so economically important, they have the potential to overwhelm the signal of informative but lesser abundant taxa in the dataset.

We see a clustering of sites at the elevation ranges of 0-100m and 500-600m. Taxa that need more moisture tend to be located at lower elevations, closer to water sources. However, the clustering of sites at different elevations cannot be confidently explained at this moment, probably since more variables are simultaneously at play here. Detailed GIS studies or stable isotope analysis will be able provide more insight in these questions.

4.3. Methodological challenges

In this project, we encountered several challenges, starting with the ways in which we can integrate faunal and botanical remains. A basic difference between faunal and botanical datasets is that individual records differ in their qualities as placeholders for living specimen, so despite differences in preservability of different bone types (Binford and Bertram, 1977; Lyman, 1994, 1984), finds of animal bones represent fragments of certain bones of the animal body and thus represent NISP (Grayson, 1984). Seed records, on the other hand, only represent parts of reproduction units of a mostly unknown entity, so there is no such equivalent for transferring a certain number of seeds into one individual. From a mathematical perspective the quantification problem, immanent to archaeobotanical assemblages, would need to be solved, for example by applying a conversion factor to the taxonomic records to receive placeholders for individual plants (Jacomet et al., 1989), before comparing this transferred botanical dataset to the faunal record. As such basic research is missing for Near Eastern floras, future studies may address these issues.

Besides this, the interpretive power of the recovered remains is incomplete for both disciplines. Both faunal and botanical remains represent household or cooking refuse, and in the case of plants, what people stored for later consumption, but in contrast to the faunal remains, plant remains usually do not reflect what went through human metabolism or only if the seeds derive from gut contents or human faeces. Finally, reports on botanical material will encompass most taxa which were available in the diet, whereas reports on faunal material are often lacking other important meat sources such as fish and birds; the former is especially important since we have large coastal areas in the southern and central Levant. We also have to accept the reality that due to the importance of ovicaprids and cattle in faunal assemblages and comparatively low species diversity, botanical assemblages are more likely to determine the trends we see in the integrated dataset, since they reflect environmental variability better. This is because they are generated through accumulations of wild taxa that were not used for human nutrition and as a result are more diverse. As opposed to viewing this as detrimental, however, it only supports the importance of integrating the two kinds of data to understand larger trends in subsistence.

The second challenge we faced, is the way in which faunal and botanical material are recovered and treated. All datasets show a considerable clustering of multi-period sites. Whenever we see this phenomenon, we need to be careful with our interpretation. Sometimes patterning can be attributed to biases introduced by either the excavators or analysts. In some cases, for example, when EBA samples plot together with IA samples from the same site (considering the chronological trend of our datasets shows differences between EBA and IA samples of the same site) we should take into consideration that there may have been difficulties in the stratigraphic dating of samples in the field or limitations during the laboratory process. We also observe that the separate datasets show stronger and clearer trends than the integrated dataset. This is because the individual datasets are represented by more sites and samples, but also because the integrated dataset amalgamates contradicting patterns between the faunal and botanical material or in other words, is dependent on whether faunal or botanical data dominate the integrated dataset. Such unbalanced representation of the two different data classes is visible, for example, at Iron Age II Khirbet el-Mudeyineh (see fig.9, no. 7), which is determined mainly by faunal data, whereas Iron Age II Qubur el-Waleyide or Iron Age II Aphek are almost exclusively clustering in response to botanical taxa.

Crop cultivation and animal husbandry are closely interlinked in agricultural systems (Bogaard, 2005; Dalman, 1932; Miller, 2001) and for subsistence. Our research shows the merit of integrative analyses when dealing with a large dataset for providing a synthesis. We found patterns in all three of our variables used here (chronology, mean annual precipitation and elevation), but also managed to put these in a framework of broader historical processes. If, however, we were to perform integrative analysis as part of standard procedure, and apply this methodology on a site-specific basis, we would be able to obtain more detailed knowledge on what happens locally regarding subsistence and agricultural practices. Gaining this knowledge, would in turn help us expand the historical framework and provide a better context to place and understand social and political changes.

5. Conclusion

Our separate and integrated datasets indicate developments in subsistence through time. We saw differences between EBA/MBA samples and LBA/IA samples corresponding with changes in society and economic practices. In our biplots the former is characterised by the presence of pig and shows a prevalence of emmer, the latter by the presence of dromedary and high amounts of free-threshing wheat, flax, and pomegranate. We see an indication of pigs being more present in one IA sample from a Philistine urban centre, but our dataset does not have enough Philistine material to confirm this. We should also note that the IA II witnessed the arrival of territorial states, which could influence the differences we see. Our datasets show differences between sites in higher and lower precipitation areas. Sites in lower precipitation areas are caused by a higher presence of arid adapted taxa, whereas those in higher precipitation areas are characterised by forest and shrubland adapted taxa. The main domesticated animals such as ovicaprids, cattle and pigs are present at all sites and are not affected by the amount of precipitation, indicating precipitation is not as important a variable regarding animal husbandry. With plants, some specific crop and wild taxa seem to be connected to some minor degree to precipitation ranges, such as free-threshing wheat often in sites in regions of higher precipitation. Elevation determines some trends, but as all our variables (and surely some others we have not investigated) they seem to be influenced by other factors. Possible explanations for the elevation variable should be discussed on a site-specific basis. Other relevant variables to consider are pastoral mobility, political hierarchies, and trade.

Our research attempts to show the merit of integrative analysis and argues for this to become part of standard procedure. To obtain a holistic understanding of subsistence (and agriculture), the first step is to provide faunal and botanical data fit for integrative analyses already on a site-specific level, (i.e. similarly extensive studies to produce equivalent datasets). This will not only improve our understanding on a local level but will help us reconstruct subsistence on a regional level as well since subsistence patterns are not determined by singular factors, but are modulated by environmental preconditions, cultural traditions, the economic layout, and many other factors within a continuously transforming regional system, and supra-regional relationships. This will not only allow us to get more detailed information about the interplay between plant and animals, but also help establish the framework to understand social and political changes. We still have trends to detect within these different scales of transformations which will help us find answers to fundamental questions of cultural change. Once we standardise integrative analysis, we will be able to not only work in a truly interdisciplinary way, but also gain a better understanding of subsistence patterns of the past and expand the framework we use to explain social and political developments in the region.

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SI 2: Additional graphs
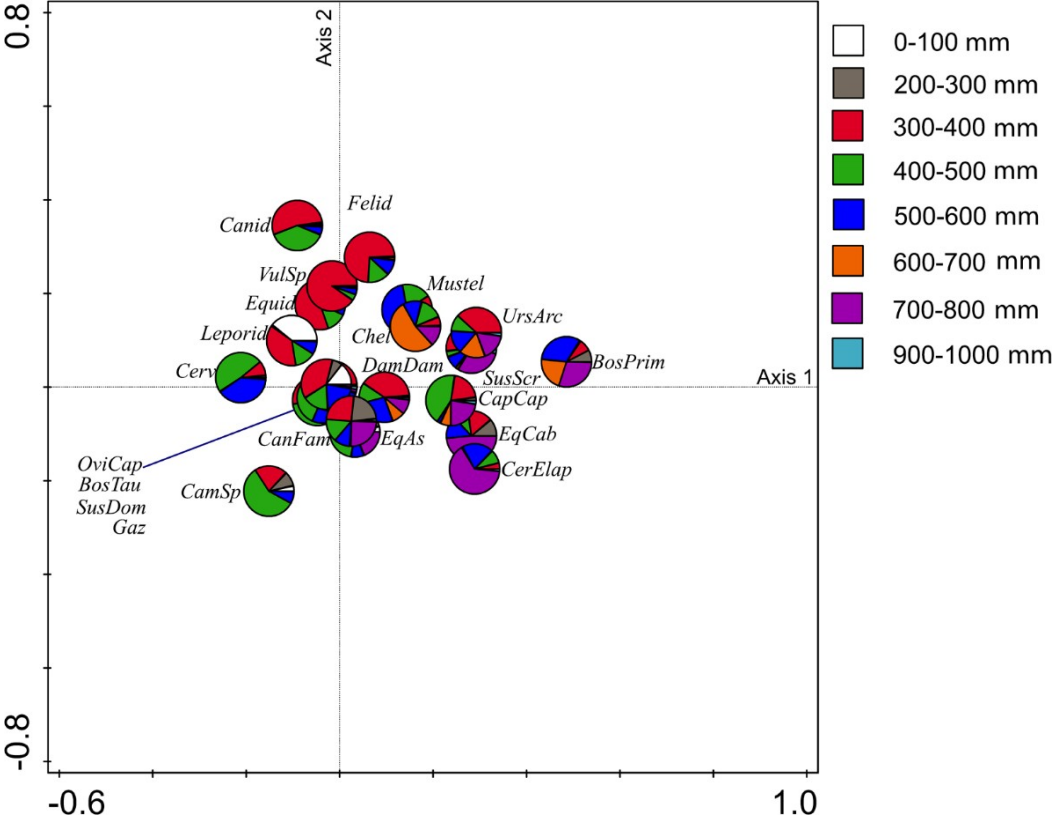
SI 2.1: Pie diagrams representing the presence of all faunal taxa against precipitation ranges, showing an explained variation (cumulative) of 15.29% on axis 1 and 27.35% on axis 2. The eigenvalues of axis 1 and 2 are 0.1277 and 0.1007, respectively.
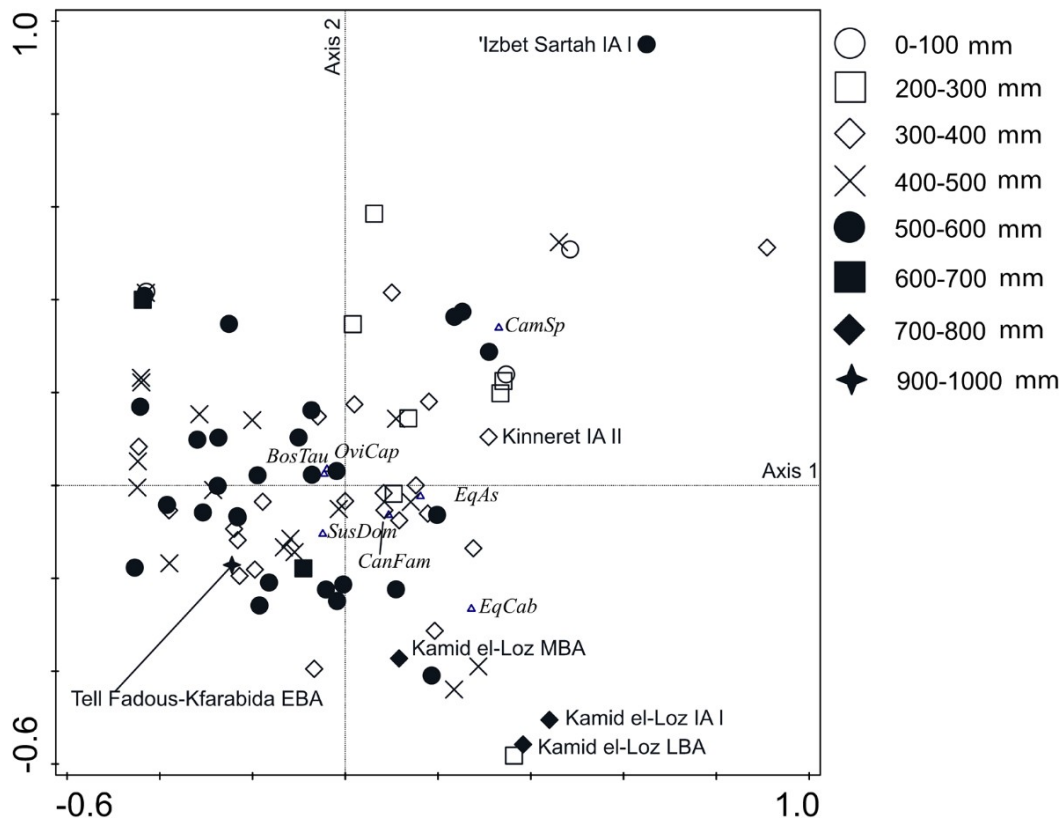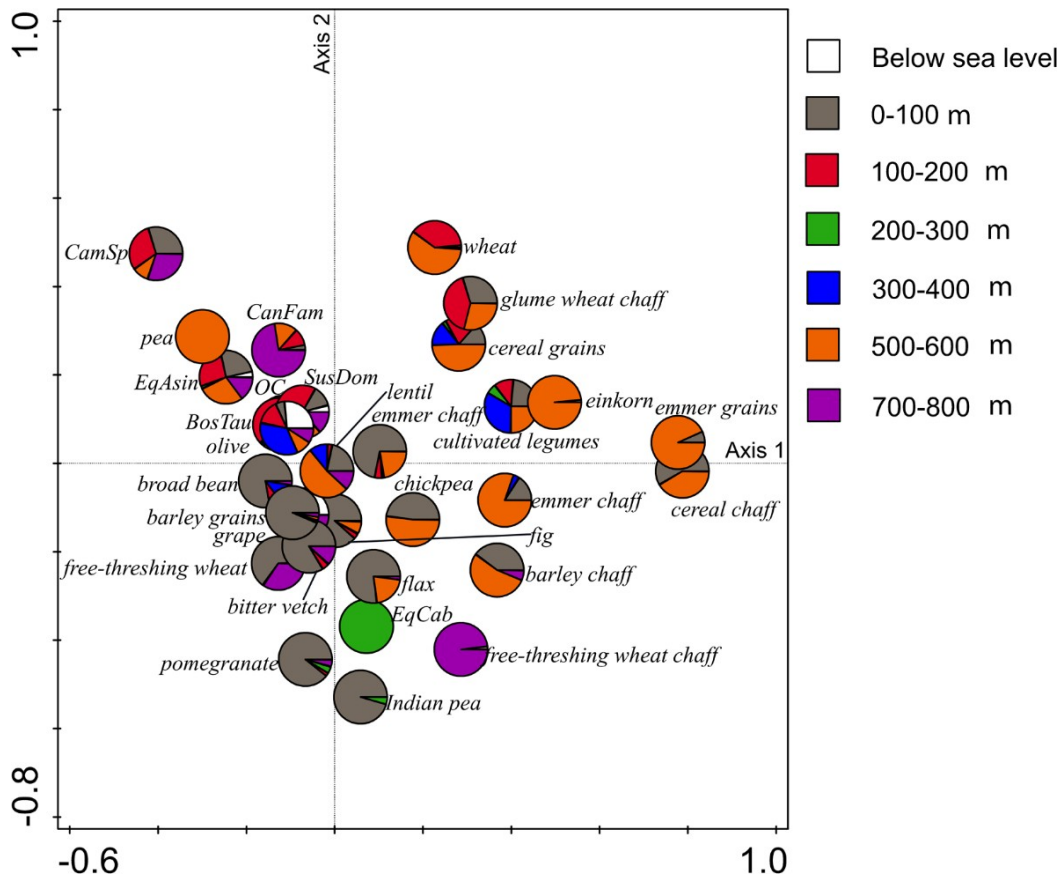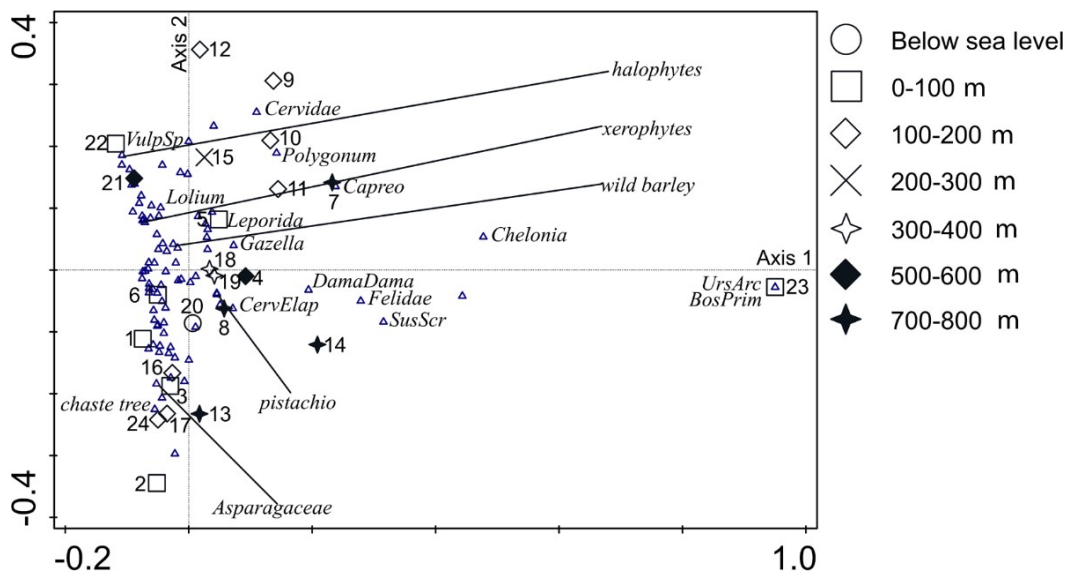
SI 2.2: CA biplot of fauna-domesticates against precipitation, showing an explained variation (cumulative) of 33.31% on axis 1 and 58.57% on axis 2. The eigenvalues of axis 1 and 2 are 0.0973 and 0.0738, respectively.
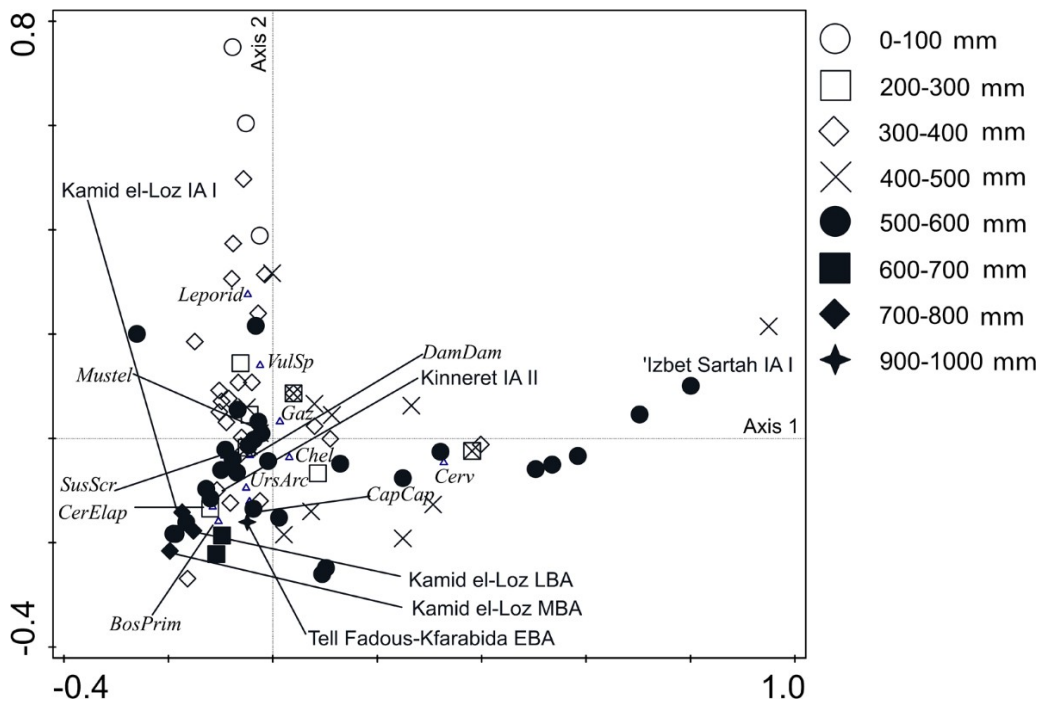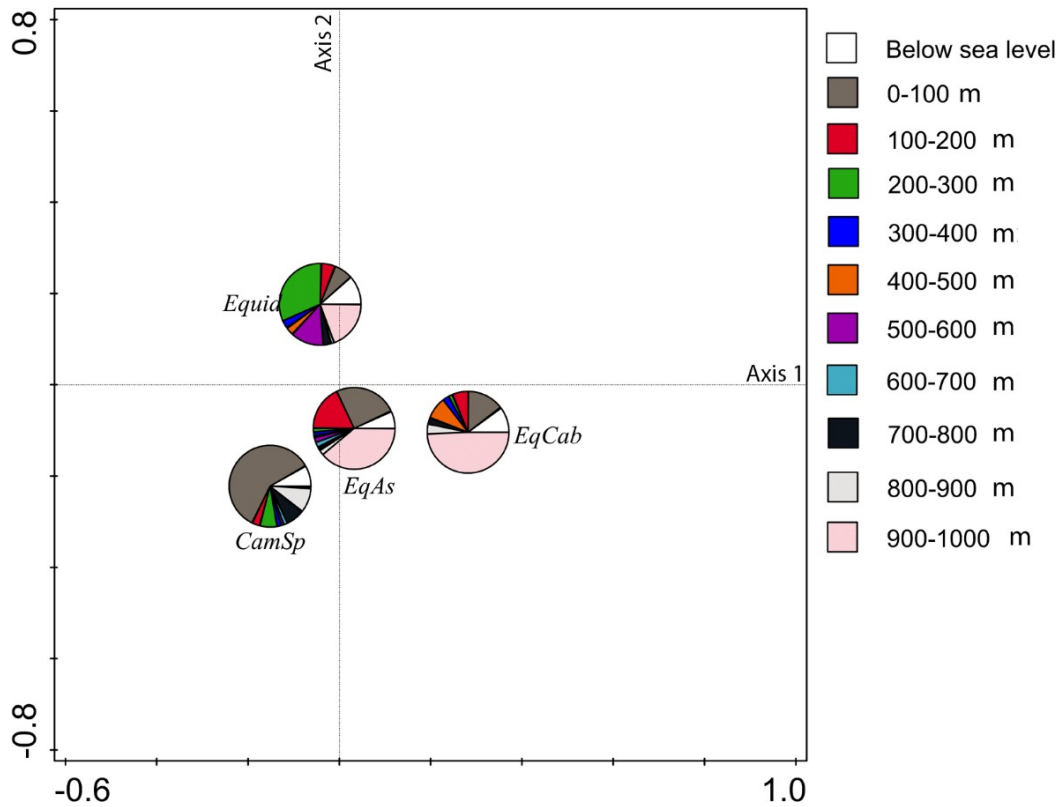
SI 2.4: Pie diagrams representing the presence of faunal taxa against elevation ranges, showing an explained variation (cumulative) of 15.29% on axis 1 and 27.35% on axis 2. The eigenvalues of axis 1 and 2 are 0.1277 and 0.1007, respectively.

SI 2.3: DCA biplot of fauna-wild against precipitation, showing an explained variation (cumulative) of 20.98% on axis 1 and 36.59% on axis 2. The eigenvalues of axis 1 and 2 are 0.3449 and 0.2567, respectively.
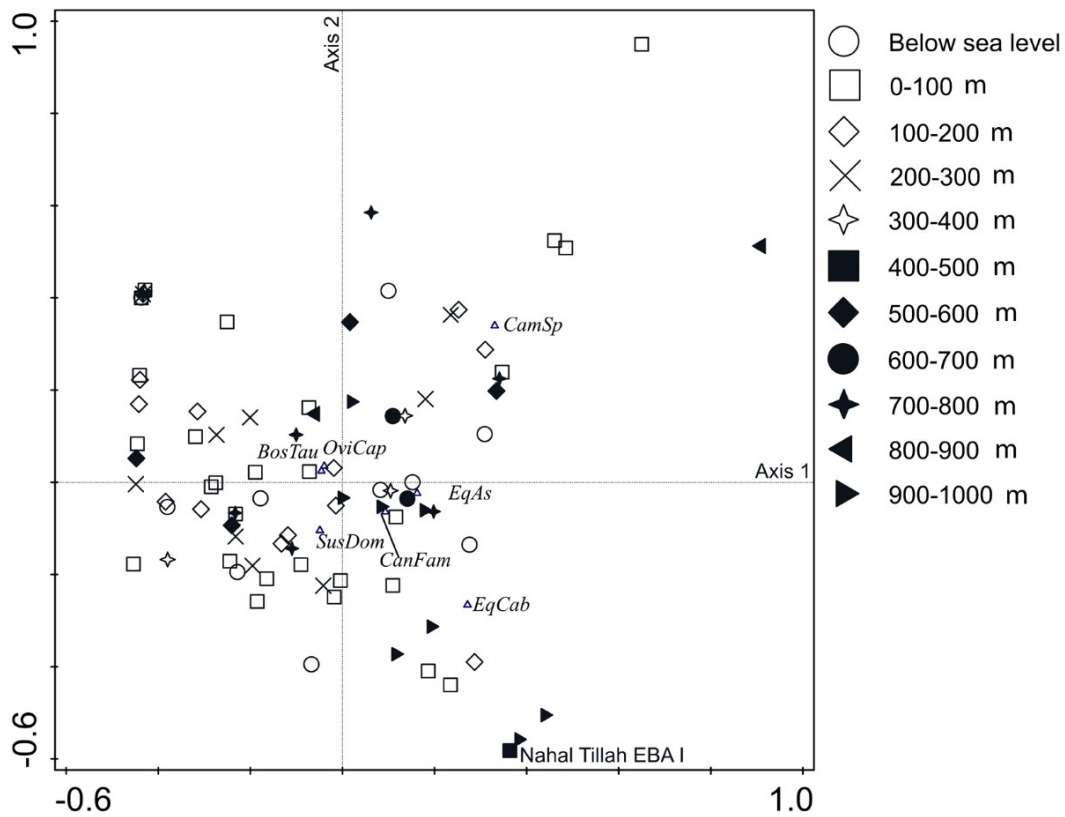
SI 2.5: CA biplot of fauna-domesticates against elevation, showing an explained variation (cumulative) of 33.31% on axis 1 and 58.57% on axis 2. The eigenvalues of axis 1 and 2 are 0.0973 and 0.0738, respectively.
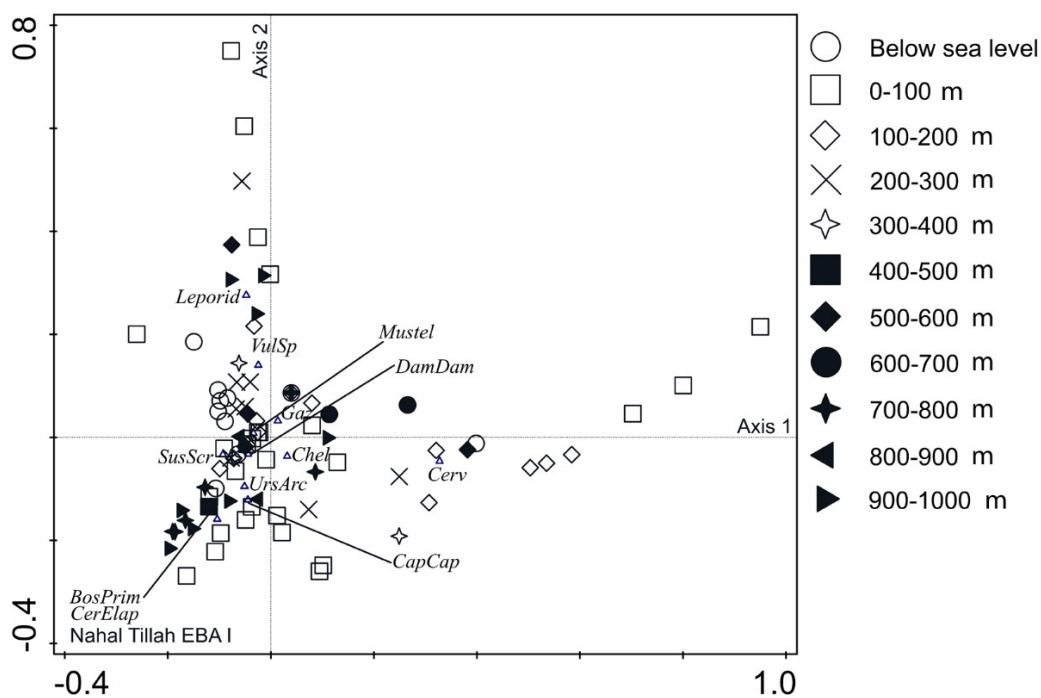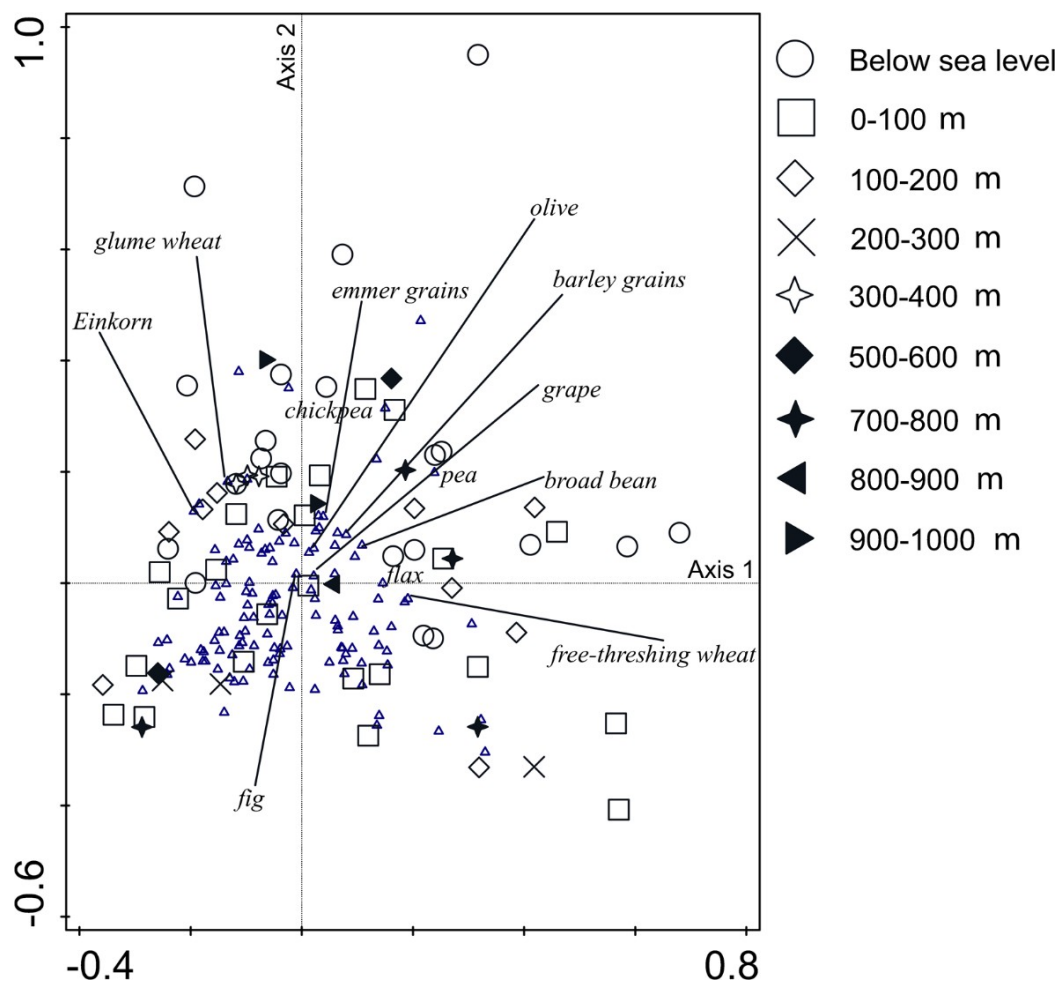
SI 2.7: CA biplot of botany-all-taxa against elevation, showing an explained variation (cumulative) of 8.79% on axis 1 and 15.53% on axis 2. The eigenvalues of axis 1 and 2 are 0.2516 and 0.1932, respectively.

SI 2.6: DCA biplot of fauna-wild against elevation, showing an explained variation (cumulative) of 20.98% on axis 1 and 36.59% on axis 2. The eigenvalues of axis 1 and 2 are 0.3449 and 0.2567, respectively.

SI 2.8: CA biplot of integration-all-taxa against chronology, showing an explained variation (cumulative) of 14.28% on axis 1 and 26.40% on axis 2. The eigenvalues of axis 1 and 2 are 0.3001 and 0.2549, respectively.

SI 2.9: DCA biplot of integration-wild against chronology, showing an explained variation (cumulative) of 14.65% on axis 1 and 26.17% on axis 2. The eigenvalues of axis 1 and 2 are 0.4340 and 0.3413, respectively.

SI 2.10: CA biplot of integration-domesticates against precipitation, showing an explained variation (cumulative) of 19.40% on axis 1 and 35.73% on axis 2. The eigenvalues of axis 1 and 2 are 0.2310 and 0.1945, respectively.

SI 2.11: Pie diagrams representing the presence of domesticates against precipitation ranges, showing an explained variation (cumulative) of 19.40% on axis 1 and 35.73% on axis 2. The eigenvalues of axis 1 and 2 are 0.2310 and 0.1945, respectively.
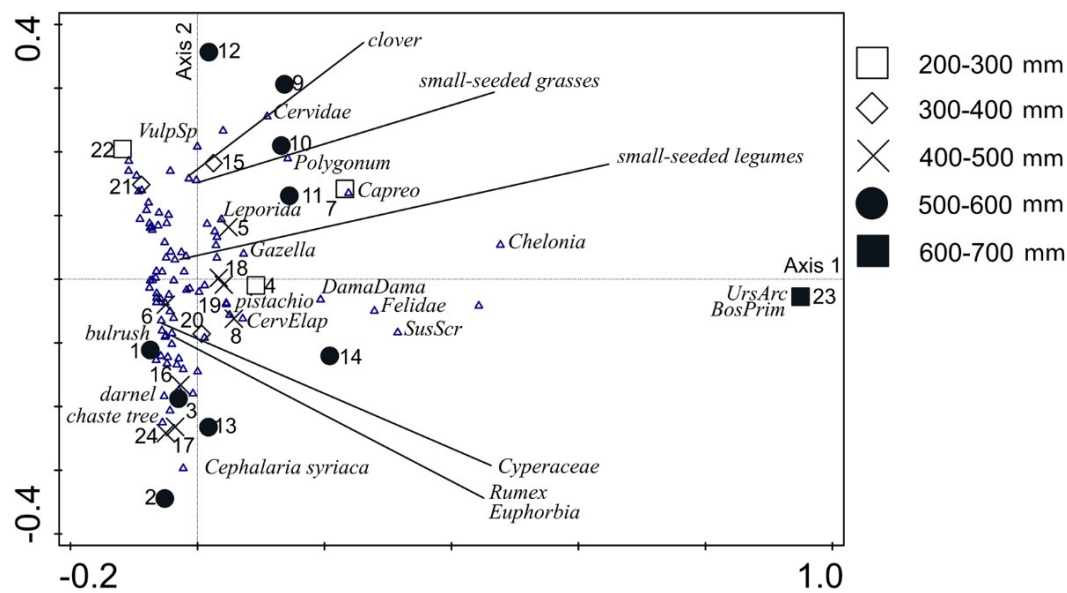
SI 2.12: DCA biplot of integration-wild against precipitation, showing an explained variation (cumulative) of 14.65% on axis 1 and 26.17% on axis 2. The eigenvalues of axis 1 and 2 are 0.4340 and 0.3413, respectively.

SI 2.13: Pie diagrams representing the presence of domesticates against elevation ranges, showing an explained variation (cumulative) of 19.40% on axis 1 and 35.73% on axis 2. The eigenvalues of axis 1 and 2 are 0.2310 and 0.1945, respectively.

SI 2.14: DCA biplot of integration-wild against elevation, showing an explained variation (cumulative) of 14.65% on axis 1 and 26.17% on axis 2. The eigenvalues of axis 1 and 2 are 0.4340 and 0.3413, respectively.

Appendix 2

Vermeersch, S., Riehl, S., Starkovich, B. M., Streit, K., Höflmayer, F., 2021. Animal husbandry from the Middle Bronze Age through the Iron Age in the Shephelah – Faunal remains from the new excavations at Lachish. *Archaeological and Anthropological Sciences ,*13(3), pp. 1-16.

Attached is the final, published article.

Supplementary info 1 can be accessed online through the DOI.

ORIGINAL PAPER

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 δ18O 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 northeastern 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 (Behrensmeyer 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 (*Bos taurus*)	332	11.2	4
Medium-large ungulate	1	0.0	-
Medium ungulate	396	13.4	-
Donkey (*Equus asinus*)	26	0.9	1
Fallow deer (*Dama dama*)	24	0.8	1
Pig/boar (*Sus* sp.)	29	1.0	1
Ovicaprid	1011	34.2	11
Goat* (*Capra hircus*)	256	8.7	11
Sheep* (*Ovis aries*)	86	2.9	14
Gazelle (*Gazella* sp.)	35	1.2	2
Hare (*Lepus* sp.)	4	0.1	1
Tortoise	38	1.3	1
Large carnivore	2	0.1	-
Dog (*Canis familiaris*)	96	3.2	2.0
Cat (*Felis catus*)	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 (*Bos taurus*)	25	8.3	2	22	7.5	1	12	3.8	1
Donkey (*Equus asinus*)	-	-	-	7	2.4	1	-	-	-
Medium ungulate	18	6.0	-	39	13.4	-	33	10.3	-
Fallow deer (*Dama dama*)	5	1.7	1	1	0.3	1	2	0.6	1
Pig/boar (*Sus* sp.)	5	1.7	1	4	1.4	1	-	-	-
Ovicaprid	150	49.7	5	140	47.9	4	215	67.2	12
Goat* (*Capra hircus*)	8	2.6	1	16	5.5	1	40	12.5	5
Sheep* (*Ovis aries*)	7	2.3	1	31	10.6	2	28	8.8	3
Gazelle (*Gazella* sp.)	3	1.0	1	3	1.0	1	4	1.3	1
Hare (*Lepus* sp.)	-	-	-	1	0.3	1	-	-	-
Dog (*Canis familiaris*)	7	2.3	1	15	5.1	1	3	0.9	1
Fox (*Vulpes* sp.)	-	-	-	5	1.7	1	-	-	-
Cat (*Felis catus*)	-	-	-	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
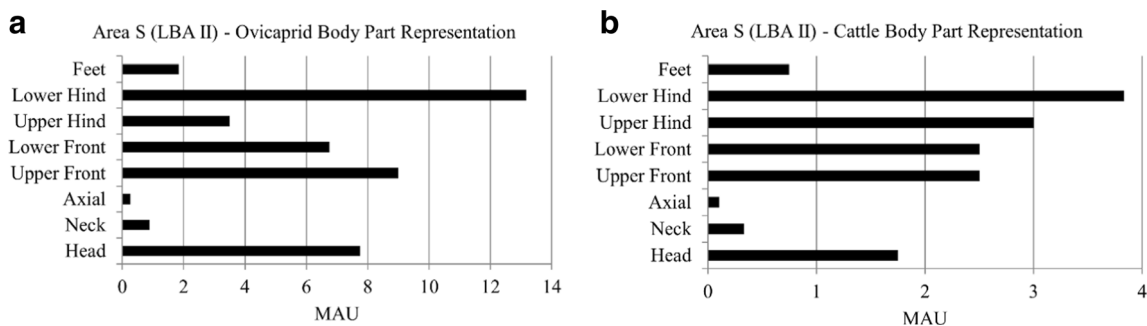
Fig. 2 Body part representation for ovicaprids (a) and cattle (b) during the LBA II in area S

a Area P - Ovicaprid Body Part Representation (MBA III)

b Area P - Ovicaprid Body Part Representation (LBA II)

c Area P - Ovicaprid Body Part Representation (IA II)
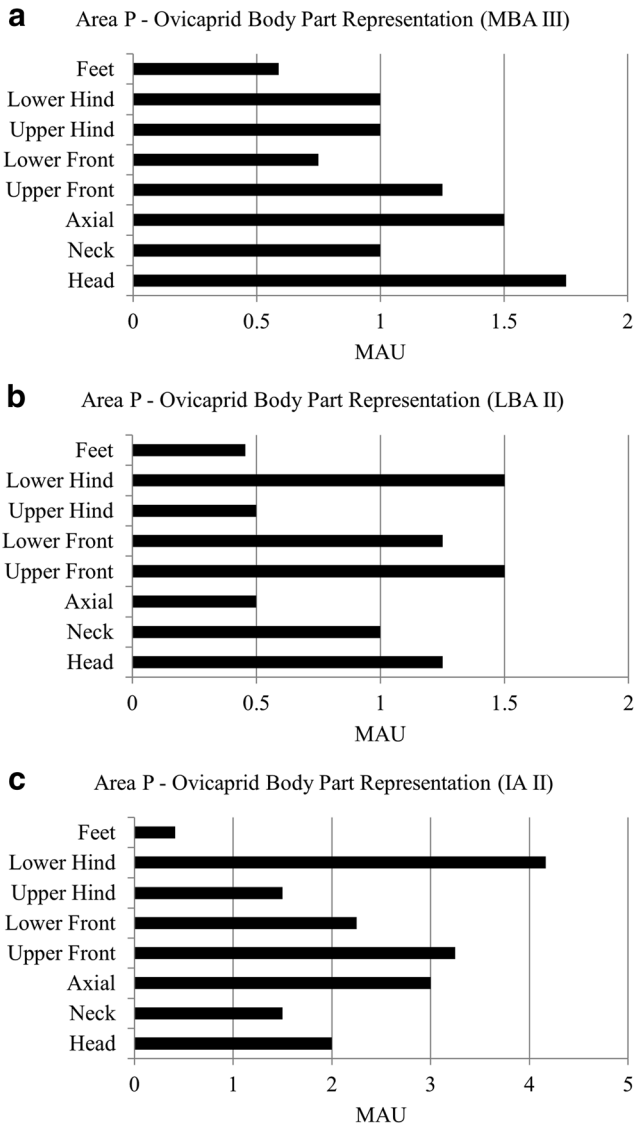
Fig. 3 Body part representation for ovicaprids through time in area P. A: body part representation during the MBA III, B: body part representation during the LBA II, C: body part representation during the IA II

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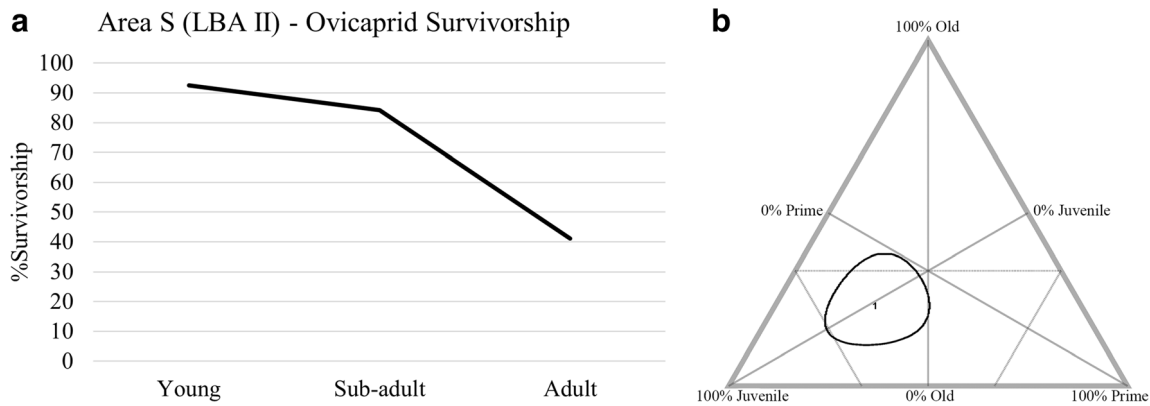
Fig. 4 Ageing for ovicaprids during the LBA II in area S. A: %survivorship graph based on epiphyseal fusion. B: tripolar graph represented by 29 juvenile, 14 prime aged adult, and 13 old specimens

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
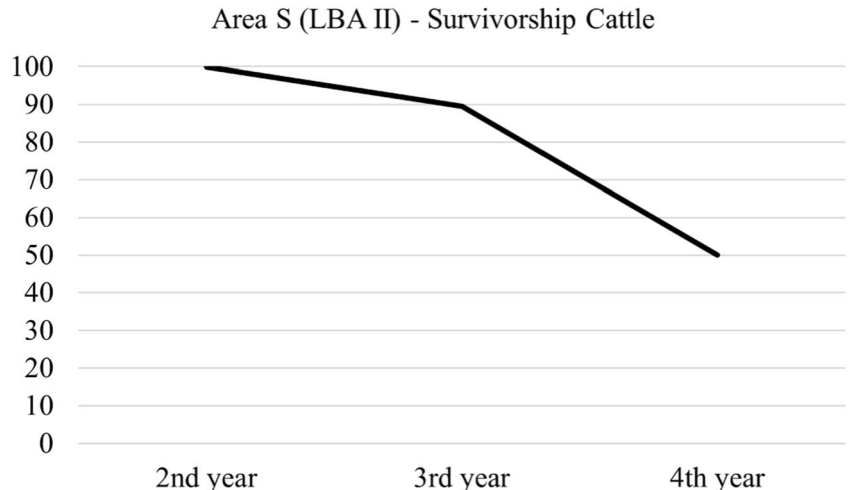
Table 6   Epiphyseal fusion data for ovicaprids in area P

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

Area P - Ovicaprid Survivorship
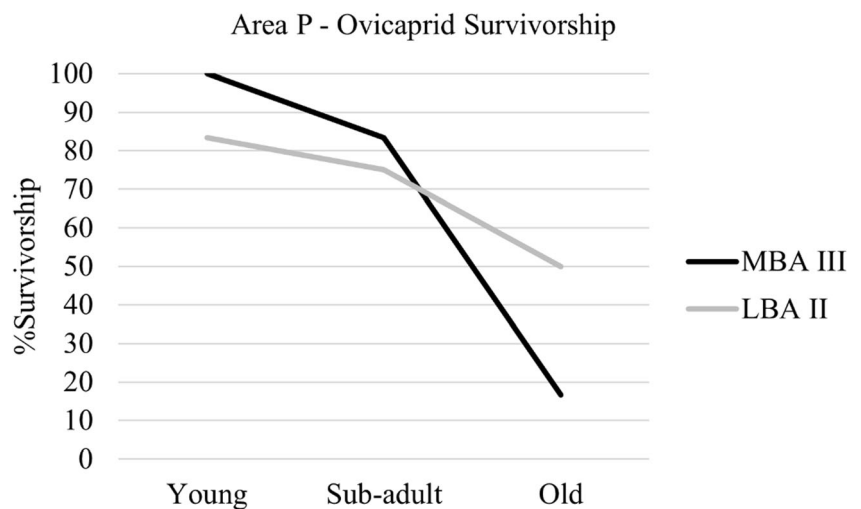
Table 7 Results of the mixture analysis performed on the distal breadth measurements of the first phalanx on ovicaprids

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
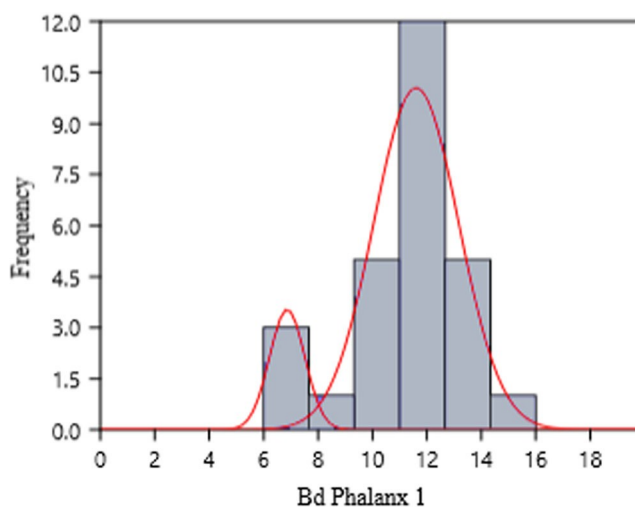
Fig. 7 Mixture analysis for ovicaprids during the LBA II in area S

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	-	-	-	-
	Second phalanx	-	-	1	-	-
Medium ungulate	Cervical vertebra	1	-	-	-	-
	Thoracic vertebra	-	1	-	-	-
	Rib	2	-	-	-	-
	Lumbar vertebra	1	-	-	-	-
	Pelvis	1	-	-	-	-
	Metatarsal	1	-	-	-	-
Pig	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). Tell Miqne/Ekron and Tell el-Hesi had

sheep outnumbering goats. Age data at Tell Miqne/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

(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

Site	Sheep	Goat	OC	S:G	Reference
Lachish IA II	325	265	1,861	1.23	(Croft 2004a; Lernau 1975; this paper)
Tel Halif IA II	65	177	217	0.37	(Sapir-Hen, 2015)
Tell Miqne/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; Lernau 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	(Lernau 1988)
Tell Miqne/Ekron LBA	196	95	1,437	2.06	(Lev-Tov 2010, 2000)
Lachish MBA	295	147	2,751	2.01	(Croft 2004a; Lernau 1975; this paper)
Tell Miqne/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)
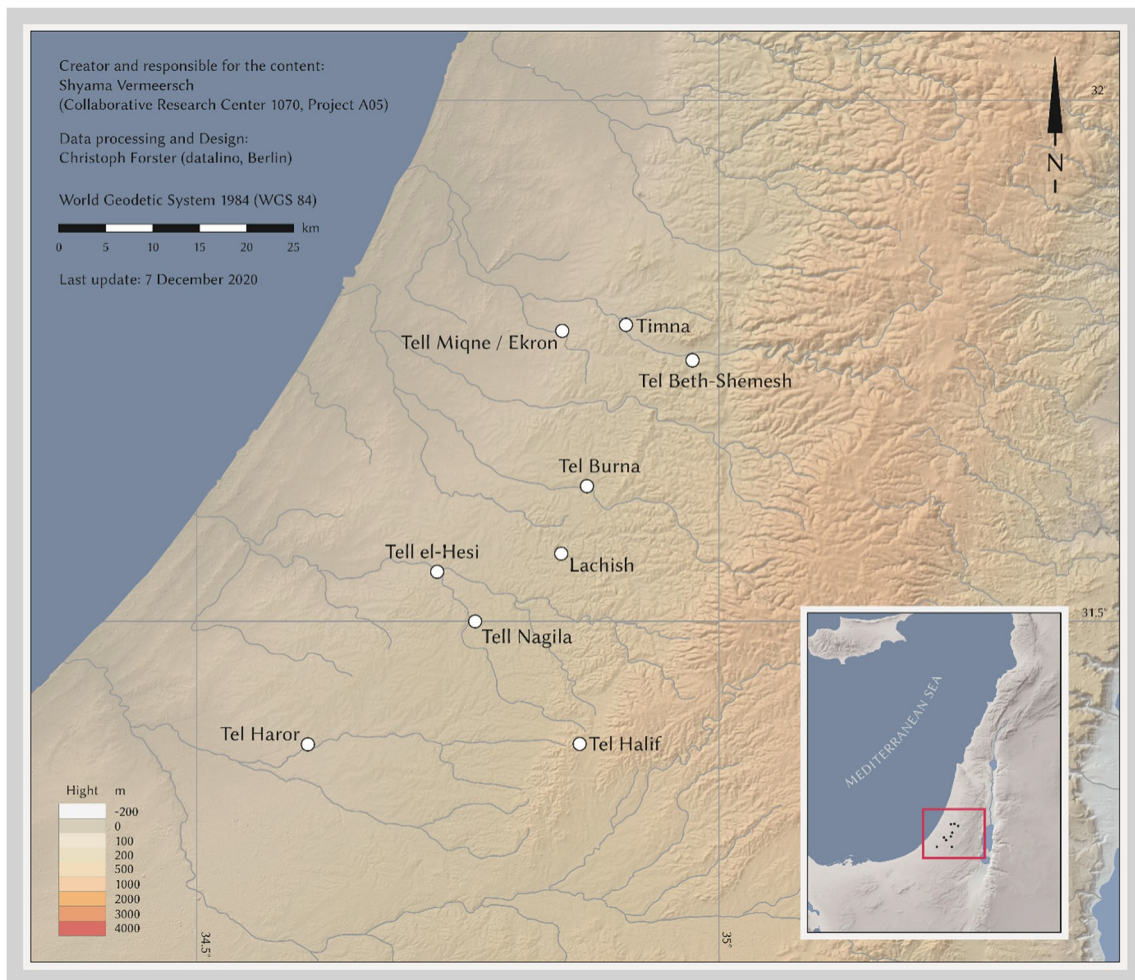
Fig. 8 Map showing the location of Lachish and the sites used for comparing subsistence patterns

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.

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

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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Supplementary Information 2: Additional figures
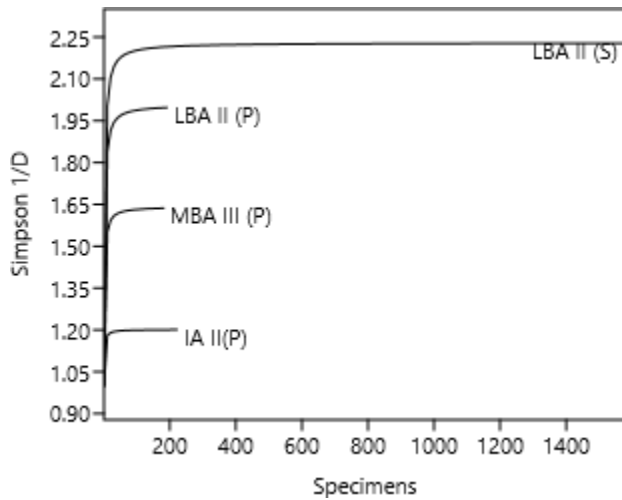
SI 2.1: Results of the individual rarefaction to check the effect of sample size (specimens) on taxonomic richness (inverse Simpson's, 1/D). The graph shows the variables are independent.
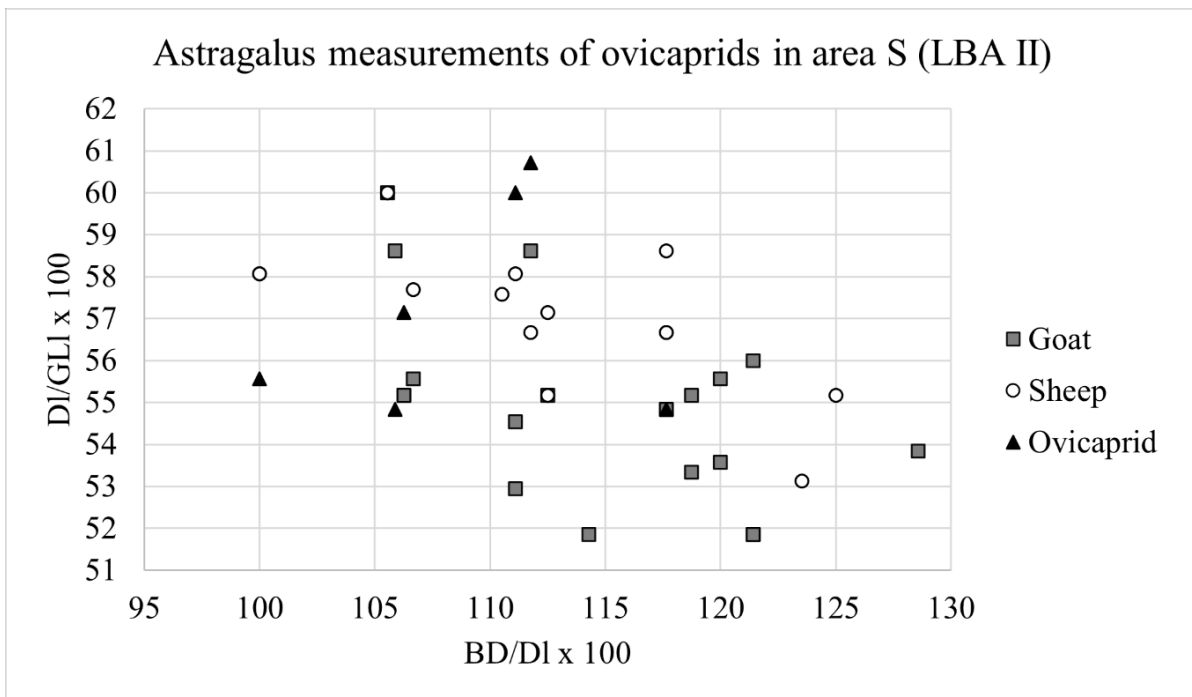
SI 2.2: Scatterplot expressing the shape of 41 ovicaprid astragali by using the following measurements established by Von den Driesch (1976): Dl = (greatest) depth of the lateral half, GLl = greatest length of the lateral half, and BD = (greatest) breadth of the distal end. Sheep tend to have larger Dl/GLl x 100 ratios than goats. This graph shows our morphological identification have an accuracy of 85.4%, seeing only three specimens morphologically identified to sheep are positioned in the goat group, and three specimens morphologically identified as goat are positioned in the sheep group.
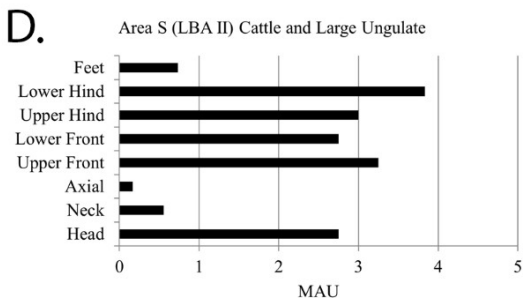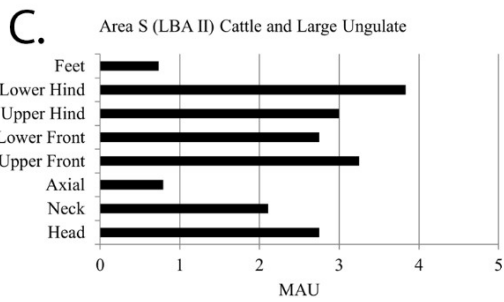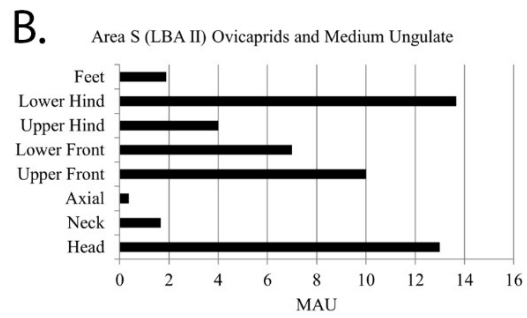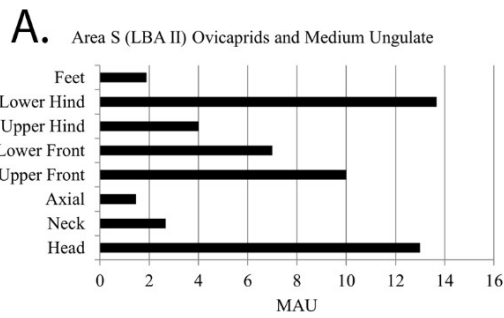
SI 2.3: Anatomical profiles of ovicaprids combined with medium ungulates and cattle combines with large ungulates for the LBA II in area S. A: anatomical profiles of ovicaprids combined with medium ungulates, including vertebrae and ribs. B: anatomical profiles of ovicaprids combined with medium ungulates, excluding cervical, thoracic, lumbar, and sacral vertebrae and ribs. C: anatomical profiles of cattle combined with large ungulates, including vertebrae and ribs. D: anatomical profiles of cattle combined with large ungulates, excluding cervical, thoracic, lumbar, and sacral vertebrae and ribs.
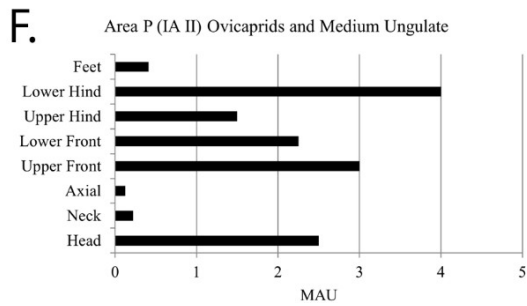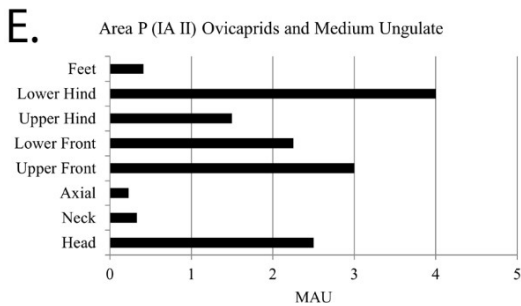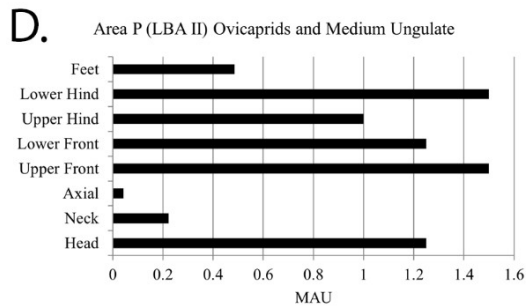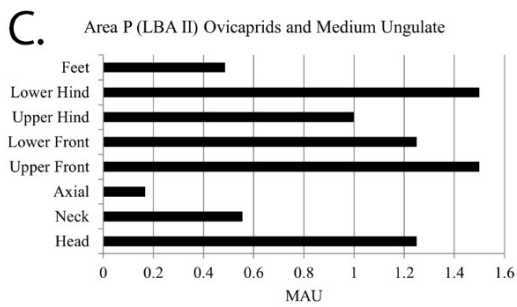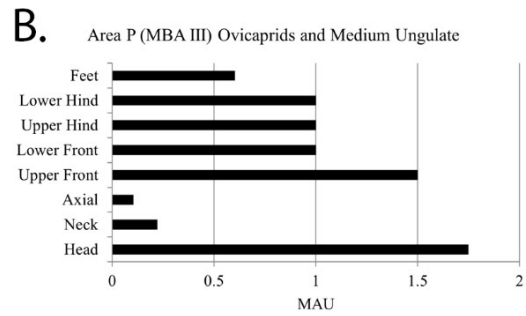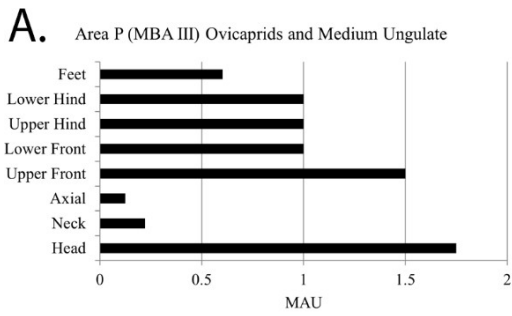
SI 2.4: Anatomical profiles of ovicaprids combined with medium ungulates through time in area P. Graphs A, C, and E show anatomical profiles of ovicaprids combined with medium ungulates, including vertebrae and ribs. Graphs B, D, and F show anatomical profiles of ovicaprids combined with medium ungulates, excluding cervical, thoracic, lumbar, and sacral vertebrae and ribs.
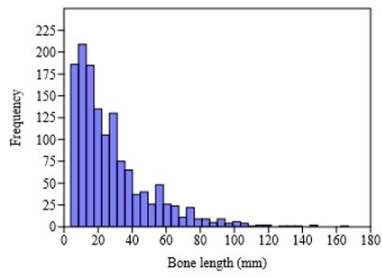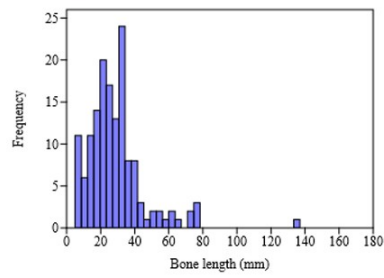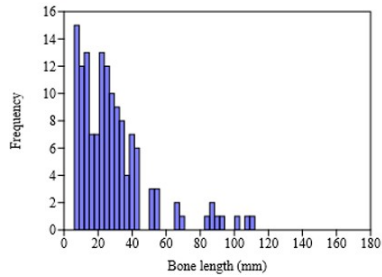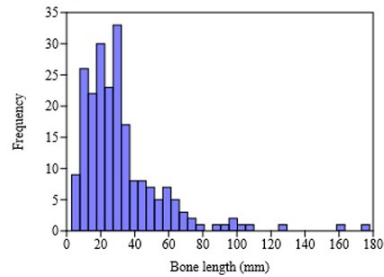
SI. 2.5: Histograms depicting the measurements of bone length in mm. A = the LBA II sample in area S, B = the MBA III sample in area P, C = the LBA II sample in area P, and D = the IA II sample in area P.

Appendix 3

Vermeersch, S., Riehl, S., Starkovich, B. M., Kamlah, J., Integrating faunal and botanical remains using multivariate statistics to reconstruct developments in subsistence in (pre)history. *MethodsX,* 8*,* pp.101336.

Attached is the final, published article.

Supplementary info can be accessed online through the DOI.

Method Article

Integrating faunal and botanical remains using multivariate statistics to reconstruct (pre)historic subsistence developments

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a b s t r a c t

Archaeological faunal and botanical remains are often treated and published separately to understand past subsistence practices. This distinction is an arbitrary one based on methodological differences, especially since we know from ethnological sources that animal husbandry and crop cultivation are usually interdependent in agricultural systems. Here, we use correspondence, detrended correspondence, and canonical correspondence analyses to integrate these different lines of evidence. We customise this method by:

- Adjusting criteria to select and prepare data for integration.
- Including independent parameters such as chronology and mean annual precipitation to study relationships.
- Presenting additional visualisations of data to aid interpretation.

The customised method we present can be applied to any time period, geographical region or research question, as long as botanical and faunal data are available. By analysing these data in an integrative way, we can improve our knowledge of subsistence and agriculture, which in turn can provide a context to better understand social and political changes in past societies.

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Specifications Table

Subject Area	
More specific subject area	Archaeology
Method name	Correspondence Analysis
Name and reference of original method	Correspondence Analysis
	Smith, A., Munro, N.D. [44]. A Holistic Approach to Examining Ancient Agriculture: A Case Study from the Bronze and Iron Age Near East. Curr. Anthropol. 50, 925–936. https://doi.org/10.1086/648316
Resource availability	Any statistical software able to run multivariate statistics (e.g., Canoco 5, SPSS, PAST)

Method details

Data selection and preparation

Before performing multivariate analyses to integrate archaeological faunal and botanical remains, analysts need to select and prepare these data. The criteria we use in our customised method are based on those established by Smith and Munro [44] but we elaborate on them. The created dataset should be a cross table, representing taxa (variables) and samples (cases). Whether taxa are represented in rows or tables will depend on the statistical software used. In Canoco 5, both options are possible. We recommend publishing the obtained dataset in the supplementary information so readers can replicate the results. Here, we provide specific recommendations based on our research question to investigate general patterns in subsistence from the Bronze through Iron Age in the southern and central Levant. Analysts should note parameters can differ depending on their research question.

First, analysts must decide whether to use quantitative (abundance measures) or binary (presence/absence) data. Advantages and disadvantages of different data types heavily depend on the primary research question and are discussed in various archaeobotanical reports (e.g., [2,3]). When using quantitative data, we recommend using NISP (number of identified specimens) for faunal remains and seed/chaff counts for botanical remains. We believe that, at present, NISP is the best suited counterpart to seed count since both represent primary data which reflect observed specimens [9,32,33]. These two quantitative measures are also most frequently provided in archaeological reports. When selecting data from published reports for one's dataset, make sure they represent the same types of contexts, i.e., only compare samples from household contexts when looking for an overall dietary or economic pattern or only use data from ritual or burial contexts from different sites when looking for regionally diverse ritual practice. Additionally, only include reports which present data for both wild and domesticated taxa when trying to obtain a complete understanding of subsistence (this is a criterion we added to those established by Smith and Munro [44]). Furthermore, try to preferably use data that have been achieved through standardised methods of sampling and sample processing.

Second, analysts need to decide how to classify their data: for example, cases (samples) per relative dating (e.g., Early Bronze Age), absolute dating (3600–2000 BCE), or function (urban vs. rural), variables (taxa) per biological, ecological, or economic characteristics. In the dataset we provide here as an example (raw data see SI 1), we classified our data using relative dating.

Third, as a part of data manipulation, analysts need to broaden taxonomic categories to account for the different levels of taxa identification between analysts since they will identify specimens to a different taxonomic level. An example in our dataset is to merge *Dama dama, Dama mesopotamica,* and *Dama dama mesopotamica* to *Dama* sp. Similarly, archaeobotanists use a broad range of individual taxonomies to compensate for diverse uncertainties during the identification process, resulting in an immense number of taxa in large datasets with very low overall ubiquities. To receive interpretable patterns, one would need to amalgamate taxa names that are beyond the species level. When using correspondence analyses, different levels of taxonomic identifications are possible, so the dataset can have specimens identified to the species levels and, for example, family level.

Fourth, analysts need to establish a threshold for the presence of taxa in their dataset [8]. This threshold can vary between 5 and 10% and will depend on how many samples there are in the dataset

[8]. Establishing such a threshold is important since rare taxa will introduce strong numerically based patterns into the biplot of the correspondence analyses that reduce the visibility of associations of the better represented taxa, i.e., we see patterns that are based on the lack of presence rather than on meaningful contextual relationships. In our dataset, we used a 5% threshold for the presence of a taxon in all samples.

Finally, when using abundance data and working with a dataset with many samples, analysts need to establish a threshold for the total number of specimens per sample. For botanical remains we recommend samples have a minimum of ten taxa and a minimum abundance of a 100 seed counts. Higher thresholds are better [48], but are frequently not provided in archaeobotanical studies. For faunal remains, we recommend running some test biplots for correspondence analyses in 100 NISP increments until a threshold is reached where samples with too little data are eliminated but the trends in the data are still visible. Alternatively, when dealing with a small dataset, one can drop the abundance threshold in favour of gaining more comparative material, which we did for the dataset provided here. There are no fixed ruled for establishing this threshold.

Once analysts have selected and prepared their data, they should prepare several specific datasets depending on their research question and parameters. For example, in our dataset we investigate general subsistence practices, so we made three datasets: a domesticated, wild, and all available taxa dataset. The domesticated taxa dataset allows to investigate agricultural patterns and practices, and the wild taxa dataset allows to investigate the environment and the role of hunting, agricultural techniques via weeds, and fodder. The dataset with all available taxa combines these data and provides an in-depth look into subsistence practices in their entirety. Note that when making the domesticated and wild taxa dataset, analysts might have to re-evaluate the presence and abundance thresholds. Analysts should also choose some known parameters or classifiers to explore their dataset. One possibility would be to group cases (samples) according to such parameters following point two in data preparation (e.g., relative dating). Other examples are mean annual precipitation or elevation. Finally, once analysts have chosen their classifiers, it is important to check the distribution of samples within these, i.e., whether the samples evenly contribute to these set categories. Establishing this can help interpret the integrative data, by knowing which, for example, zones of mean annual precipitation are underrepresented in your data.

Types of correspondence analysis

Multivariate statistics consist of a wide range of methods. For our integrative analyses, we focus on correspondence analysis (CA), detrended correspondence analysis (DCA), and canonical correspondence analysis (CCA). These types of statistical analyses are useful to recognise patterns in larger datasets and provide several benefits, outlined by Ter Braak [47]:

- Both quantitative and binary data are accepted.
- large numbers of taxa are allowed (10–500 taxa).
- Allows a dataset containing many zero values.
- Manages to show a non-linear, unimodal relationship between taxa and quantitative environmental parameters.

CA, DCA, and CCA are visualised by a biplot. The first axis (the horizontal axis) represents the greatest amount of variance within the data, whereas the second axis (the vertical axis) represents lesser variance [25]. It is important to remember correspondence analyses are multivariate statistics, meaning these axes only manage to give a two-dimensional view of results. It is good practice to check the biplots represented by other axes (the third and fourth axis), especially when patterns are unclear.

Sometimes, when running a CA, analysts will see the points in the biplot are scattered in the shape of an arch, which is called the 'arch effect' [21]. Whenever this occurs, analysts should run a DCA, which will remove the arch by detrending the data using polynomials or segments [46]. We recommend first trying to detrend data using polynomials, and if this does not work, to use segments. For example, in our dataset, we use second-order polynomials for detrending.

CCA helps recognizing patterns against known parameters, it does this by constraining the ordination axes to assess the effect they have on the data [45]. Analysts are free to choose any parameter but should publish the criteria for these parameters. For example, in our dataset we use chronology and mean annual precipitation as parameters, so we need to provide these data either as raw data or by a representative map. The advantage of CCA is that its results can be tested for the statistical significance of the null hypothesis by performing a Monte Carlo permutations test.

Data interpretation

The results of the correspondence analyses are expressed in a biplot which shows both taxa (variables) and samples (cases). It is important to check the explained cumulative variation of the correspondence analysis for the first and second axis (or the other appropriate axes) to see how much variation is explained by the two axes. There are no statistical tests which can provide the significance of the results for CA and DCA, so it relies on a critical, visual assessment of the data. It is useful to visually classify the samples per parameter to aid in interpretation. For example, in our dataset, we give samples with a different relative dating a different symbol (Fig. 1). The closer a taxon is located to the origin of the biplot (the point where the two axes cross), the more common it is throughout all samples and as such is not ideal to differentiate between samples. Samples with similar taxa composition and proportions will plot in close vicinity to each other, essentially forming a group or cluster. When outliers are present, so samples plotting separately or far from other samples or clusters, analysts should investigate why they are different and then create a biplot leaving these outliers out. Sometimes, this will change the way your samples plot, other times it will not change anything. When interpreting the biplot it is important to also check the raw data of the dataset and reread the original reports. Often, this will help to understand the observed clustering of samples or will enable the analysts to explain outliers. The biplot of a CCA should be interpreted similarly, although the software amalgamates samples of one category (Fig. 2). We recommend always running a CCA since this can test the statistical significance and help you recognise which groups cluster together, followed by a (D)CA where one can see more details on what taxa are associated with what samples or clusters.

Another useful type of biplot to help interpret the dataset, is to plot the taxa as pie charts to see their contribution to your chosen sample categories (e.g., mean annual precipitation) instead of plotting the samples (Fig. 3). These biplots are more intuitive to interpret, since one only need to look at the proportions reflected by the different sections of the pie diagram to see in where the taxon occurs most frequently. We recommend using quantitative data for making these biplots. We suggest making these plots for taxa which seem promising or are regarded as important for past subsistence. It can also be used to verify trends where one taxon lost popularity in favour for another.

Finally, attribute plots of a taxon or several taxa can be helpful for interpreting your data (Fig. 4). Our recommendations are similar to those for the biplots expressing taxa as pie diagrams, namely using quantitative data and taxa which are of interest. These biplots are easy to interpret, the bigger the symbol, the more frequent the taxon appears in the sample. Analysts will notice the position of the samples in the attribute plot is the same as in the (D)CA biplot.

Method validation

We first applied the methodology described here to investigate developments in subsistence practices from the Early Bronze Age through the Iron Age (3600–586 BCE) in the central and southern Levant. We investigated how the results of the correspondence analyses for the integrative dataset compared to those of the separate faunal and botanical datasets [49]. In this paper, we will use the same integrative dataset but instead of quantitative data, we will apply binary data to show that using either quantitative or binary data will usually yield similar results. The dataset uses a 5% taxa presence threshold and consists of 24 samples representing 15 sites (Table 1), which we have selected and prepared using the guidelines described earlier. We also provide the distribution of the parameters used in our dataset (Table 2). The raw data we used for the correspondence analyses and the legend of the sites can be found in SI 1.
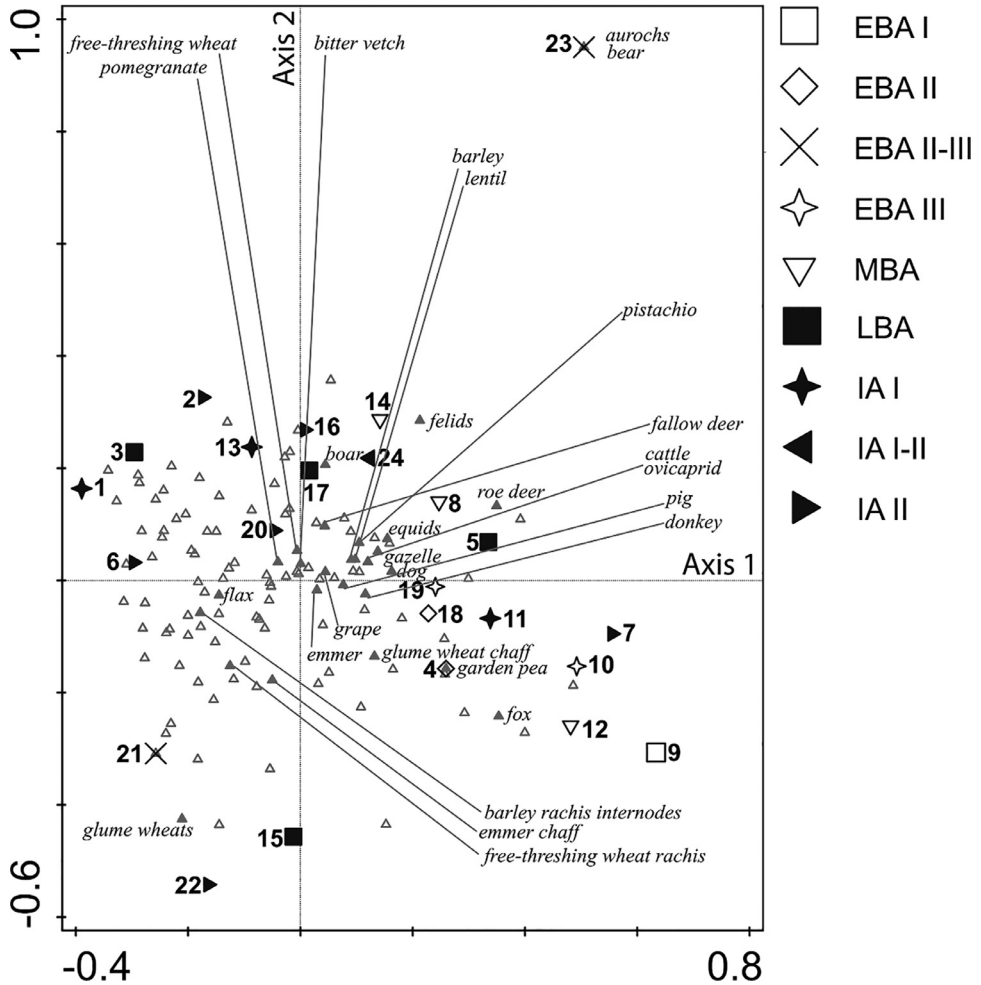
Fig. 1. DCA biplot of our integrative dataset, showing an explained cumulative variation of 13.02% on axis 1 and 22.63% on axis 2. The eigenvalues of axis 1 and 2 are 0.2799 and 0.2065, respectively.

We use the Canoco 5 software to perform a detrended correspondence analysis on our integrative dataset and classify our data using relative chronology. The biplot presented here (Fig. 1) has been cleaned and is not the original output from the Canaco 5 software (we provide a step-by-step manual on how to use Canoco 5 most efficiently in the additional information section of this paper). First, we try to observe clustering of samples, or relationships in the biplot representing the first two axes. We see that the samples of the Early Bronze Age (EBA) and Middle Bronze Age (MBA) tend to plot on the right side of the first axis and on the negative part of the second axis. These samples are associated with the main animal domesticates (pig, cattle, ovicaprids), equids and fox. If we look at the botanical taxa driving this association, we see garden pea, glume wheats, lentil, and wild pistachio are determining EBA and MBA samples. However, two outliers are present in this group, Hirbet ez-Zeraqon (21) and Sidon (23) for which we must find an explanation. This should be done by looking at the raw data and rereading the original reports. When we do this, we see Hirbet ez-Zeraqon has a high diversity (i.e., the number of taxa represented in the sample) and has high frequencies of emmer chaff, wild botanical taxa, fox, and equids. Sidon has a low diversity, and a high frequency of bear,
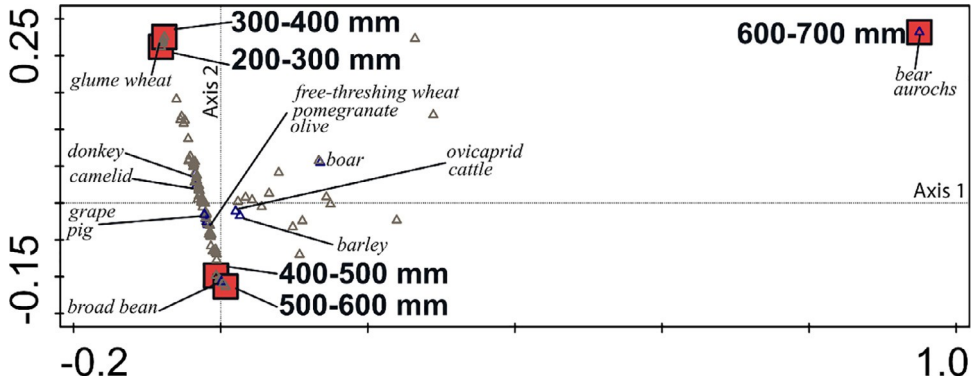
Fig. 2. CCA biplot of our integrative dataset, showing an explained cumulative variation of 8.82% on axis 1 and 15.97% on axis 2. The eigenvalues of axis 1 and 2 are 0.1896 and 0.1538, respectively.
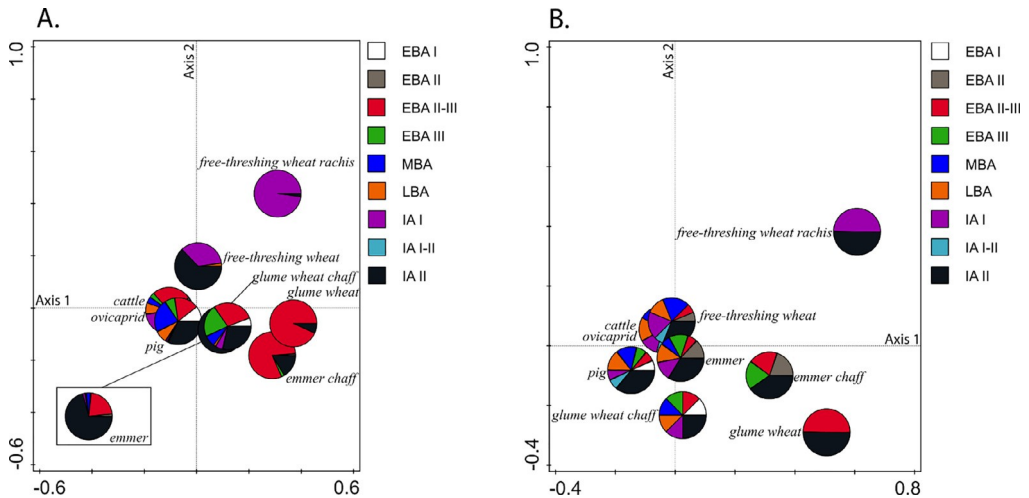

Fig. 3. Biplots representing the most common domesticated taxa as pie diagrams, which reflect the division of the parameter relative chronology. 3A: CA biplot with quantitative data, showing an explained cumulative variation of 36.37% on axis 1 and 61.52% on axis 2. The eigenvalues of axis 1 and 2 are 0.2414 and 0.1670, respectively. 3B: DCA biplot with binary data, showing an explained cumulative variation of 31.65% on axis 1 and 50.94% on axis 2. The eigenvalues of axis 1 and 2 are 0.2467 and 0.1504, respectively.

aurochs, and barley which causes this sample to plot separately. Samples classified to the Late Bronze Age (LBA) plot heterogeneously which suggests a lot of variety in the taxonomic composition for these samples. Samples classified to the Iron Age mostly cluster together on the left side of the first axis and on the positive part of the second axis. These samples are mainly associated with boar, felids, free-threshing wheat, pomegranate, grape and bitter vetch. Once clusters of samples and trends have been recognised, we need to put these trends in their socio-political contexts. We refrain from doing this here since data interpretation will differ between time periods, geographical context, and research question.

Next, we present a CCA biplot using our integrative dataset expressed with binary data against the known parameter of mean annual precipitation (Fig. 2). Using this analysis, we can check whether subsistence significantly changes between zones of mean annual precipitation. As mentioned before, this can be done using a Monte Carlo permutations test. Here, it indicates a significant difference
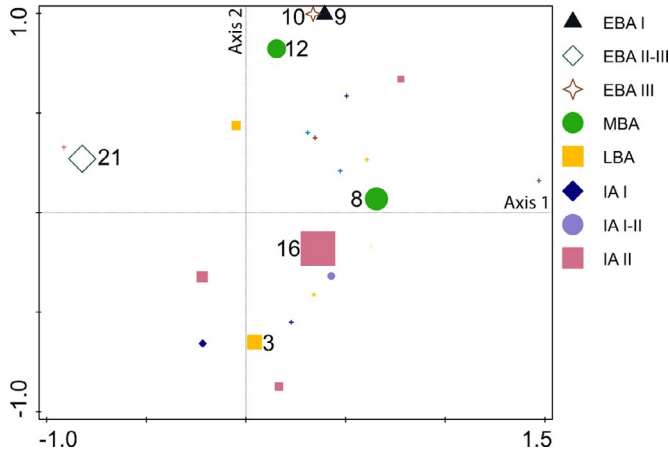
Fig. 4. Attribute plot of pig against the parameter of relative chronology. Small "+" signs indicate absence of pigs.

Table 1

Sites used for our integrative analyses with their references.

Site	Reference
Aphek	[13,17,30]
Arad	[16,26]
Ashdod	[12,35,37]
Ashkelon	[15,52]
Bet-Shean	[18,30]
Hirbet el-Mudeyine el-'Aliye	[7,28,38]
Hirbet ez-Zeraqon	[6,40]
Manahat	[19,23]
Megiddo	[1,31,42,51]
Qubur el-Waleyide	[34,39] + Orendi unpublished data
Shiloh	[14,24,29]
Sidon	[5,50]
Tel Burna	[11,43] + Orendi unpublished data
Tell es-Safi	[22,27,36]
Tell Yarmuth	[4,41]

Table 2

Distribution of the parameters relative dating and mean annual precipitation in our dataset.

Parameter	Number of samples
Relative Dating	
Early Bronze Age I	1
Early Bronze Age II	2
Early Bronze Age II-III	2
Early Bronze Age III	2
Middle Bronze Age	3
Late Bronze Age	4
Iron Age I	3
Iron Age I-II	1
Iron Age II	6
Mean Annual Precipitation	
200–300 mm	3
300–400 mm	3
400–500 mm	8
500–600 mm	9
600–700 mm	1

between different zones of mean annual precipitation (pseudo-$F = 1.6$, $p = 0.002$). The interpretation of the CCA is like that of the (D)CA. We see three clusters of precipitation zones: 200–400 mm, 400–600 mm, and 600–700 mm. The lower precipitation zones are amongst other taxa associated with glume wheat, donkey, and camelid. The latter is particularly known to be adapted to dry climates. The 400–600 mm precipitation zone is characterised by a range of taxa including grape, pig, broad bean but also ovicaprid, cattle, and barley. The wettest precipitation zone is distinguished by the frequencies of bear, aurochs, and boar. Although the CCA biplot is informative and can be tested statistically, we recommend comparing its results with those of the (D)CA biplot to obtain a more in-depth look regarding samples.

It is also possible to represent taxa as pie diagrams in the biplot, the pie diagram representing the proportion of a specific parameter (in this example, relative chronology). We choose to represent the most common domesticates in the past diet of the people of the Bronze and Iron Age in the southern and central Levant: ovicaprids, cattle, pig, free-threshing wheat, glume wheat, and emmer. The first biplot uses quantitative data (Fig. 3A) where we observe emmer occurring more often in the Early Bronze Age II-III, whereas free-threshing wheat occurs most frequently in the Iron Age. Note, there is still a large quantity of emmer during Iron Age II. This needs to be explained and could be related to the different functionalities of chaff and grain. The high frequency of emmer grains comes from the Ashkelon Iron Age II sample. If we return to the raw data and original report, we see the authors considered this to be exceptional, and emmer was used as a food staple at the site or was imported from inland sites. We now compare these results to a biplot using binary data (Fig. 3B). Here, we see similar results as in the previous biplot (i.e., a shift from emmer to free-threshing wheat) but the trend is less clear, because it reflects the number of sites in which a taxon is present and our dataset used for this example contains only 15 sites, i.e., is comparatively small. Hence, both taxa will still be present in the sample. Note the dominance of the Iron Age II in the pie diagram for emmer is not as noticeable as it was in the previous biplot. We recommend using quantitative data for biplots expressing taxa as pie diagrams in particular if site or sample numbers are low, and to compare the results with a biplot using binary data, which helps to discover differences in taxa abundance and frequency. Visually, we see the pie diagrams for ovicaprid and cattle overlap in both biplots (Fig. 3A and 3B) but since these taxa appear in all time periods, we did not create a pop-out window for these taxa.

Finally, a last visualisation option are attribute biplots representing a taxon (or taxa) following a classification using quantitative data. Attribute plots can help analysts understand in what category or parameter a taxon is more prominent, which can aid in explanations of the integrative data. Here, we create an attribute plot for pigs classified per relative chronology (Fig. 4). Notice the samples plot similarly to the CA biplot containing all data. These biplots are intuitive to understand: the bigger the symbol, the more frequent the taxon appears in the sample. Generally, pigs are more present in earlier time periods (i.e., the Early and Middle Bronze Age) but we see one notable exception: the Iron Age II sample of Tell es-Safi. In consulting the original report, we see that Tell es-Safi is identified as having a Philistine culture where pig consumption was higher than in contemporary settlements [27].

Pitfalls

The methods presented here are not without issues. A first problem, which might seem trivial, is the aesthetics of the biplots produced. When working with large datasets containing many samples and numerous taxa, it can be difficult to interpret the data, but more importantly, to present the biplot clearly to the reader. We recommend labelling samples with numbers and providing a corresponding legend, and only labelling those taxa which affect the trends and clusters in the biplot. When plotting taxa as pie diagrams representing a category or specific parameter, quite often pie diagrams will overlap. In this case, some editing of the biplot using visualisation software is necessary.

A more pressing issue is the methodological challenges faced when trying to integrate archaeological botanical and faunal remains. We described these in depth previously [49] but summarise the main issues here.

- Different qualities as placeholders for living plants and animals

Archaeological faunal material is represented by fragments from specific animal bones (quantified as NISP) [10], so we can reconstruct the MNI (minimum number of individuals). Archaeological botanical material, however, is represented by parts of the reproduction unit and - at present - we cannot reconstruct the number of individuals [20]. This means, although we use NISP and seed count to integrate these two lines of evidence, inherently they do not represent equivalent values.

- Different functionality

Faunal remains generally represent cooking or household refuse and most often indigestible food debris, whereas plant remains can derive from multiple activities, such as crop processing, storage, cooking, the use of dung or animal feed. Whereas faunal remains typically have been consumed by humans, botanical remains typically are not (except for human faeces or gut contents).

- Different taxonomic representations

Faunal analysts tend to publish results on macrofauna (i.e., larger mammals), fish, molluscs, reptiles, birds, and microfauna separately. Adding to this, quite often only the macrofauna of a site is published, although this situation is rapidly improving thanks to proper recovery methods being employed at excavations. In contrasts, archaeobotanists publish all botanical remains in a single report. Besides this, faunal remains tend to be dominated by domestic taxa, specifically ovicaprids and cattle, whereas plant remains have a broader taxonomic diversity which will reflect environmental conditions better.

- Potential bias in clustering

Clustering of samples of multi-period sites in the biplots should always be treated carefully. Sometimes, this can be related to biases introduced by either excavators or analysts, caused by, for example, stratigraphic difficulties or limited laboratory resources.

- Weaker patterns

Biplots using integrative data tend to show trends weaker than biplots using only faunal or plant data. This is because faunal and botanical remains may have contradictory trends which will be amalgamated in the final output, where the more dominant remain group will lead the clustering.

Declaration of Competing Interest

Acknowledgments

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mex.2021.101336.

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Appendix 4

Vermeersch, S., Starkovich, B. M., Orsingher, A., Kamlah, J., Animal husbandry and diet in the Phoenician heartland –Tell el-Burak (Lebanon) in its context during the Iron Age II.

Attached here is the draft of the manuscript, which will be submitted to *Journal of Anthropological Archaeology*.

To obtain the final version of this article, please contact the corresponding author, Shyama Vermeersch.

1   Subsistence practices in Phoenicia and beyond: faunal investigations at Tell el-Burak,

2   Lebanon (c. 725 - 350 BCE)

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13   Abstract:

14   The agricultural practices of Iron Age Phoenicia are an understudied field of research. The

15   latest faunal evidence from Tell el-Burak, a coastal agricultural domain linked to either Sidon

16   or Sarepta in present-day Lebanon, will help us understand this topic. This paper provides the

17   first diachronic and detailed analysis of the late Iron Age and Persian period faunal data from

18   Tell el-Burak and investigates the subsistence practices of its inhabitants during the late eighth

19   to mid-fourth centuries BCE. The diet mainly consists of ovicaprids, but a high percentage of

20   donkeys and cattle coincides with the peak of wine-making activities at the site. We then

21   compare our results with the faunal data from other sites in the territory traditionally known as

22   Phoenicia, as well as with faunal data from the neighbouring regions of the Levant. The

23   comparisons show differences between the northern and southern Levant and similarities

24   between southern Phoenicia and the southern Levant.

25   Key words: Levant, Iron Age, Phoenicians, subsistence, agriculture, animal husbandry

26   1. Introduction

27   In recent years, scholars are gaining interest in the Phoenicians, the Iron Age inhabitants of

28   the coastal central Levant (e.g., López-Ruiz and Doak, 2019, with references). The monolithic

29   and stereotypical image of the Phoenicians provided by biblical and Graeco-Roman sources

30   has come under scrutiny, particularly regarding their cultural identity and distinction from

31   other Levantine peoples (Quinn, 2018). The role the Phoenicians allegedly played in

32   introducing technologies, iconographies, a writing system, but also plant and animal species

33   in the western and central Mediterranean regions where they established new settlements from

34   the late ninth century BCE, is also being questioned. In the framework of this debate, new

35   faunal and botanical data from their homeland are important to obtain a better understanding

36   of the Phoenician diet and to compare it with those of other Levantine regions. Due to the

37   long absence of archaeological investigations in Lebanon (Sader, 2019), at present, Iron Age

38   faunal and botanical data are only published from four sites: Kamid el-Loz (Behre, 1970;

39   Bökönyi, 1990), Tyre al-Bass (Montero, 2014; Rovira, 2015), Tell el-Burak (Çakırlar et al.,

40   2013; Orendi and Deckers, 2018), and Jiyeh (Piątkowska-Małecka, 2017).

41   This paper provides new faunal data from late Iron Age and Persian period Tell el-Burak.

42   Previous faunal analyses at the site concentrated on the Middle Bronze Age remains (Çakirlar,

43   2019), Persian-period dog burials (Çakırlar et al., 2013), which includes reference to the

44   faunal remains from the Iron Age deposits (Çakırlar et al., 2013), and human-turtle

45   interactions (Çakırlar et al., 2021).This article has two goals for the analysis of the faunal

46   material from the late Iron Age and Persian periods at Tell el-Burak. Since this is the first

47   time a faunal dataset from a long and reliable stratigraphic sequence in the core of ancient

48   Phoenicia is published, our first goal is to understand how subsistence practices develop at

49   Tell el-Burak during this period and determine whether there are differences between two of

50   the excavated areas of the site. These results will serve as a reference point for addressing

51   subsistence practices in the western Mediterranean and will provide us with a better

52   understanding of the impact that the Phoenicians had in the various regions where they

53   settled. A second goal is to compare the diet of the inhabitants of Tell el-Burak to those of

54   other sites in Phoenicia and in other Levantine regions by using correspondence analysis

55   which allows us to contextualise the patterns found in the species composition and explore the

56   long-debated issue of cultural identity.

57   2. An archaeological background of Tell el-Burak and the comparative sites

58   2.1. Tell el-Burak: excavations and periodisation

59   The site of Tell el-Burak is located on the southern Lebanese shore, nine kilometres south of

60   Sidon (fig. 1). Since 2001, it has been excavated by a Lebanese-German team. The Tell el-

61   Burak Archaeological Project is a joint venture of the American University of Beirut, the

62   University of Tübingen, the German Archaeological Institute – Orient Department, and, since

63   2013, the University of Mainz. Tell el-Burak is irregularly occupied between the Middle

64   Bronze Age I (c. 1900 - 1700 BCE) and the Mamluk-Ottoman period (c. 13th - 17th/18th

65   centuries CE) (Kamlah and Sader, 2019). Either Sidon or Sarepta is likely responsible for the

66   re-occupation of the site and the establishment of a Phoenician agricultural domain during the

67   late Iron Age and Persian periods (c. 725-350 BCE). On the top of the tell (Area 3),

68   excavations have uncovered the remains of four buildings, Houses 1-4, which are bordered by

69   a wall to the southwest and southeast (fig. 2). A variety of domestic, agricultural, and ritual

70   activities took place in this part of the site, including cooking facilities, structures for small

71   scale processing of agricultural products, storage spaces, and a cultic installation.

72   Furthermore, archaeologists have unearthed a large and well-preserved wine press (fig. 3) at

73 the southern slope of the hill (Area 4), where large-scale processing activities of agricultural

74 products probably took place (Kamlah et al., 2016, forthcoming; Orsingher et al., 2020). The

75 late Iron Age and Persian period occupation of Tell el-Burak is subdivided into five major

76 phases (E - A), which for the purpose of this study have been arranged into three groups:

77 Early, Middle, and Late assemblages (table 1).
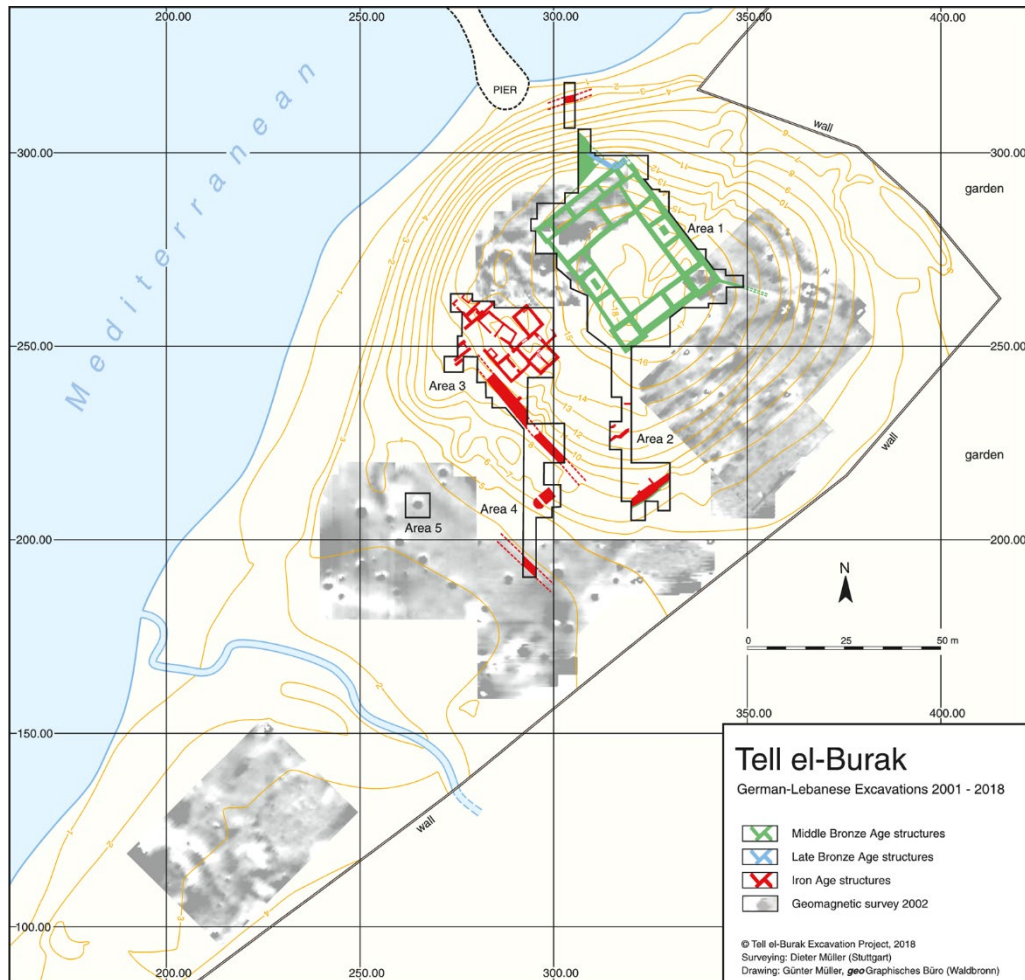
78

79 Fig. 1: Plan of the settlement at Tell el-Burak, showing the location of Areas 3 and 4 (courtesy

80 of the Tell el-Burak Archaeological Project).

Fig. 2: Tell el-Burak, Area 3. 1: House 3, from the west; 2: Houses 1 and 3, from the northwest (courtesy of the Tell el-Burak Archaeological Project).

84

Fig. 3: Tell el-Burak, Area 4: the wine press, from the southwest (courtesy of the Tell el-Burak Archaeological Project).

Table 1: The assemblages at Tell el-Burak with their corresponding archaeological phases and dating as used in this study.

Assemblage	Archaeological Phase	Dating
Late	A	c. 500-350 BCE
	B	c. 550-500 BCE
Middle	C	c. 600-550 BCE
Early	D	c. 650-600 BCE
	E	c. 725-650 BCE

89

90   2.2. Comparative sites in Phoenicia and neighbouring regions in the Levant

91   We evaluate and contextualise the diet from Tell el-Burak by selecting Levantine sites with

92   published coeval Iron Age faunal data. By comparing the taxonomic composition, we can

93   draw conclusions regarding similar or different diets in the region and what causes this. We

94   choose the sites based on several criteria: 1) a position within or close to what is

95   conventionally assumed to be Phoenicia, 2) coastal settlements along the Levantine shore, and

96   3) sites with an agricultural function (fig. 4). There are, however, some exceptions to these

97   parameters, which will be outlined and explained below.

98
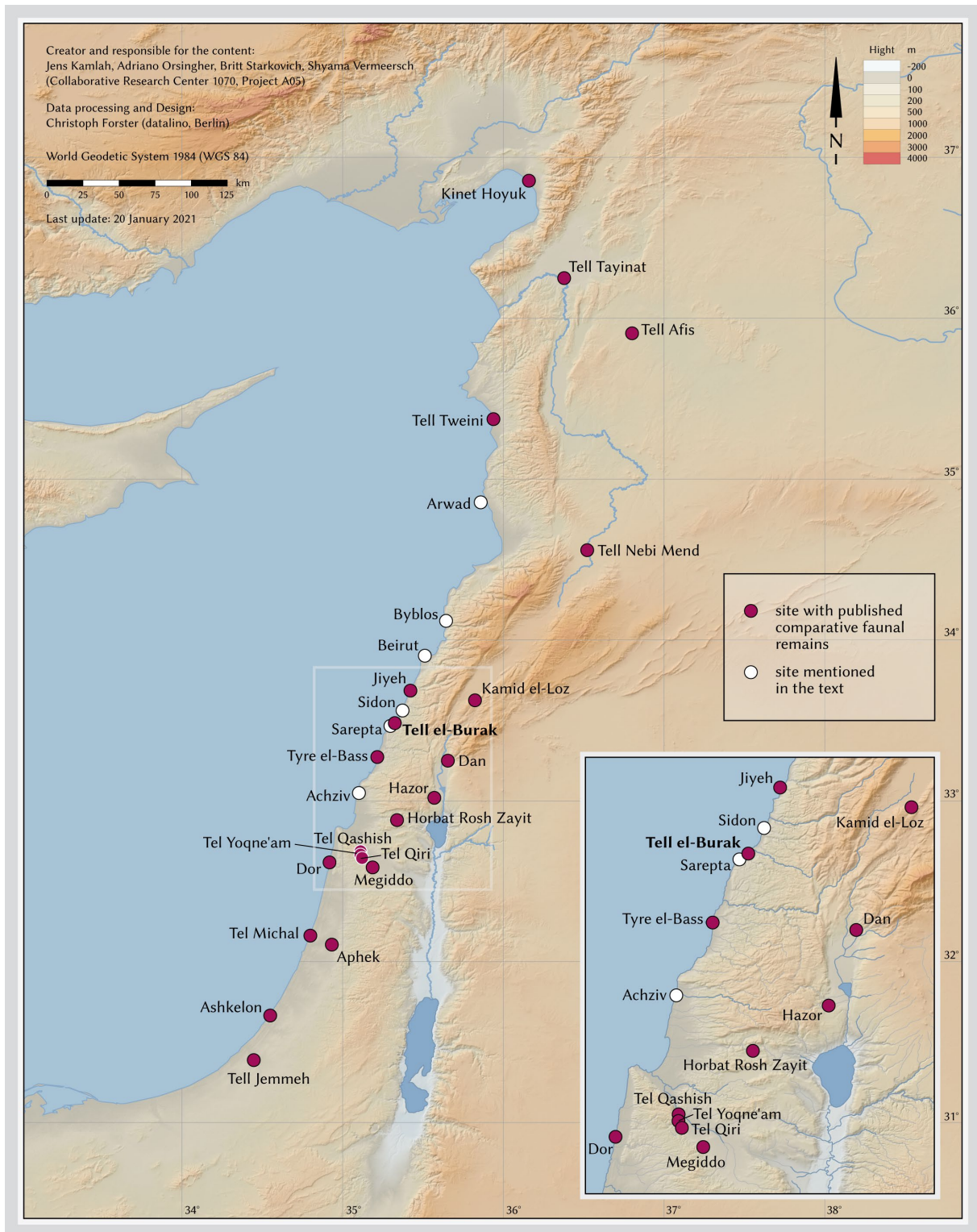
Fig. 4: Map showing the location of Tell el-Burak and the comparative sites used here. Red
circles indicate sites with published faunal data used for comparison, white circles indicate
important sites in the region.

The region of Phoenicia during the Iron Age is traditionally identified with the coastal

territory between the city of Arwad in the north and those of Tyre or Akko in the south,

including major sites like Byblos, Beirut, Sidon, Sarepta and Achziv, but, "the territorial and

ethnic borders were flexible and fluctuating, subject to change over time" (Lehmann, 2019,

466).

Kamid el-Loz, one of the major sites in Lebanon's Beqa'a Plain, is occupied by a modest

rural village during the Iron Age (c. 1200-540 BCE) and is interpreted as a meeting place and

camp used by sedentary and mobile groups (Heinz 2016, 185-199). The site is abandoned in

the sixth century BCE when it is transformed into a burial ground (Heinz, 2016). There is no

published faunal data for the late Iron Age.

Tyre el-Bass is a cremation cemetery of Tyre on the mainland. It is used at least between the

end of the tenth and the first half of the sixth century BCE, although earlier isolate finds are

discovered out-of-context (Núñez, 2017). Faunal remains are probably related to the use of

this area as a burial ground and could result from ritual feasts held as part of the burial

practices. Those from urns dating to Period V (c. 730 - mid-sixth century BCE) and from

stratum 4 (c. 850 - 550 BCE) are considered as comparative material in our study (Montero,

2014).

Jiyeh, which can be identified with the Roman town of Porphyreon, is located on the coast

between Beirut and Sidon (Waliszewski et al., 2015; Waliszewski and Gwiazda, 2015). The

only Iron Age remains so far discovered are residential buildings in sectors D and E, which

have been assigned to four horizons: Iron Age II (c. eighth-seventh century BCE), Persian (c.

sixth-fourth century BCE), Hellenistic (c. 3rd–2nd/1st century BCE), and Byzantine (5th –

6th/7th century AD). The published post-consumption animal remains of the Iron Age II and

Persian period come from the dwelling area (sector D: rooms 4, 20 and 72) (Piątkowska-

Małecka, 2017).

127   Outside Phoenicia, we consider other contemporary sites from the southern and northern

128   Levant (fig. 4) based on: 1) proximity to Phoenicia or the presence of a connection with this

129   region, evidenced – for instance – by the material culture, 2) a coastal location, and/or 3) a

130   relation to agricultural activities.

131   A significant case is represented by the inland site of Horbat Rosh Zayit, 15 km east of Akko,

132   which according to the excavators is occupied during the tenth to eighth centuries BCE (strata

133   III - I).. Within this village located on the top of a ridge in the western lower Galilee, a

134   fortified building in the upper terrace is used as a central storage facility, surrounded by

135   houses, a complex for olive oil processing and other subsidiary structures (Gal and Alexandre,

136   2000). Its strong link to agricultural processing and storage, both functions observed at Tell

137   el-Burak, explains why its entire faunal assemblage is considered in this paper (Horwitz et al.,

138   2000).

139   Further south, three sites in the Jezreel valley within proximity of one another have yielded

140   faunal remains dating to this period. For the assemblage from Tel Yoqne'am (Horwitz et al.,

141   2005), one of the major sites in this region, we consider the animal remains from the

142   fortifications and domestic structures of stratum XII (Iron Age IIB: c. late 9th - 8th century

143   BCE) and those from the sparse dwellings of stratum XI (Iron Age III: c. 7th - 6th century

144   BCE; see: Zarzecki-Peleg, 2005). At Tel Qashish, on the north bank of the Kishon River, the

145   last occupation phase (stratum IIA-I) dates to the Persian period, when a farmhouse occupies

146   the lower part of the mound (Ben-Tor, 1993). Animal remains dating to this period are yielded

147   by evidence of occupation in areas A and B (Ben-Tor and Bonfil, 2003a, 2003b).

148   Unfortunately, the Iron Age faunal assemblage from the first two excavation seasons at Tel

149   Qiri are published without any chronological distinction (Davis, 1987), and are not considered

150   in this study.

151 Megiddo is important due to its strategic position in the Jezreel Valley at the crossroads of

152 two military and trade routes, its control of a major water source, and its proximity to arable

153 land. Due to chronological reasons, we only consider animal remains from the end of Stratum

154 IVA (destruction c. 732 BCE) (Sasson, 2013). They come from two areas: the north western

155 part of the mound (Level H-3), and the northern stables complex (Level L-2), both dating to

156 the Late Iron IIB (Finkelstein, 2009).

157 To the south of the Carmel range lies the harbour-city of Dor. As the faunal data from the

158 horizon Ir2c (= Phase 5: c. 730-650/625 BCE) in Area G at Dor are not included in the recent

159 excavation report (Bartosiewicz and Lisk, 2018) and the coeval ones from other areas of the

160 site are combined with those of the earlier Ir2b horizon in a previous publication (Sapir-Hen

161 et al., 2014), we only examine the animal remains from the Persian Period.

162 Another site along the coast is Tel Michal (Herzog, 1993). We integrate the faunal

163 assemblages from both the Iron Age (strata XIV-XII: c. second half of the 10th - 8th century

164 BCE) and – after a gap of around 150 years – the Persian Period (strata XI-VI: c. end of the

165 6th – end of the 4th century BCE) in our analysis (Hellwing and Feig, 1989; Sade, 2006).

166 During the Iron Age, houses, an open-air cultic place, and wine presses are attested, while

167 during the Persian Period, the site is occupied by a fort and related structures (e.g., silos, camp

168 for soldiers, garrison's headquarters).

169 At Ashkelon, two find-contexts of the seventh century BCE, Grid 38 and Grid 50, have

170 yielded large collections of faunal remains (Hesse et al., 2011). Grid 38 encompasses

171 materials from the use and destruction phases of Building 776 – a structure where activities

172 focused mostly on wine production – and the alley flanking its east side. Those from the Grid

173 50 are recovered from the filling of a large pit resulting from earlier stone-quarrying activities

174 and from surfaces and rooms in the marketplace built on top of the refilled quarry.

175 Further south in the north-western Negev lies Tell Jemmeh. Although it provides a long

176 sequence of faunal remains (Maher, 2014), our focus is on those from Field IV, in the upper

177 tell near one of the central northern slopes (Ben-Shlomo, 2014), which cover the IA IIB (c. 8th

178 century BCE), IA IIC (c. late 8th-6th century BC), and Persian period (c. 5th-4th century BC).

179 Given the paucity of Iron Age published faunal assemblages from the northern Levant, we

180 include three inland sites (i.e., Tell Nebi Mend/ancient Qadesh, Tell Tayinat and Tell Afis)

181 along with two coastal centres (i.e., Tell Tweini/ancient Gibala, Kinet Höyük).

182 Tell Nebi Mend occupies a strategic position north of the Beqa'a Valley, at the heart of the

183 Homs-Tripoli Gap, the major east-west route from the Mediterranean coast to inland Syria.

184 Faunal remains dating to the Iron Age II-III (c. 900 - 600 BCE) come from domestic deposits

185 in Trenches III and V (Grigson, 2015; Grigson et al., 2015)

186 Moving to the Syrian coastal plain, Tell Tweini is located on the southern bank of the

187 Rumeilah River. Among its faunal data (Linseele et al., 2019), those coeval to the

188 assemblages of Tell el-Burak come from IA III layers (levels 5-4: c. 700 - 333 BCE) in Field

189 A, where archaeologists documented installations associated with olive oil production in

190 many houses (Bretschneider et al. 2019).

191 The site of Tell Afis, 45 km south-west of Aleppo, lies on the ancient route towards

192 Damascus across the plain east of the Rift Valley depression (Mazzoni et al., 2014). Faunal

193 remains dating to the IA IIB-III (c. late 8th - 7th centuries BCE) come from almost all

194 excavated areas (Wilkens, 2000, 2002, 2005).

195 Further north, in the Amuq plain of south-eastern Turkey, is Tell Tayinat (Harrison, 2014).

196 Faunal remains dating to the IA III (c. 738-600 BCE) were found in Field 5 on the east side of

197 the upper mound, and come from a sequence of layers to the exterior face of the eastern wall

198 of a building possibly having administrative function when it was the Assyrian provincial

199 capital of Kunalia (Lipovitch, 2017).

200 Kinet Höyük, a coastal site in southeast Cilicia, is identified as Classical Issos on the east side

201 of the Gulf of Iskenderun. Faunal data, dating to periods 7 and 6 (c. 700 - 550 BCE), come

202 from residential and open-air activity areas, disuse levels and pits on the western (Operation

203 E/H) and eastern slopes (Operations A-AII and D; see: Çakırlar et al., 2018).

204 3. Methods

205 We analyse faunal remains from hand-collection and flotation samples recovered during the

206 2014, 2015, and 2018 seasons at Tell el-Burak. The heavy residues from flotation are

207 collected from a 1mm mesh and sorted for faunal remains. We measure bones following Von

208 den Driesch (1976) and identify specimens to skeletal element and bone portion. We

209 determine genus and species when possible, otherwise to body-size class (e.g., medium

210 mammal) (Stiner, 2005) and identify all mammalian, avian, and Testudines remains. Aquatic

211 fauna is being analysed by Dr Canan Çakirlar and her team (University of Groningen), so we

212 do not include it in this study. Specimens which could not be identified in the field are

213 analysed using the osteological reference collection at the University of Tübingen.

214 We choose NISP (number of identified specimens) as our primary quantification unit and

215 provide MNI (minimum number of individuals) for comparisons with other sites. We use

216 MNE (minimum number of elements) to study anatomical profiles and density-mediated

217 attrition (Lyman, 2018, 2008). We use the reciprocal of Simpson's index, a measure of

218 taxonomic evenness (Simpson, 1949), to assess diversity in our assemblages. To do so, we

219 use species-specific identifications, except for the ovicaprid category which includes

220 specimens determined as sheep or goat.

We record bone surface modifications (Behrensmeyer, 1978; Fisher, 1995; Lyman, 1994; Stiner et al., 1995) and analyse density-mediated attrition to check for preservation bias by calculating the tooth:bone ratio. This is done by dividing the MNE of the most frequent lower tooth by the mandibular MNE; a disproportionate representation of teeth would indicate that bone loss might have occurred (Stiner, 1991). We examine body part profiles per taxon by dividing the body into nine anatomical regions: horn, head, neck, axial column, upper front limbs, lower front limbs, upper hind limbs, lower hind limbs, and feet (Stiner, 1991). Here, we exclude vertebrae (cervical, thoracic, lumbar, sacral) and ribs to avoid the issue of certain elements being highly recognisable for certain taxa. Therefore, the neck consists of the atlas and axis, and the axial section consists of the innominate. We calculate MAU (minimal animal units) within these regions by dividing the number of observed elements in the assemblage by the number of expected elements in a complete individual, which standardises our MNE values allowing us to examine anatomical profiles of taxa.

We perform aging using epiphyseal fusion, tooth wear and tooth eruption. We use epiphyseal fusion to calculate survivorship profiles for ovicaprids (Moran and O'Connor, 1994). We utilise tripolar graphs to analyse age at death, using deciduous and adult fourth premolars since these teeth typically do not appear simultaneously in life. Juveniles are represented by deciduous fourth premolars, prime-aged adults and older animals are determined using wear stages of the fourth premolar, with the cut-off representing about half of the use life of the tooth (Greenfield and Arnold, 2008; Steele and Weaver, 2002; Stiner, 1990; Weaver et al., 2011).

We differentiate sheep and goat morphologically when possible (Boessneck, 1969; Zeder and Lapham, 2010; Zeder and Pilaar, 2010) and establish the sheep:goat ratio to interpret herding strategies. A mixed flock, consisting of an almost equal number of sheep and goats, aims towards herd security, which is a common risk avoidance strategy since sheep and goats have

246   different biological and ecological requirements and susceptibilities (Perevolotsky et al.,

247   1989; Redding, 1981; Sasson, 2016). A mixed flock is more resistant against disease and

248   temperature changes. When we see a clear preference for sheep or goats in a flock, this

249   indicates a strategy focussed on maximising energy and protein intake (Redding, 1984, 1981).

250   We reconstruct economic strategies by analysing the mortality profiles of sheep and goat

251   (Payne, 1973). An economy focussed on producing mainly meat will be reflected by a low

252   survivorship of young males at an age when they reach their optimum weight gain (usually at

253   two or three years old). If herders aim for milk production, this will result in low survivorship

254   of young ovicaprids. A third focus can be wool production, which will result in low

255   survivorship of adult animals in the faunal record. However, quite often flocks are kept for

256   obtaining a variety of products, without a focus on meat or secondary products, which reflects

257   a mixed economy (Payne, 1973).

258   We use correspondence analysis (Gauch, 1982; Leps and Smilauer, 2003) to compare the

259   taxonomic composition of Tell el-Burak with our comparative sites. We use NISP values for

260   our comparative dataset because this is the most common measure of abundance available in

261   the literature. When a site has several faunal reports or samples for one time period, we merge

262   these data to create one sample per site. We only include mammals and turtles (Testudines),

263   since birds, fish, and molluscs are not always consequently retrieved and recorded. Specimens

264   identified to taxonomic families which contain domestic and wild taxa are left out in the

265   correspondence analysis, for example, Canidae. Despite the sheep:goat ratio being important

266   to recognise herding strategies, we merge these into ovicaprid, since not all faunal analysts

267   differentiate between the two taxa or the sample sizes are too small. To avoid the effects of

268   analyst bias as much as possible, we broaden certain taxonomic categories which are easily

269   confused. For example, we merge *Gazella gazella*, *Gazella dorcas* and *Gazella subgutturosa*

270   to *Gazella* species. We impose a 10% threshold for taxa presence in samples since rare taxa

271   can make it hard to interpret the biplot of the correspondence analysis (Gauch, 1982).

272   4. Results

273   We present the faunal remains of the three assemblages for both areas separately. Since

274   sample size (i.e., the number of fragments in a sample) and richness (i.e., the number of taxa

275   in a sample) are known to correlate with one another (Lyman 2008). We assess the effect of

276   sample size on richness in our assemblages, and find they correlate (Pearson's correlation, r =

277   0.796, p = 0.058). The results of individual rarefaction (fig. 5) show the Late assemblage of

278   Area 3 and the Early and Late assemblages of Area 4 are lower in evenness. This means, we

279   should be careful when interpreting their faunal remains (a list of taxonomic composition for

280   all assemblages of Areas 3 and 4 can be found in SI 1).
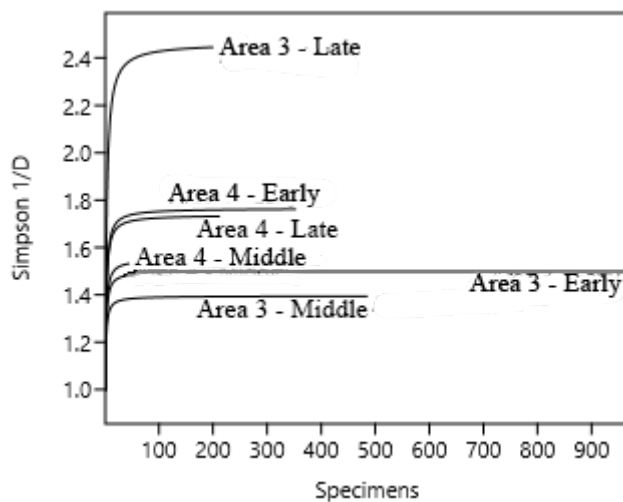
281

282   Fig. 5: Results of the individual rarefaction.

283   4.1. Taxonomic composition

284   Subsistence in Area 3 of Tell el-Burak (table 2) does not change much through time; the

285   taxonomic composition between the Early and Middle assemblages (Pearson's chi-square =

286   40, DF = 35, P = 0.258, Cramer's V = 1) and between the Middle and Late assemblages are

287   similar (Pearson's chi-square = 20, DF = 16, P = 0.220, Cramer's V = 1).

288   Ovicaprids dominate all assemblages, with goats outnumbering sheep (sheep:goat ratios:

289   Early = 0.75, Middle = 0.68, Late = 0.68). Cattle are the second most abundant taxon. The

290 ovicaprid:cattle ratio stays consistent throughout time (Early = 7.18, Middle = 6.43, Late =

291 7.33). Suids are present in small numbers, indicating they do not play a big role in the diet.

292 Hunting only contributes a little to subsistence practices. Dogs are present in a higher

293 frequency during the Late assemblage because specimens represent two almost completely

294 preserved (but not articulated) individuals. Evenness in the Early and Middle assemblages is

295 low (1/D: 1.5 and 1.4, respectively), reflecting the dominance of ovicaprids. The Late

296 assemblage has a slightly higher diversity (1/D = 2.4), though this is probably due to the small

297 sample size.

298 Table 2: Taxonomic composition of the Early, Middle, and Late assemblages of Area 3.

299 Sheep and goat counts are not included in the ovicaprid category.

Taxon	Early NISP	%NISP	MNI	Middle NISP	%NISP	MNI	Late NISP	%NISP	MNI
Large ungulate	183	8.8	-	92	10.7	-	25	8.9	-
Cattle (*Bos taurus*)	109	5.2	2	63	7.3	2	12	4.3	1
Large cervid	-	-	-	1	0.1	-	-	-	-
Red deer (*Cervus elaphus*)	3	0.1	1	-	-	-	-	-	-
Donkey (*Equus asinus*)	8	0.4	1	5	0.6	1	-	-	-
Medium ungulate	909	43.7	-	277	32.1	-	54	19.3	-
Fallow deer (*Dama dama*)	31	1.5	1	4	0.5	1	4	1.4	1
Suid (*Sus sp.*)	15	0.7	1	1	0.1	1	1	0.4	1
Ovicaprid (*Ovis/Capra*)	605	29.1	7	299	34.7	7	67	23.9	2
Goat (*Capra hircus*)	102	4.9	5	63	7.3	3	13	4.6	1
Sheep (*Ovis aries*)	76	3.7	6	43	5.0	5	8	2.9	2
Gazelle (*Gazella sp.*)	2	0.1	1	1	0.1	1	-	-	-
Turtles	3	0.1	1	-	-	-	3	1.1	1

Hare (*Lepus sp.*)	1	0.0	1	1	0.1	1	-	-	-
Dog (*Canis familiaris*)	13	0.6	1	2	0.2	1	91	32.5	2
Small carnivore	1	0.0	-	-	-	-	-	-	-
Fox (*Vulpes sp.*)	-	-	-	2	0.2	1	-	-	-
Huge bird	-	-	-	3	0.3	-	-	-	-
Large bird	2	0.1	-	-	-	-	1	0.4	-
Great bustard (*Otis tarda*)	1	0.0	1	-	-	-	-	-	-
Medium bird	9	0.4	-	3	0.3	-	1	0.4	-
Small bird	5	0.2	-	2	0.2	-	-	-	-
Total	**2,078**	**100**	**-**	**862**	**100**	**-**	**280**	**100**	**-**
Medium mammal	548	-	-	308	-	-	72	-	-
Small/Medium mammal	2	-	-		-	-		-	-
Small mammal	61	-	-	16	-	-	5	-	-
Small mammal/Bird	1	-	-	1	-	-		-	-
Grand total	**2,690**	**-**	**-**	**1,187**	**-**	**-**	**357**	**-**	**-**

300

Subsistence patterns in Area 4 at Tell el-Burak (table 3) are similar through time; the taxonomic composition between the Early and Middle assemblages (Pearson's chi-Square = 10, DF = 8, P = 0.265, Cramer's V = 1) and between the Middle and Late assemblages are similar (Pearson's chi-Square = 8, DF = 4, P = 0.092, Cramer's V = 1).

In all assemblages from Area 4, ovicaprids are dominant. A small difference is observed through time concerning the sheep:goat ratio, although this is probably due to the small sample sizes for the Middle and Late assemblages. Whereas in the Early assemblage sheep outnumber goat (sheep:goat ratio = 1.30), the Middle and Late assemblages have goats outnumbering sheep (sheep:goat ratio: Middle = 0.6, Late = 0.76). Cattle are an important part of the diet and the ovicaprid:cattle ratio stays similar from the Early to Middle assemblages, but we see a large increase in ovicaprids to cattle in the Late assemblage (Early = 5.78,

Middle = 5.83, Late = 8.26). Suids appear in low numbers during the Early and Late

assemblages and are absent during the Middle assemblage. Hunting does not play an

important part of the diet, and the frequency of wild animals declines through time. The

diversity through time in Area 4 is low (1/D: Early = 1.76, Middle = 1.53, Late = 1.73).

Table 3: Taxonomic composition of the Early, Middle, and Late assemblages of Area 4.
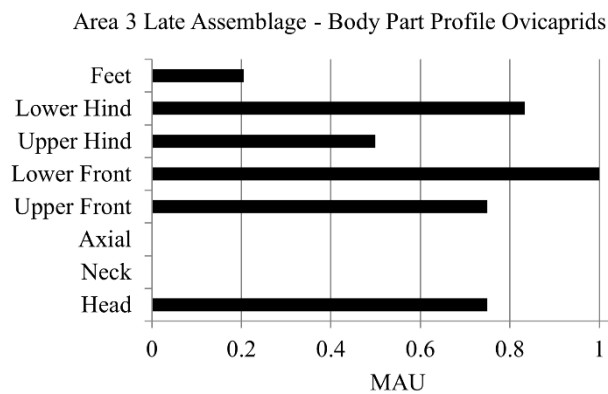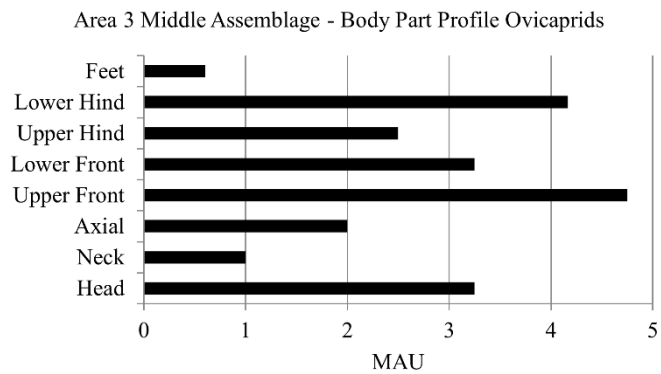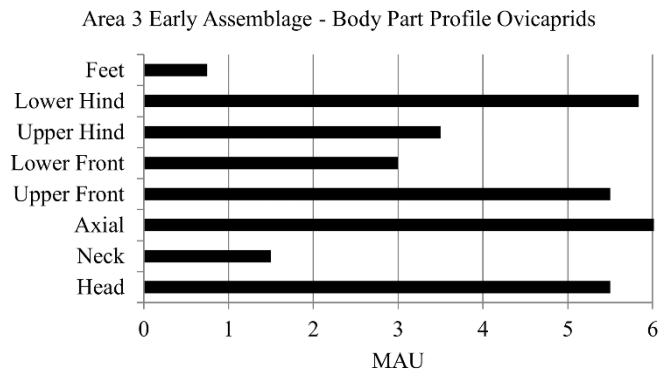
Sheep and goat are not included in the ovicaprid category.

Taxon	Early NISP	%NISP	MNI	Middle NISP	%NISP	MNI	Late NISP	%NISP	MNI
Large ungulate	68	6.6	-	15	10.9	-	43	9.1	-
Cattle (*Bos taurus*)	45	4.3	2	6	4.3	1	19	4.0	1
Equid	2	0.2	-	-	-	-	-	-	-
Donkey (*Equus asinus*)	2	0.2	1	1	0.7	1	1	0.2	1
Medium ungulate	610	58.8	-	77	55.8	-	217	46.1	-
Fallow deer (*Dama dama*)	25	2.4	2	-	-	-	3	0.6	1
Suid (*Sus sp.*)	4	0.4	1	-	-	-	4	0.8	1
Ovicaprid (*Ovis/Capra*)	184	17.7	4	19	13.8	1	85	18.0	2
Goat (*Capra hircus*)	33	3.2	4	10	7.2	2	41	8.7	3
Sheep (*Ovis aries*)	43	4.1	4	6	4.3	1	31	6.6	3
Gazelle (*Gazella sp.*)	7	0.7	1	1	0.7	1	1	0.2	1
Turtles	3	0.3	1	1	0.7	1	-	-	-
Hare (*Lepus sp.*)	1	0.1	1	-	-	-	-	-	-
Dog (*Canis familiaris*)	3	0.3	1	-	-	-	26	5.5	1
Cat (*Felis catus*)	1	0.1	1	-	-	-	-	-	-
Large bird	-	-	-	1	0.7	-	-	-	-
Great bustard (*Otis tarda*)	1	0.1	1	-	-	-	-	-	-

|									
Medium/Large bird	1	0.1	-	-	-	-	-	-	-
Medium bird	4	0.4	-	1	0.7	-	-	-	-
Small bird	1	0.1	-	-	-	-	-	-	-
Total	**1,038**	**100**	**-**	**138**	**100**	**-**	**471**	**100**	**-**
Medium mammal	51	-	-	1	-	-	8	-	-
Small mammal	8	-	-	-	-	-	4	-	-
Grand total	**1,097**	**-**	**-**	**139**	**-**	**-**	**483**	**-**	**-**

318

319   4.2. Body Part Profiles

320   We present body part profiles for ovicaprids of Area 3 for the different assemblages (fig. 6, SI

321   2). The anatomical profiles for different time periods are similar, though note the small MAU

322   values. We see a preference for front limbs, hind limbs, and head elements, Axial parts are

323   also prominent in the Early and Middle assemblages. Neck and feet elements are

324   underrepresented.

Area 3 Early Assemblage - Body Part Profile Ovicaprids

Area 3 Middle Assemblage - Body Part Profile Ovicaprids

Area 3 Late Assemblage - Body Part Profile Ovicaprids

325

326   Fig. 6: Anatomical profiles for ovicaprids of Area 3 in different phases.

327   Body part profiles for ovicaprids in the Early and Late assemblages for Area 4 are found in

328   fig.7 but note the low MAU values. We could not make an anatomical profile for ovicaprids

329   dating to the Middle assemblage because there are not enough data. In both the Early and Late

330   assemblages, the anatomical profiles are similar to those in Area 3, with a higher frequency of

331   head elements, front and hind limbs. The Early assemblage also has a high representation of

332   neck and axial elements. Feet elements are underrepresented.

Area 4 Early Assemblage - Body Part Profile Ovicaprids

Area 4 Late Assemblage- Body Part Profile Ovicaprids
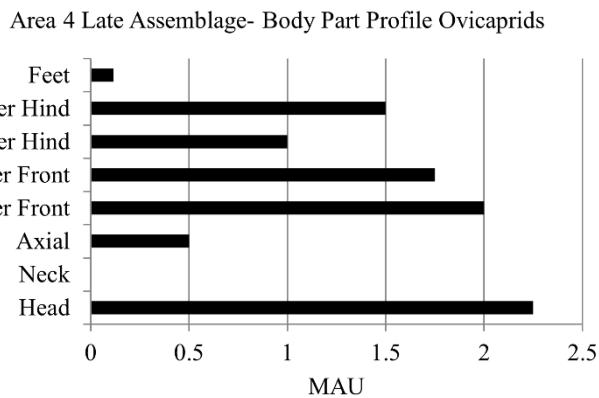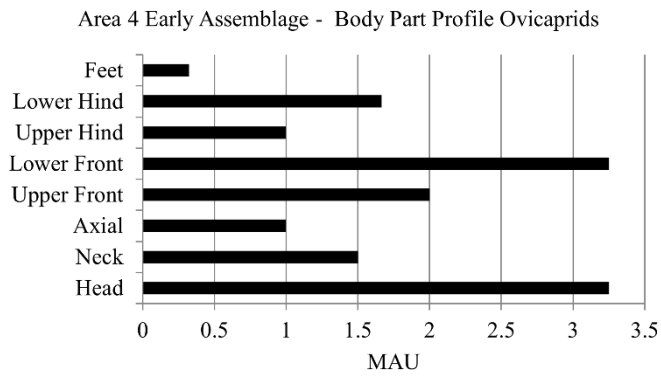
333

334 Fig. 7: Anatomical profiles for ovicaprids of Area 4 through time.

335 4.3. Ageing

336 We analyse age at death for ovicaprids in Area 3 using bone fusion data (table 4, fig. 8A).

337 During the Early assemblage, most ovicaprids are slaughtered when they are sub-adults, and

338 only a few get slaughtered as adults. For the Middle and Late assemblages, our sample size is

339 too small to reconstruct survivorship for all age groups. Due to the sample size, we only

340 created a tooth-based tripolar graph for the Early assemblage (fig. 8B), which shows a mix of

341 adults and juveniles, with a slight bias toward juveniles.

342 Table 4: Bone fusion data for ovicaprids in Area 3 through time. F = Fused, U = Unfused,

343 dist. = distal, and prox. = proximal.

Skeletal Element	Early		Middle		Late	
	F	U	F	U	F	U
Radius prox.	5	2	5	5	5	0
Humerus dist.	10	6	12	3	1	1

|						
Phalanx 1	16	7	15	5	5	0
Phalanx 2	6	2	4	1	2	1
Young (1 year)	**37**	**17**	**36**	**14**	**13**	**2**
Metapodial dist.	6	7	8	8	1	0
Humerus prox.	1	2	0	1	1	1
Tibia dist.	16	5	7	8	1	1
Tibia prox.	1	5	1	0	0	0
Femur dist.	5	4	1	1	0	0
Calcaneum	7	0	5	2	2	0
Femur prox.	5	9	2	6	0	1
Sub-adult (2 years)	**41**	**32**	**24**	**26**	**5**	**3**
Ulna prox.	1	2	0	1	0	0
Radius dist.	4	2	8	0	2	0
Adult (>2 years)	**5**	**4**	**8**	**1**	**2**	**0**

344

345
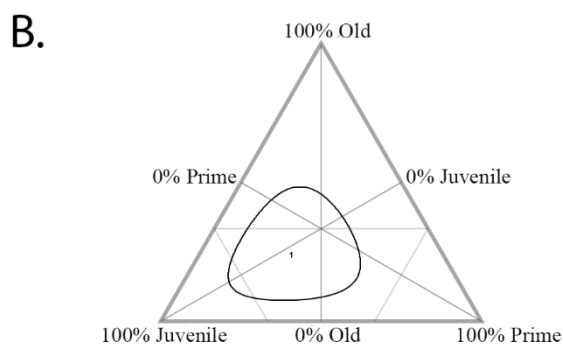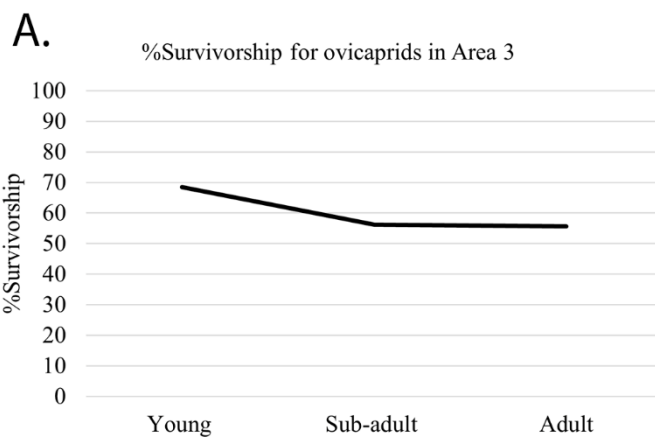
Fig. 8: Ageing profiles for ovicaprids in Area 3 through time. A: survivorship graph for
ovicaprids during the Early assemblage based on bone fusion. B: Tripolar graph for ovicaprid
ageing during the Early assemblage (ten juvenile, six adult, and five old ovicaprid teeth).

349   We examine mortality profiles for ovicaprids in Area 4 using bone fusion (table 5, fig. 9). We

350   could only do this for the Early assemblage since the other assemblages have too few data.

351   Most ovicaprids survive until old age during the Early assemblage in Area 4, although note

352   the small sample size. The tooth eruption and wear data are too limited in all assemblages to

353   create a tripolar graph.

354   Table 5: Bone fusion data for ovicaprids in Area 4 during the Early assemblage. F = Fused, U

355   = Unfused, dist. = distal, and prox. = proximal.

Skeletal Element	Early	
	F	U
Radius prox.	7	3
Humerus dist.	4	3
Phalanx 1	6	3
Phalanx 2	1	1
Young (1 year)	**18**	**10**
Metapodial dist.	3	1
Humerus prox.	0	0
Tibia dist.	3	3
Tibia prox.	1	1
Femur dist.	1	0
Calcaneum	1	1
Femur prox.	0	2
Sub-adult (2 years)	**9**	**8**
Ulna prox.	1	1
Radius dist.	3	2
Adult (>2 years)	**4**	**3**

356

%Survivorship for ovicaprids in area 4
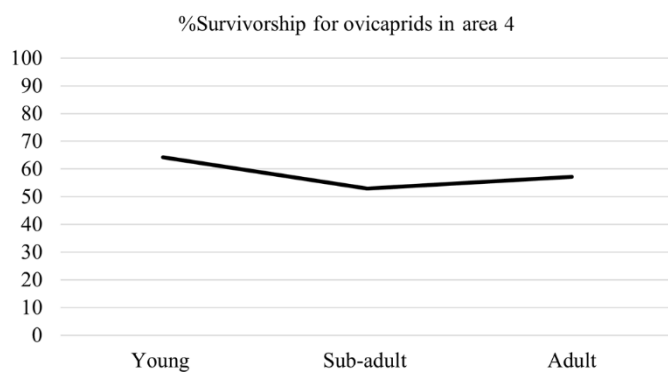
357

358   Fig: 9: Survivorship graph for ovicaprids in Area 4 during the Early assemblage.

359   4.4. Taphonomy

360   Density mediated attrition does not play a big role in bone survivorship at the site (table 6).

361   Burning is infrequent for all assemblages (table 7). In Area 4, we see no calcined or darkened

362   bones, as opposed to in Area 3. The frequency in burning is only different during the Early

363   assemblage (chi-square test, Early: Chi2 = 22.59, DF = 1, p = 2.00E-06, Monte Carlo p =

364   0.0001), but not during the Middle (Chi2 = 1.19, DF = 1, p = 0.27, Monte Carlo p = 0.41) and

365   Late (Chi2 = 1.06, DF = 1, p = 0.30, Monte Carlo p = 0.40) assemblages.

366   Table 6: Mandibular tooth to bone MNE ratios for Areas 3 and 4.

Assemblage	Lower tooth MNE	Mandible MNE	Tooth:Bone MNE
Area 3			
Early	23	21	1.10
Middle	11	12	0.92
Late	2	2	1.00
Area 4			
Early	16	15	1.07
Middle	5	4	1.25
Late	8	6	1.32

367

368   Table 7: Burning values for the discussed assemblages at Areas 3 and 4.

Burning	Early	%Early	Middle	%Middle	Late	%Late
Area 3						
Unburned	2,583	96.9	1,172	99.2	359	99.7
Carbonised	74	2.8	9	0.8	1	0.3
Calcined	10	0.4	1	0.1	0	0
Area 4						
Unburned	1,092	99.5	140	100	480	99.2
Carbonised	6	0.5	0	0	4	0.8

369

370   We document 119 cutmarks on Area 3 material and 111 cutmarks on specimens from Area 4,

371   most of which are on medium ungulates and ovicaprids (SI 3). We present anatomical profiles

372   using the NISP of bones with cutmarks for ovicaprids combined with medium ungulates (fig.

373   10). We see most cutmarks on axial elements (consisting of pelvis, vertebrae, and ribs) during

374   the Early assemblage of Area 3. The other assemblages have small sample numbers, but front

375   limbs consistently have more cutmarks.

376
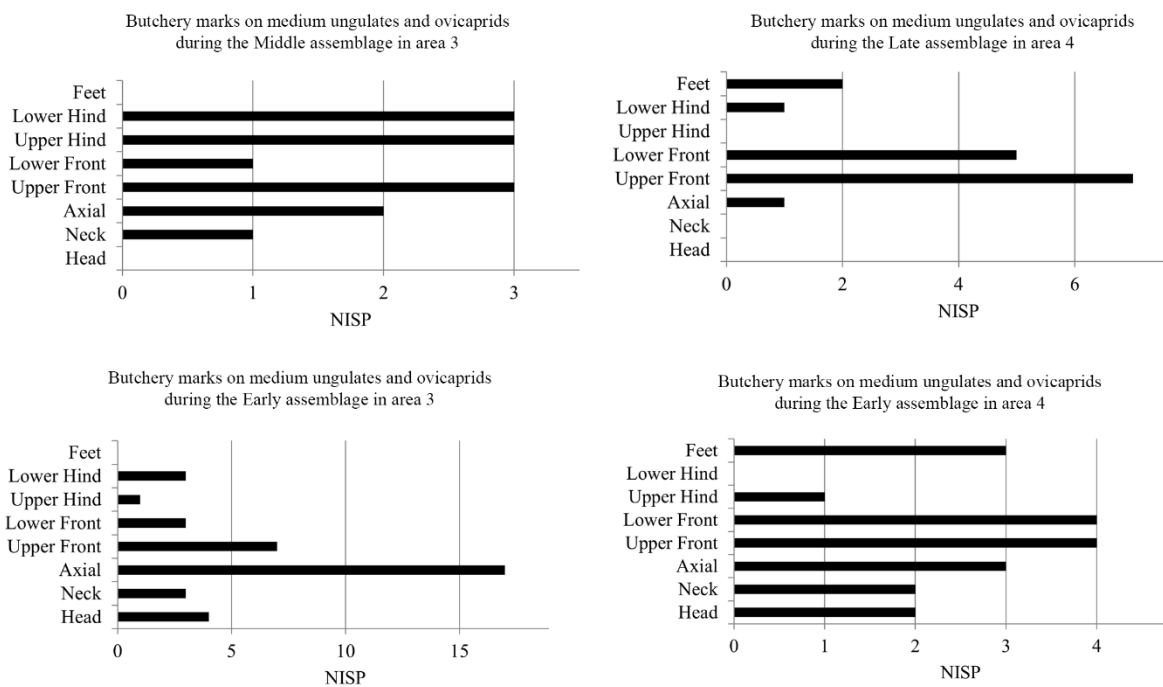
Fig. 10. Anatomical profiles showing the frequency of cutmarks for medium ungulates

combined with ovicaprids through time in areas 3 and 4. Note, these are raw counts and are

not standardized by MNE.

Twelve bones in Area 3 and five bones in Area 4 show traces of pathologies (table 8, SI 4). It

seems most of these pathologies are related to arthritis. Pathologies in Area 3 are most

frequent on ovicaprids and cattle, appearing on a wide range of skeletal elements. Area 4 has

pathologies on equids and cattle.

Table 8: Pathologies on bones from the Early, Middle, and Late assemblages from Areas 3

and 4.

| Assemblage	Taxon	Skeletal Element	Pathology
Area 3			

Early	Cattle	Ulna	Arthritis
Early	Cattle	Lower First Molar	Caries
Early	Medium Ungulate	Unknown bone	Arthritis
Early	Medium Ungulate	Humerus	Arthritis
Early	Ovicaprid	Atlas	Arthritis
Early	Sheep	Lower Second Molar	Heavily worn
Middle	Goat	First Phalanx	Arthritis
Middle	Ovicaprid	First Phalanx	Arthritis
Late	Cattle	Ulna	Arthritis
Area 4			
Early	Cattle	Carpal/Tarsal	Arthritis
Early	Cattle	Unknown Incisor	Heavily worn
Early	Equid	Unknown Bone	Arthritis
Early	Equid	Unknown Bone	Arthritis

386

387   4.5. Subsistence in Phoenicia and the neighbouring regions

388   We compare the results from Tell el-Burak with coeval late Iron Age to Persian Period faunal

389   material in the region (table 9, fig. 7), which we chose using the criteria described in section

390   2.2. We investigate the taxonomic composition using a correspondence analysis (CA) to

391   check for clusters related to chronology, geography, or cultural entities (fig. 11).

392   A visual inspection of the CA shows most samples plot on the right side of the first axis and

393   along the second axis. These samples are associated by their proportions of cervids, fallow

394   deer, cattle, and ovicaprids. There are two sets of outliers to this group. The first group

395   consists of two sites, Kinet Höyük and Tell Tayinat, and is characterised by higher

396   proportions of pig, and wild taxa such as roe deer, red deer, and turtles. The other outlier

397   consists of one site, Tell Afis. It plots separately due to its proportion of horse, donkey,

398   camelids, and wild taxa such as mustelids and fox. In general, the outliers contain the highest

399   frequency of pigs, especially when compared to the larger group on the right side of the first

400   axis. Note, we see no clusters regarding chronology.
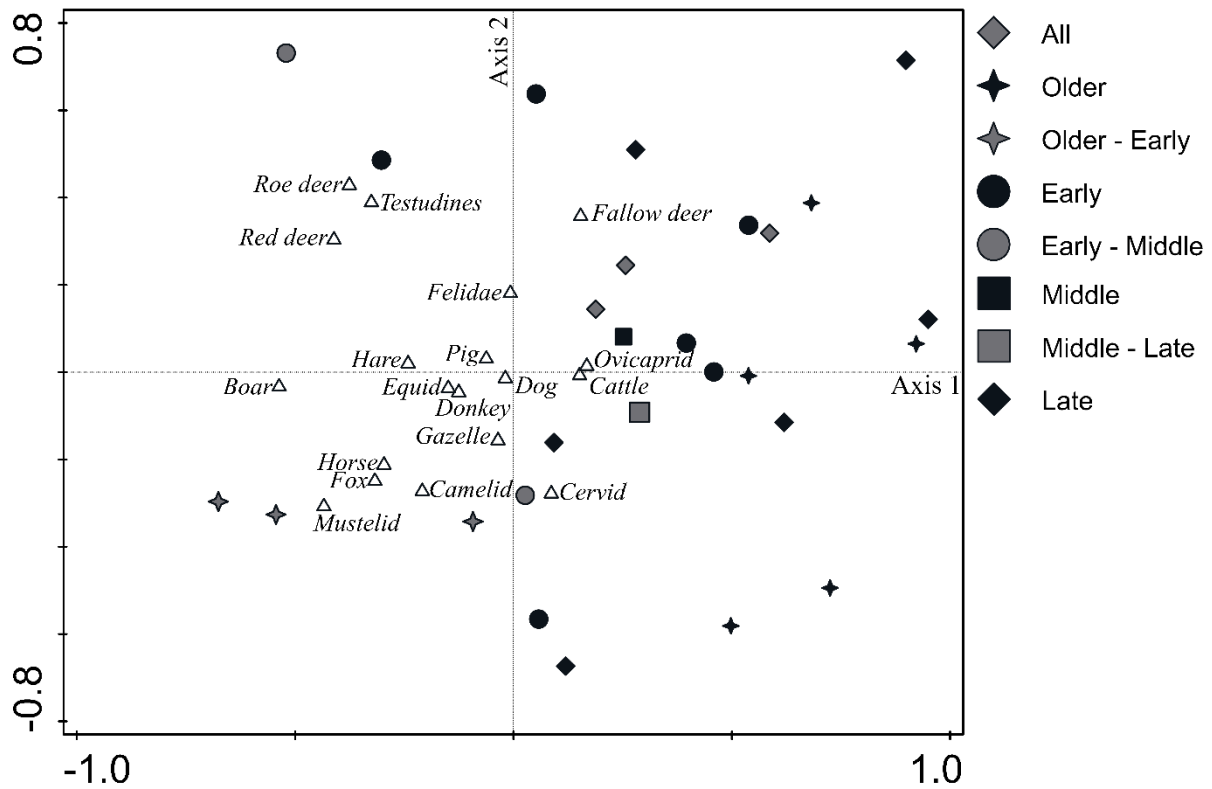
401

402 Figure 11: CA biplot representing the taxonomic composition of all samples, categorised per

403 assemblage as used at Tell el-Burak. Explained cumulative variation is 25.25% and 41.27%

404 for axis 1 and 2, respectively.

405 Table 9: Archaeological information and references for the sites used for the comparison of

406 the Tell el-Burak faunal material. Faunal data from comparative sites have been assigned an

407 assemblage based on the absolute dating of the context. 'Older' indicates faunal material

408 predating the Tell el-Burak faunal material. 'All' indicates faunal material covering the Early,

409 Middle, and Late assemblages of Tell el-Burak. Between brackets is the site abbreviation used

410 in the correspondence analysis (see Online Supplementary Material 5).

Site	Dating	Assemblage	Contexts	Reference
Burak (TB)	725 - 600 BCE	Early	Areas 3 and 4	This paper
	600 - 550 BCE	Middle	Areas 3 and 4	This paper
	550 - 350 BCE	Late	Areas 3 and 4	This paper

	725 - 350 BCE	All	Area 3	(Çakırlar et al., 2013)
Tyre el-Bass (TYR)	mid-9th - early 6th cent. BCE	Older	Urns from Period V (c. 730 - mid-sixth century BCE) and stratum 4 (c. 850 - 550 BCE)	(Montero, 2014)
Jiyeh (JIY)	8th - 7th cent. BCE	Early	Rooms 4, 20 and 72 (sector D)	(Piątkowska-Małecka, 2017)
	6th - 4th cent. BCE	Middle - Late	Rooms 4, 20 and 72 (sector D)	
Horbat Rosh Zayit (HRZ)	10th - 8th cent. BCE	Older	Strata III - I	(Horwitz et al., 2000)
Yoqne'am (YOQ)	late 9th - 8th cent. BCE	Older	Fortifications and domestic structures of stratum XII	(Horwitz et al., 2005)
	7th - 6th cent. BCE	Early/Middle	Dwellings of stratum XI	
Tel Qashish (TQ)	539 – 332 BCE	Late	Stratum IIA-I in areas A and B	(Horwitz, 2003)
Megiddo (MEG)	732 BCE	Older	Level H-3 and Level L-2	(Sasson, 2013)
Dor (DOR)	450 – 332 BCE	Late		(Sapir-Hen et al., 2014)
Tel Michal (MIC)	mid-10th - 8th cent. BCE	Older	Strata XIV-XII	(Hellwing and Feig, 1989)
	end 6th – end 4th cent. BCE	Late	Strata XI-VI	(Hellwing and Feig, 1989; Sade, 2006)
Ashkelon (ASH)	7th cent. BCE	Early	Grid 38 and Grid 50	(Hesse et al., 2011)
Tell Jemmeh (JEM)	8th cent. BCE	Older	Field IV	(Maher, 2014)
	late 8th - 6th cent. BC	Early/Middle	Field IV	
	5th - 4th cent. BC	Late	Field IV	
Tell Nebi Mend (TNM)	900-700 BCE	Older	Trenches III and V	(Grigson, 2015; Grigson et al., 2015)
	700-600 BCE	Early	Trenches III and V	
Tell Tweini (TWE)	700-550 BCE	Early/Middle	Level 5, Field A	(Linseele et al., 2019)

	550-333 BCE	Late	Level 4, Field A	
Tell Afis (AF)	Late 8th. BCE -7th cent. BCE	Early		(Wilkens, 2002, 2000, 2005)
Tell Tayinat (TT)	738 - 600 BCE	Early	Field 5	(Lipovitch, 2017)
Kinet Höyük (KH)	700 - 550 BCE	Early - Middle	Periods 7 and 6	(Çakırlar et al., 2018)

411

412   5. Discussion

413   5.1. Subsistence at Tell el-Burak

414   The diet at Tell el-Burak is consistent throughout time, suggesting stable subsistence

415   practices, although we see some small spatial and chronological variations.

416   Ovicaprids are the dominant taxon, and, except for the Early assemblage of Area 4, goats

417   consistently outnumber sheep. The general preference for goats suggests that Tell el-Burak is

418   part of a food system aiming to optimise their energy and protein intake in a warm

419   environment since goats are better adapted to such an environment than sheep (Redding,

420   1984). During the Early assemblage, we see similar survivorship for ovicaprids in both areas.

421   Since there is no clear focus on slaughtering animals of a specific age group, the inhabitants at

422   Tell el-Burak probably practised a mixed economy during this period, which was aimed at the

423   production of meat, milk, and wool (Payne, 1973). Anatomical profiles show inhabitants

424   prefer front limbs, hind limbs, and head elements throughout all assemblages in both areas.

425   Cattle are the second most abundant taxon at the site, although the ovicaprid:cattle ratio

426   indicates that ovicaprids vastly outnumbered cattle, especially during the Late assemblage in

427   Area 4. This suggests the keeping of many cattle might not have been worth the investment

428   for the inhabitants, since cattle require more food and water (Sasson, 2016; Tchernov and

429   Horwitz, 1990). The decrease of the proportion of cattle in the Late assemblage corresponds

430   to the architectural decline at Tell el-Burak, which shows that during its late stage the

agricultural domain only plays a peripheral role in the settlement system of the region.
Donkeys are most common during the Middle assemblage in both areas, which parallels to the period when the wine press in Area 4 has its highest production rate. This could indicate the use of donkeys as labour animals in connection to the viticulture activities at the site. Pigs do not contribute significantly to the diet. Hunting (e.g., gazelle, fallow deer) occurs on occasion but is not necessary to complete the diet.

Finally, we should note the high numbers of dogs in both areas during the Late assemblage. Previous work at Tell el-Burak uncovered two dog burials and scattered bone remains related to the Late assemblage in Area 3. The first dog (individual A) has an age-at-death of six months or slightly earlier, whereas the second dog (individual B) died between three and four years of age (Çakırlar et al., 2013). Although the newly analysed dog remains are not found in situ, they probably are related to the Persian custom of dog burials (Çakırlar et al., 2013; Dixon, 2018).

5.2. Subsistence in Phoenicia and Beyond: features and regional differences

A correspondence analysis comparing the taxonomic composition of the different assemblages at Tell el-Burak and those from coeval sites in the Levant, shows no clustering per chronological assemblage nor do the sites situated in what is traditionally known as Phoenicia group. We do, however, see the grouping of central and southern Levantine sites, which share similar taxonomic composition determined by the proportions of common domesticates, such as ovicaprids and cattle, and wild species such as fallow deer and cervids. The similar taxonomic composition of these sites suggests that the subsistence practices of the Phoenicians are not different from those currently documented within the southern Levantine regional framework of subsistence practices. However, two sets of samples differ from this general pattern, particularly due to the higher frequencies of pig in their diet. The first group consists of two sites situated in south-eastern Anatolia, Tell Tayinat and Kinet Höyük. Both

456 sites are further distinguished from the southern Levantine group by their high proportions of

457 roe deer, red deer, and turtles. The importance of wild species could be explained due to these

458 sites being situated in higher zones of mean annual precipitation (Fick and Hijmans, 2017),

459 compared to the sites in the southern Levant. The other group consists of Tell Afis, which is

460 an inland site situated in northern-central Syria and differs from the other samples due to its

461 proportion of equids, camelids, mustelids, and gazelle. Regarding mean annual precipitation

462 and elevation values, the site does not differ much from the main southern Levantine group it

463 is situated more inland.

464 6. Conclusion

465 The prevailing agricultural function of Tell el-Burak could imply animals are selected and

466 used at the site based also on how they contribute to such activities. This would explain the

467 frequencies of draught animals such donkeys and cattle, which are likely employed to plough

468 the fields and transport heavy loads, especially during the grape and olive harvest seasons.

469 Both donkeys and cattle are less common in the Late assemblages. As grapes (*Vitis vinifera*)

470 are the predominant crop until the sixth century BCE (Orendi and Deckers, 2018), perhaps a

471 change occurs in agricultural processing at Tell el-Burak during the last two centuries of its

472 occupation. However, ovicaprids heavily outnumber cattle and are the dominant taxon

473 throughout time at Tell el-Burak. Ovicaprids are easier to keep than cattle since the latter

474 require more water and food. Herding strategies for ovicaprids focus on optimising protein

475 and energy intake, and mortality profiles indicate a mixed economy. The contribution of suids

476 and wild taxa is minimal to the diet. Given the function of the site, one may even speculate

477 that their consumption may have occasionally occurred in relation to feasts that usually

478 marked the beginning and, more frequently, the end of the harvest seasons (e.g., Wright &

479 Chan 2013), when it is very likely that the number of people at Tell el-Burak was greater. In

480 fact, it is reasonable to assume that, while a small group of people are involved in the

management of the site and its agricultural activities throughout the year, seasonal workers may have reached Tell el-Burak at the peak of the harvest season. Slight variations in the taphonomy of the faunal assemblages from Areas 3 and 4 probably account for differences in the function and activities carried out in these two sectors of the site. The higher number of animal bones with burning traces in Area 3 compared to Area 4 testifies to the presence of cooking activities, while a similar distribution of bones with traces of pathologies remains unexplained. As it is typical of Persian-period Phoenician and coastal sites, dog burials are found at Tell el-Burak in the Late assemblage. However, most of the dog remains are found scattered due to the disturbance of the original dog burials by the settlement activities of the Mamluk-Ottoman Periods at the site.

When comparing the faunal dataset from Tell el-Burak with other coeval sites in the Levant, with special attention to those located on the coast or having mostly an agricultural function, a distinction between the northern and central/southern Levant emerges. The diet of the people of the latter sites are characterised by the frequency of fallow deer, cervids, cattle, and ovicaprids. However, currently there are no patterns separating the region traditionally identified as Phoenicia, since the diet appears to have been similar to that of the selected sites in the southern Levant. On the contrary, the diet in the northern Levant is characterised by the higher frequency of pigs. Higher percentages of equids, camelids, and gazelle are found in the faunal assemblages of inland sites (i.e., Tell Afis), while a larger quantity of roe deer, red deer, and turtles occurs at both Kinet Höyük and Tell Tayinat.

Overall, Tell el-Burak continues to provide essential evidence for the analysis of the Iron Age central Levant and the adoption of a historical and stratigraphically reliable approach to the investigation of the Phoenicians. The current faunal dataset allows the first characterisation of the diet in this region during the late eighth to mid fourth centuries BCE, and while its comparison to contemporary sites in the Levant does not support the existence of distinct

506 subsistence practices in Phoenicia, instead it suggests a high degree of similarity with what

507 can be observed in other coastal sites in the southern Levant. Hopefully, when further, coeval

508 faunal data from ongoing fieldwork activities in Phoenicia are published, it will be possible to

509 better understand whether variation occurs in the diet of this region and determine if some of

510 the patterns presented in this article are related to the specific function of Tell el-Burak. As

511 such, the current work represents not only a first step in the study of the Phoenician diet, but,

512 consequently, will be pivotal in understanding how subsistence practices of the Phoenicians

513 may have developed when they settled in other regions of the western Mediterranean and

514 whether they contributed to the local diet and livelihood strategies.

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