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For the birds — An environmental archaeological analysis of Byzantine pigeon towers at Shivta (Negev Desert, Israel)

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ABSTRACT

Pigeon rearing was an integral part of the agricultural regime that dominated the Negev region in Israel throughout the Roman and Byzantine periods. Dozens of structures have been documented that relate to the raising of pigeons and the exploitation of their dung as a fertilizer as is attested in the literary sources (Pliny, Columella and Varro). Excavation of a dovecote near Shivta produced large quantities of pigeon dung and sediments. The material recovered was processed for floral remains (both macro and micro) and archaeozoological remains. We present a holistic look at pigeon diet and local environmental conditions in the Byzantine Negev through the archaeobotanical remains. Demographic and morphometric analysis of size and shape of the pigeon bones refine our understanding of pigeon species that were bred in antiquity as well as inform on their life-histories. This integrated examination from an agro-archaeological perspective illustrates the complexity of desert agriculture.

1. Introduction

The site of Shivta is located in the Negev Desert of Israel (Fig. 1). It was, according to current research, founded in the early Roman period (ca. 1st century BCE – 1st century CE) and reached its peak during the Byzantine period (4th – 7th centuries CE). It appears that the Roman military presence in the area of southern Israel and Jordan during the 4th century CE, following an empire-wide economic collapse, likely played a significant role in causing an increase in agricultural production throughout the region (cf. Barker, 2002; Rubin, 1991). Farming was the primary occupation of the inhabitants of the site, who were prosperous enough to build large and complex agricultural installations such as wine presses, aqueducts, cisterns, water pools and dovecotes (Segal, 1983; Negev, 1993; Hirschfeld, 2003), as well as three Byzantine churches.

A good deal of recent scholarship on the Roman–Byzantine period has increasingly focused on the nature and capacity of its agricultural economy in arid environments (Kehoe, 1990; Barker, 1996, 2002, 2012; Avni et al., 2009, 2013; Ashkenazi et al., 2012; Erickson-Gini, 2012; Haiman, 2012; Kamash, 2012; Ramsay and Parker, 2016). Understanding the empire's economy is indeed a formidable task as in general there is a lack of surviving documentary evidence that relates to agricultural production and trade. Therefore archaeological investigations of agricultural sites are one of the only ways to elucidate information about arguably the most important economy in the ancient world.

Evidence for regional rain-water harvesting agriculture in southern Israel and Jordan appears to have had a long history and has been documented as early as the Neolithic. It appears to continue in relation to precipitation levels through to the recent past (for example see: Kedar, 1956; Bruins and van der Plicht, 2004; Hunt and el-Rishi, 2010; Barker, 2012; Bruins, 2012). Shivta was supported by sophisticated systems of water collection and irrigation during the Roman-Byzantine period that allowed large-scale agriculture. These included dams, channels cisterns and reservoirs. Early research at the site determined that the agricultural fields coincided with the watershed lines of the basin of the valleys and tributaries (Kedar, 1956). Kedar's (1956) study determined that agriculture was based on a hydrographic system and distribution of rainfall. He noted that all fields depended on episodic rainfall for irrigation as there were no perennial or seasonal water sources in the area. Cereal agriculture was still being carried-out on these systems when Kedar's study was conducted as the water-carrying ditches were still intact and the ancient fields still had flat surfaces. In antiquity these

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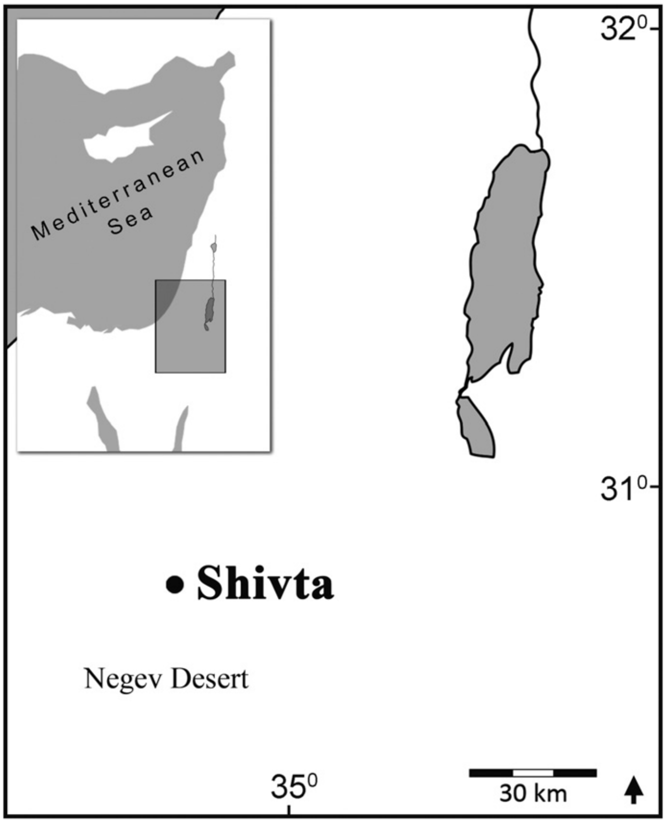

Fig. 1. Location of Shivta in the Negev desert, Israel.

large-scale agricultural field systems were also supported by intensive pigeon-raising and four large dovecotes remains are scattered around them.

According to written accounts, archaeological evidence and artistic representations, pigeon-raising was a widespread livestock industry in the Roman-Byzantine world. Pigeons were raised primarily for the production of fertilizer and as a year-round source of meat (Tepper, 2007a, 2007b). All of the dovecote remains were excavated between 2000 and 2004 by Hirschfeld and Tepper (2006; Fig. 2). On a small hill 500 m north of the site a round dovecote was excavated (Fig. 2:1; Fig. 3) and the structure's debris buried under the collapsed stones consisted of large quantities of pigeon (*Columba livia*) remains, as well as pigeon manure, and various botanical remains. Though numerous dovecots are known, no research has so far been carried out on the remains themselves.

Barker has stated that a major problem with research on desert settlements has been a lack of interdisciplinary research (Barker, 2002, 2012). Therefore the aim of this paper is to contribute to our understanding of desert agricultural in the Roman-Byzantine period by analyzing the various well preserved floral and faunal materials that are part of the complex agricultural regime in this arid landscape of the Negev and use them to reconstruct pigeon diet, home range, taphonomy, demographic profiles of pigeons and environment (<100 mm mean annual precipitation) (Fig. 4).

1.1. Excavation background

The excavation of the dovecote was carried out in two seasons during 2003–2004 by Hirschfeld and Tepper on behalf of the Institute of archaeology of the Hebrew University, Jerusalem. A round dovecote was revealed with an external diameter of 5.2 m and preserved to a maximum height of 1.65 m. The internal diameter is 4 m divided by Y-shaped walls into three rooms, with open doors at the interior wall (Fig. 5). Two main strata were excavated under the surface layer at the top of the ruined tower. The first stratum was a collapse layer (1.2–1.3 m) of the walls and the second was a pigeon dung layer, that attained a depth of 0.4 m above the dovecote floor (Fig. 5). The debris layer and the dung on the floor probably point to the destruction of the dovecote (Hirschfeld and Tepper, 2006). The pottery retrieved from the second stratum can date the construction and use of the building to the Byzantine period (Hirschfeld and Tepper, 2006: 102, Fig. 25: 10–13). Likewise, a Greek inscription (*ΔOPON* = present) with an associated cross was found on top of the first strata and supports our assumption of the destruction period of the dovecote during the Byzantine period (Hirschfeld and Tepper, 2006: 97, Fig. 14). Although we cannot be completely certain, all the above evidence, supports the abandonment

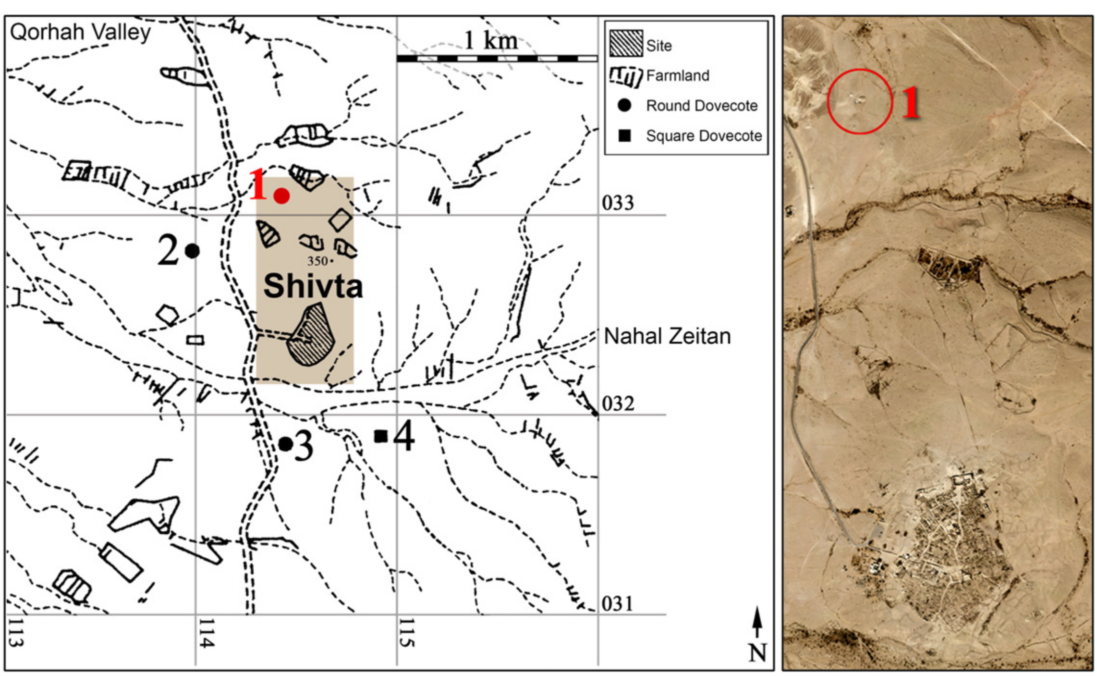

Fig. 2. Location map of the four dovecotes around Shivta (no. 1 is the dovecote presented in this study).

Fig. 3. View of dovecote no.1.

of the dovecote (with the dung layer above the floor), having been related to a critical event that happened in the middle of the 6th century CE.

2. Materials and methods

The material obtained for the current comprehensive analysis of botanical and zoological remains recovered from the pigeon tower was excavated between 2003 and 2004 by Hirschfeld and Tepper (2006). At this time, two barrels that contained 500–600 l of organic matter were collected from the floor deposit and stored for future analysis. These were from two rooms, the northern (#814) and the western (#817) rooms of the dovecote. The floor of both rooms, located under collapse debris which consisted primarily of stone slabs used for the construction of nesting compartments, consisted of easily distinguished dark-colored sediment. The material from the floors was rich in organic remains (pigeon bones, archaeobotanical remains and pigeon droppings). These archaeological remains constitute the materials studied here. This excavated dovecote represents the best preserved of all the pigeon towers at the site (Hirschfeld and Tepper, 2006: Buildings No. VI).

2.1. Archaeobotany

2.1.1. Macro remains

From the 500–600 l of dung that were collected, 200 l were processed, using the flotation technique. The botanical material that was

Fig. 4. Current environment around Shivta, looking from the dovecote to the south. The site of Shivta is in the background.

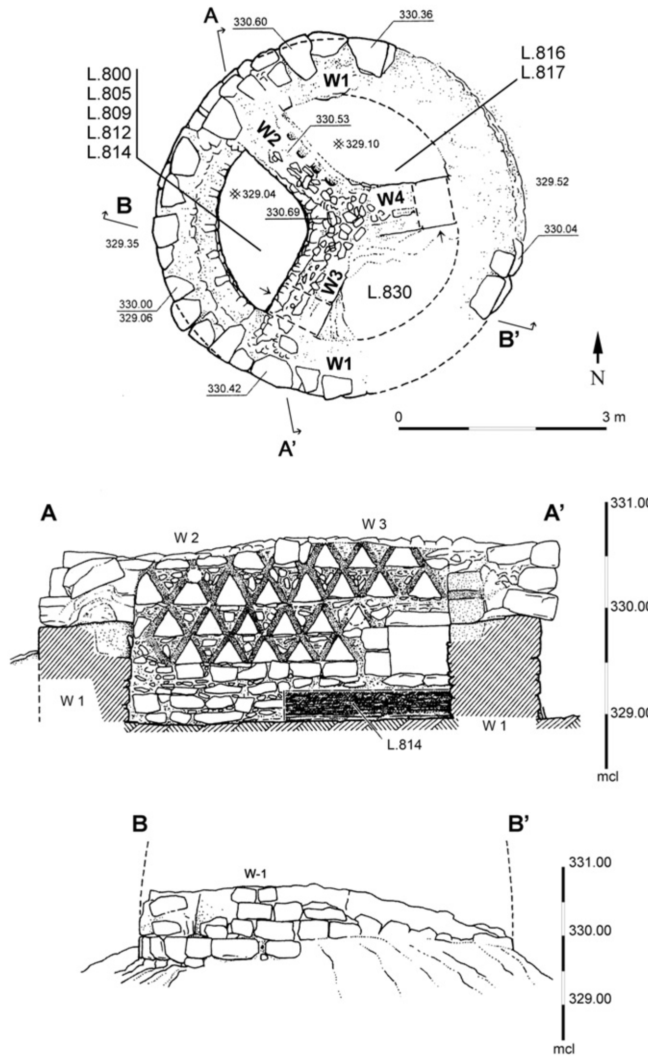

Fig. 5. Dovecote no. 1 – plan and sections.

recovered from the dung matrix was collected in three parts: 1) material that sank to the bottom was collected in a 1 mm mesh screen (heavy fraction), 2) material that floated (light fraction) was collected in nested 1 mm and 3) 250 μm sieves. The heavy fractions of each sample were sorted in the field. The light fractions were dried and transferred to labeled plastic bags and shipped to Ramsay's lab at The College at Brockport, State University of New York.

Due to the large amount of material recovered from each context and to time constraints the material was sub-sampled to 25% of the original volume using the riffle-box method. The riffle-method consistently produces random samples and therefore is a suitable way of sub-sampling (van der Veen and Fieller, 1982: 291). The sub-samples of the light fractions were sorted using a Motic stereoscopic microscope using up to 40× magnification. The plant remains recovered and analyzed consisted of seeds, fruit stones, fruit pips, achenes and other plant parts (mainly cereal chaff).

The recovered botanical material was identified by comparing morphological characteristics of the archaeological specimens to modern material from the archaeobotanical reference collection at the Department of Anthropology, The College at Brockport, State University of New York and reference seed atlases (Post, 1932; Beijerinck, 1947; Berggren, 1969, 1981; Zohary, 1966, 1972; Feinbrun-Dothan, 1978, 1986; Anderberg, 1994; Cappers, 2006).

2.1.2. Palynology

Two samples were taken for pollen analysis. The first was collected from the dung layer above the floor of the dovecote (Fig. 5; section A-A; L-814) during excavation. The second was taken as a control from the surface layer 2 m south of the dovecote. Both samples were taken with no human intervention by clean tools and packed in plastic-bags (zipbags).

Thirty grams of sediment were processed. Pollen grains were extracted, identified and counted, and their relative ratios calculated. A tablet of *Lycopodium* (containing 10,679 spores in average) added (in order to calculate pollen concentration), which was subsequently treated with HCl to remove the carbonates, and then a density separation was carried out by a $ZnCl_2$ solution with specific gravity of 2.0, together with sieving. After acetolysis, the organic residue was stained with safranin and mounted in silicone oil.

A light microscope, with magnifications of 200×, 400× was used for identifying and counting the pollen grains. The comparative reference collection of the Palynological Laboratory of the Zinman Institute of Archaeology, University of Haifa and the atlas *Pollen et Spores d'Europe et d'Afrique du Nord* (Reille, 1995, 1998, 1999) were used to identify the pollen at the family, genus and when possible, to the species level.

2.1.3. Wood remains

Carbonized and non-carbonized wood samples were collected and 0.5–1 cm^3 pieces were taken from each for identification. Samples were aspirated in absolute ethyl alcohol, dipped in Celloidin solution and transferred to paraffin. The samples were oven dried at 55 °C. Blocks were made in paraffin and cross sections and longitudinal as well as radial sections were made with a microtome. Identification of the samples to species level was based on the three dimensional structure of the wood as seen microscopically in those sections. Comparison was made with reference sections made from recent live trees and shrubs and with anatomical atlases (Fahn et al., 1986; Schweingruber, 1990).

2.2. Zooarchaeology

Faunal remains were collected from all excavated loci within the dovecote. Methodological procedures of the recovery, identification and analysis of faunal remains followed Bar-Oz (2004). The abundance of the different taxa was quantified using NISP (number of identified specimens), MNI (minimum number of individuals), MNE (minimum number of elements) and MAU (minimum animal units) using the assumptions described in Klein and Cruz-Uribe (1984) and Lyman (1994). The skeletal elements were identified anatomically and taxonomically using the comparative collections housed at the Laboratory of Archaeozoology, Zinman Institute of Archaeology, University of Haifa. All identified specimens were systematically examined for bone surface modifications. Age-at-death of the pigeon remains was determined based on level of porosity of the long bones (following Serjeanston, 2009: 35–47).

3. Results

3.1. Dating

Radiocarbon dating was based on pigeon dung found on the floor of room #817. The concentration of the radiocarbon in the sample was determined using the Accelerator Mass Spectrometry (AMS) technique. The sample was prepared by Beta Analytic Inc. (sample number 92415) and a detailed methodological protocol is available at their website (http://www.radiocarbon.com/carbon-dating-pretreatment.htm). Calibration was calculated with 2013 INTCAL program (Reimer et al., 2013). Details of the sample are given in Table 1. Calibrated age range from 1550 to 1490 years BP if only ±1 S.D. is considered and from 1520 to 1345 years BP if ±2 S.D. is considered. The obtained date (550 CAL CE; cal 1400 years BP) is in strong accordance with the analysis of pottery assemblages found in association with the dovecote, and correlations with well-established regional ceramic sequences.

3.2. Archaeobotany

3.2.1. Macro remains

From the 200 l of dung that was processed, 967 specimens of seeds and/or other plant parts (e.g. cereal chaff, peduncle, fruit stone and pip) were recovered that represented 25 plant taxa. 84 of the specimens were indeterminate. The remains have been categorized and include one cereal, twenty wild species, one legume, three fruit species and several unidentified seed fragments (Table 2).

This analysis yielded a distribution of wild and domesticated species with similar results between the two parts of the dovecote. The sample from room #817 showed a composition of 45% weed and wild species, 54% fruit and 1% legume. Room #814 sample is composed of 46% weed and wild species, 52% fruit, 1% cereal crops and 1% legumes (Fig. 6). Although the majority of the assemblage is comprised of fruit, only three taxa have been identified, *Ficus carica* (fig) (Fig. 7a), *Vitis vinifera* (grape) (Fig. 7b) and *Olea europaea* (olive). There are also several grape peduncles that have been identified as well as a possible fragment of the epidermis of the fruit of a grape. *Phoenix dactylifera* (date) was found in the preliminary work but was not recovered in this study, although there was only one fragment identified in the 2010 assemblage (Ramsay and Tepper, 2010). The only cereal crop positively identified was *Hordeum vulgare* (barley) and both the grain and rachis segment (Fig. 8) were present in the sample. Also found were cereal culm nodes and several unidentified seeds and/or plant fragments. Legumes made up <1% of the assemblage. Only one example of *Pisum sativum* (common pea) was identified and the rest were indeterminate legumes.

There were twenty new taxa identified in the current analysis (Table 2). The five previously identified taxa at the site, *Thymelaea passerina* (mezereon) (Fig. 9), *Androsace maxima* (greater rock jasmine), *Rumex* sp. (dock), *Carex* sp. (sedge) and *Fumaria* sp. (fumitory) (Ramsay and Tepper, 2010) were all present in the current assemblage. Mezereon, fumitory and greater rock jasmine were the most numerous taxa identified with only a small representation of most other taxa with the exception of *Raphanus rapistrum* (wild radish), *Anchusa* sp. (bugloss) and *Arnebia* sp. (Arnebia) that appear in significant numbers (Fig. 10).

Raphanus rapistrum (wild radish), *Anchusa* sp. (bugloss) (Fig. 11) and *Arnebia* sp. (Arnebia) have a substantial representation in the assemblage. Wild radish grows in seed pods which break up before harvest and if growing in an agricultural field, allow the seeds to become a common component of cereal crop fields. It has also been noted to be a valuable honey plant (Zohary, 1966: 326–327).

There are six species of the genus *Anchusa* found in the area covered by *Flora Palestina* (Feinbrun-Dothan, 1978) however, it is not possible to narrow the identification down to the species level due to our incomplete comparative collection for the genus. However, bugloss is fairly common in the region and is generally found in cultivated beds and in nutritionally poor soils (Feinbrun-Dothan, 1978: 81–85). The plant is also known to grow on rocky walls and therefore the seeds included in the assemblage may not have been part of the pigeon's diet but could have been naturally incorporated in the samples by plants growing near or on the walls of the dovecote. Finally the genus *Arnebia* is often classified as an agricultural weed as well as a desert annual which root contains a red dye. There are 25 species of *Arnebia* (Feinbrun-Dothan, 1978: 68–70) and as a result of not having all 25 species in the reference collection it was not possible to determine to species level. However *Arnebia* are commonly found at sites in desert habitats in the region, such as Nabataean Humayma (Ramsay, 2014), Roman Aila (Ramsay and Parker, 2016), Hellenistic Tall al 'Umayri (Ramsay and Mueller, 2016) and Byzantine Petra (Ramsay and Bedal, 2015).

Table 1
Information on the AMS dated pigeon dung samples given in year BP.

Lab #	Type	Sample ID and location	Conventional radiocarbon age	d13C	Intercept of Radiocarbon Age with Calibration Curve	Calibrated results (95% probability) - 2 sigma calibration
BETA417456	Pigeon dung	Room #817	1520 ± 30 BP	−26.0 o/oo	Cal 550 CE (Cal BP 1400)	Cal 430 to 490 CE (Cal BP 1520 to1460) Cal 510 to 515 CE (Cal BP 1440 to 1435) Cal 530 to 605 (Cal BP 1420 to 1345)

3.2.2. Palynology

Results of the pollen counts are given in Table 3. Percentages of the various pollen types are arranged in two groups: arboreal pollen (AP) and non-arboreal pollen (NAP). The total number of pollen counted in each sample and the pollen concentrations are given at the bottom of the column. Hydrophilous pollen is presented as counts (excluded from the total count). In all samples at least 200 pollen grains were counted. Pollen concentrations are high, preservation of pollen is good and a large variety of pollen types could be identified.

The pollen assemblage of the dung sample exhibits relatively high AP levels, mainly evergreen oaks (*Quercus calliprinos*; 11.8%) and olives (*Olea europaea*; 15.4%) are high in the studied assemblage. Pistachio pollen (*Pistacia* sp.; 3.2%) is also abundant. Poaceae (grasses; 17.5%) and cereal pollen (9.3%) dominate the NAP group, with high proportions of Chenopodiaceae/Amaranthus (11.8%; mostly of the *Atriplex* type), Asteraceae/Asteroideae (6.1%), Fabaceae (3.6%), Liliaceae (5.3% including *Allium* type) and Brassicaceae (3.2%) pollen. Typha (mostly *tetrads*) is the dominant hydrophilous pollen.

Table 2
Archaeobotanical remains identified from room numbers 814 and 817 from the pigeon tower at Shivta (raw counts).

Species	Common name	Part of plant	Room #817	Room #814
Ficus carica	Fig	Achene	89	228
Olea europaea	Olive	Pit	0	6
Vitis vinifera	Grape	Pip	48	85
Vitis vinifera peduncle	Grape	Peduncle	3	11
cf. *Vitis vinifera*	Possible grape skin	Epidermis	1	0
Hordeum grain	Barley	Grain	0	1
Hordeum rachis	Barley	Rachis	0	1
Cereal grain	Cereal	Grain	0	2
Indeterminate cereal	Cereal	Culm node	2	2
Pisum sativum	Garden pea	Seed	0	1
Legume indet.	Legume	Seed	2	3
Thymelaea passerina Synonyms: *Passerina annua*	Mezereon, spurge flax	Seed	80	144
Androsace maxima	Greater rock jasmine	Seed	7	16
Carex sp.	Sedge	Seed	0	1
Scripus sp.	Bulrush	Seed	0	3
Rumex sp.	Dock	Seed	1	0
Anchusa sp.	Bugloss	Seed	3	13
Spergularia sp.	Sand spurry	Seed	2	5
Chenopodium sp.	Fat Hen	Seed	1	2
Amaranthus sp.	Amaranth	Seed	1	0
Fumaria sp.	Fumatory	Seed	17	59
Crataegus sp.	Hawthorn	Seed	1	2
Lolium sp.	Canary grass	Seed	0	1
Euphorbia sp.	Spurge	Seed	1	0
Malva sp.	Mallow	Seed	0	3
Arnebia sp.	Arnebia	Seed	0	9
Trifolium sp.	Clover	Seed	0	1
cf. *Silene* sp.	Catchfly	Seed	1	7
Allium sp.	Wild onion	Seed	1	0
Echium sp.	Echium	Seed	0	2
Raphanus rapistrum	Wild radish	Seed	0	14
Unidentified seeds			21	63
Totals			282	685

The surface, control sample contains less pollen and exhibits a lower variety of types compared to the dung sample. AP levels are low (6.5%) with *Quercus ithaburensis* type pollen as the main element (2.7%). Chenopodiaceae/Amaranthus (33.5%, mainly *Atriplex* type) and Artemisia (20%) are the main NAP pollen. Cereal pollen (13%, as well as two pollen clumps) and Poaceae (8.1%) are quite abundant.

3.2.3. Wood remains

The collapse layer (Str. II) and especially the living surface of room #814 yielded dozens of pieces of wood and branches, including slender unburnt branches of *Zygophyllum dumosum* (Bean caper), *Gymnocarpos decander* and *Hammada negevensis*. Other finds were unworked wood of *Tamarix* sp. (×5) (Tamarisk with 5 sepals), *Phoenix dactylifera* (Date palm) and *Phragmites communis* (Common reed), as well as several burnt pieces of *Tamarix* sp. (×5) (Tamarisk) and Chenopodiaceae. Among the wood finds, several worked pieces of *Pinus nigra* (Austrian pine), *Pinus brutia* (Calabrian pine) and *Cupressus sempervirens* (Cypress) were identified (Table 4).

The results from the floor of room #817 show that 16 out of 25 samples identified were *Tamarix* sp. (×5). *Pistacia atlantica* (Atlantic pistachio), *Phoenix dactylifera* (Date palm), *Hammada negevensis* (Hammada) and *Cupressus sempervirens* (Cypress) were also recognized.

3.3. Zooarchaeology

A total of 143 identified bones were found at the Byzantine pigeon tower at Shivta. Nearly 80% of these remains were found on the floor (L814, L816, L817), which was rich with pigeon dung and botanical remains. The remaining bones were isolated bones of pigeon and several other taxa found in loci accumulated above the floor.

The majority of pigeon bones were found complete and bear no burning signs or butchery marks (Fig. 12), this includes complete fragile and delicate porous bones and bones of neonate specimens. Their presence and abundance testify to the high quality of bone preservation. Several complete skulls with their fully-preserved beaks were recovered (Fig. 13), as well as complete sternums and synsacra. In addition, several egg shells were found. The quality of bone preservation is also

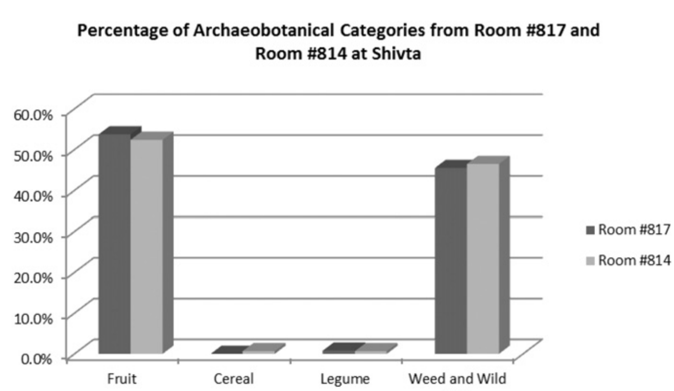

Fig. 6. Categories of archaeobotanical material recovered from room #817 and room #814 at the pigeon tower at Shivta (percentages).

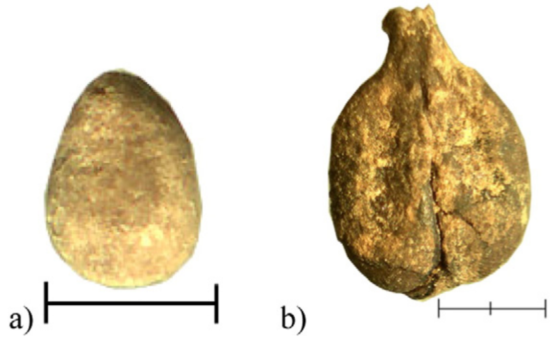

Fig. 7. a) Fig achene (scale is 1 mm), and b) grape pip (scale is 2 mm) from the pigeon tower at Shivta.

attested to from the complete absence of evidence for bone attrition or any other *in situ* chemical post-depositional bone destruction.

Exceptions for the excellent preservation condition of bones were the few bones accumulated above the dovecote floors. Some of these bones were heavily weathered and bleached, indicating that they were likely exposed to aerial conditions for long periods of time. In addition, the bone composition of the upper stratum was somewhat different and included isolated bones of domestic fowl (*Gallus gallus*), sheep (*Ovis aries*), goat (*Capra hircus*), cattle (*Bos taurus*), raptor (Accipitridae family) and fox (*Vulpes vulpes*). It seems reasonable to assume that these bones were deposited after the tower floor was buried and the tower was abandoned. As such, these remains likely post-date the period when the tower functioned as a dovecote and were probably deposited when the tower may have served as a den or a temporary shelter for local small carnivores.

The hypothesis that most pigeon bones represent catastrophic death of pigeons is also supported by the skeletal part representation (Fig. 14). It is evident that all body-parts are present, including both axial, forelimb and hindlimb and that they occur in relatively even proportions.

The age at death of the pigeons also support catastrophic death, which likely occurred during the destruction of tower. We clustered the pigeon remains to three major age categories: neonatal, juveniles and adult (Table 5). 'Neonatal' includes bones that, according to their size and texture, come from near-born fetuses or recently-born young. 'Juvenile' is defined based on the size and porosity of bones. The 'Adult' category consists of completely developed bones. The resulting mortality profiles are dominated by adult individuals while juveniles are also present in relatively high proportions. Such a mortality profile is expected from a catastrophic die-off which consists of a large number of young and adult animals.

Fig. 8. Barley rachis (scale 2 mm) from pigeon tower IV at Shivta.

Fig. 9. *Thymelaea passerina* (mezereon) from the pigeon tower at Shivta (scale is 2 mm).

4. Discussion

As noted earlier, information derived from archaeological excavations provides some of the only data available for understanding the ancient agricultural economy that existed in the arid region of southern Israel and Jordan during the Roman-Byzantine period. As a result, the information recovered in this agro-archaeological study of a dovecote provides integral data for desert agricultural practices that appear to have been a necessity to support a burgeoning population, likely stemming from an increased military presence in the region at this time. Understanding how local populations supported themselves through subsistence agriculture is important for not only gaining a greater understanding of the economy and environment in antiquity but also for potentially how these past sustainable agricultural practices might be able to contribute to modern agricultural practices in arid regions today.

Although not well studied archaeologically, pigeon raising for fertilizer and meat according to literary sources was a common practice in the Roman world. The importance of pigeon manure as a fertilizer cannot be underestimated as in many cases in the ancient Near East it was the main organic fertilizer available for traditional farmers (Harlan, 1995: 110–111) particularly in the southern parts of Israel (Tepper, 2007b: 45–47). It was used primarily as a high-quality fertilizer in annual crop farming, particularly with irrigated crops and tree orchards. The manure is especially effective in soils poor in minerals and organic matter such as chalky and loess soils. Such soils cannot support intensive agriculture without frequent fertilization (Tepper, 1986: 170–196; Felix, 1963: 93). For example, chemical data derived from chicken manure demonstrates the superior qualities of this type of manure in terms of nitrogen, potassium, and phosphorus values in comparison to other fertilizers (see Tepper, 2007b: 45–47, table 1 and Hochberg, 1956: 143), which illustrate the crucial importance of pigeon manure for ancient farms. Results of this study shed new light for understanding the complex agricultural system that was employed in the arid Negev desert during the Roman-Byzantine period.

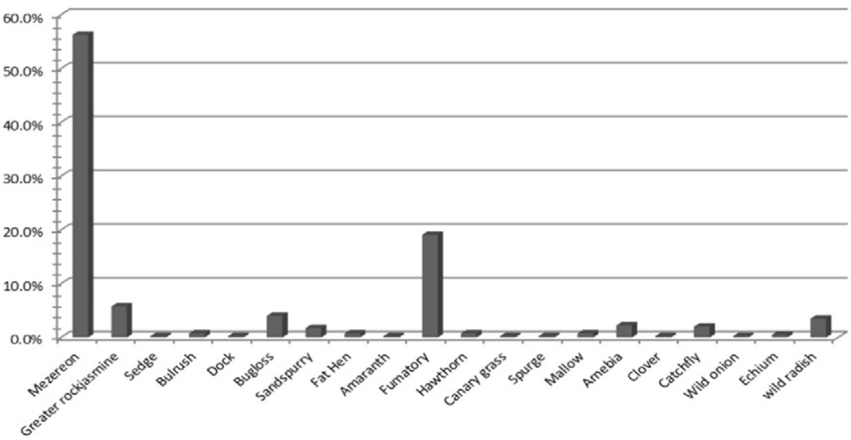

Fig. 10. Distribution of weed and wild species recovered from the pigeon tower at Shivta.

4.1. Archaeobotany

4.1.1. Macro remains

The similarity between the macro botanical collections from the different areas of the dovecote makes it possible to discuss the findings as a unit. The presence of the same fruits and wild species, as well as crop stones in the two rooms of the installation, supports many of the taxa as components of the pigeons' diet. Most of the weed and wild species identified in this study are commonly found in cultivated fields, such as *Lolium* sp. (canary grass), *Chenopodium* sp. (fat hen), *Amaranthus* sp. (amaranth), *Malva* sp. (mallow), *Allium* sp. (wild onion), *Trifolium* sp. (clover) and *Euphorbia* sp. (spurge). This provides possible food types consumed by the pigeons but since it is a reasonable assumption that pigeons likely spent some of their time foraging for themselves in the fields that surrounded their pigeon tower it also provides evidence of what field weeds would have been common in the 6th–7th century CE in the region of Shivta. In addition, regarding the fruit remains, we suggest that pigeons collected food in and near the village of Shivta and sometimes perhaps people may have fed the birds the remains of grapes and figs, which would account for the high quantities of these fruits in the assemblage, as well as the presence of several grape peduncles and a possible fragment of grape epidermis. Although, it is also likely that the birds may have been free to feed off of the trees and vines on their own and not been provisioned. Clearly grape vines would have been present at the site as numerous winepresses dating to the Byzantine period and documentary evidence indicate that the population was heavily engaged in viticulture and that wine was a major export item (Mayerson, 1985). As mentioned in the preliminary study, we can also not rule out the possibility that some of the taxa were either blown in or brought into the site by animal vectors (Ramsay and Tepper, 2010). In addition, some of the taxa in the assemblage may represent plants used by the pigeons as nesting material.

The appearance of a single barley grain and rachis segment (Fig. 8) as well as two indeterminate cereal grains, suggests that cereals were grown locally in the fields surrounding the site since we have both the grain and rachis. Although this is not a surprise as the pigeon tower is located in the midst of agricultural fields, however a determination of

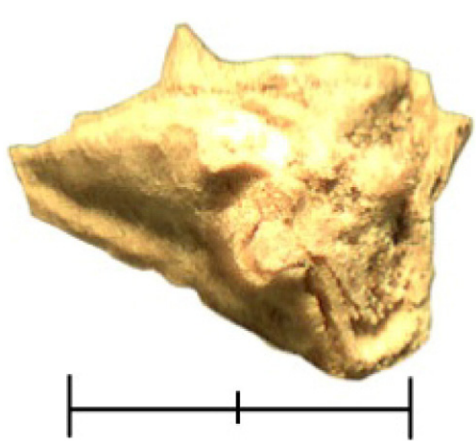

Fig. 11. *Anchusa* sp. from the pigeon tower at Shivta (scale 2 mm).

Table 3
Composition of the palynological assemblages (percentages).

Provenance pollen type	Common name	Dung (%)	Surface (%)
Quercus calliprinos	Palestine oak	11.8	
Quercus ithaburensis type	Mount Tabor's oak	0.7	2.7
Pistacia sp.	Pistachio	3.2	
Pinus sp.	Aleppo pine	1.1	1.6
Olea europaea	Olive	15.4	1.1
Myrthus sp.	Myrtle	1.1	
Salix	Willow		1.1
Total arboreal pollen		33	6.5
Poaceae	Grasses	17.5	8.1
Cereals		9.3	13.0
Cereals clump (~20 units)			1.1
Helianthemum sp.	Rock rose		0.5
Artemisia sp.	Sagebrush	0.4	20.0
Artemisia sp. clump (~20 units)			0.5
Apiaceae *(Bunium* sp. *type)*	Parsley family	1.1	1.1
Ranunculaceae	Buttercup family	5.0	
Chenopodiaceae/Amaranthus	Goosefoot family	11.8	33.5
Asteraceae/Asteroideae	Aster subfamily	6.1	
Asteraceae/Cichorioideae	Chichory-Dandelion subfamily	0.7	
Fabaceae	Legume family	3.6	1.6
Liliaceae	Lily family	3.9	
Asphodelus sp.	White asphodel		0.5
Allium type sp.	Garlic	1.4	
Ephedra sp.	Mormon tea	1.4	
Dipsacaceae	teasel family	1.5	1.0
Brassicaceae	Mustards	3.2	
Malvaceae	Mallows		1.1
Polygonaceae	Buckwheat family		2.2
Total counted		280	185
Pollen concentration (per gr. sediment)		11,500	1497
Mentha sp.	Mint	1	
Typha sp.	Cattail	6	
Typha sp. (*tetrade*)		11	
Carex sp.	True sedges		2
Total hydrophilous pollen (no.)		18	2

Table 4
Location of wood samples in building C – a round Columbarium (Byzantine period).

Locus	Basket	Tree species	Remarks
816	880/5	*Pistacia atlantica*	Non-carbonized wood
817	882/15	*Pistacia atlantica*	Non-carbonized wood
817	882/19	*Pistacia atlantica*	Non-carbonized wood
814	8037a	*Tamarix* sp. (×5)	Carbonized wood
814	8037b	*Tamarix* sp. (×5)	Carbonized wood
814	8037c	*Tamarix* sp. (×5)	Non-carbonized wood
814	8037d	*Tamarix* sp. (×5)	Non-carbonized wood
816	880/1	*Tamarix* sp. (×5)	Non-carbonized wood
816	880/2	*Tamarix* sp. (×5)	Non-carbonized wood
816	880/3	*Tamarix* sp. (×5)	Non-carbonized wood
816	880/4	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/1	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/2	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/3	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/4	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/6	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/7	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/8	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/9	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/10	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/11	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/12	*Tamarix* sp. (×5)	Non-carbonized wood
817	882/13	*Tamarix* sp. (×5)	Non-carbonized wood
814	8037	*Phoenix dactylifera*	Non-carbonized wood
817	882/5	*Phoenix dactylifera*	Non-carbonized wood
812	8034	*Zygophyllum dumosum*	Thin non-carbonized branches
809	8030	*Zygophyllum dumosum*	Thin non-carbonized branches
805	8026	*Zygophyllum dumosum*	Thin non-carbonized branches
805	8026	*Gymnocarpos decander*	Thin non-carbonized branches
814	8037	*Hammada negevensis*	Thin non-carbonized branches
817	882/14	*Hammada negevensis*	Carbonized wood
817	882/17	*Hammada negevensis*	Carbonized wood
814	8037	Chenopodiaceae	Carbonized branch
814	8037	*Phragmites communis*	Non-carbonized reeds
814	8037	*Pinus nigra*	Un-worked non carbonized long stick
814	8037	*Pinus brutia*	Worked non-carbonized stick
814	8037	*Pinus brutia*	Worked non-carbonized stick
800	8015	*Cupressus sempervirens*	Worked non-carbonized wood
814	8037a	*Cupressus sempervirens*	Worked non-carbonized wood
814	8034b	*Cupressus sempervirens*	Worked non-carbonized wood
817	882/16	*Cupressus sempervirens*	Worked non-carbonized wood
817	882/18	*Cupressus sempervirens*	Worked non-carbonized wood

what was growing in these fields is significant. Therefore barley could have been eaten by the pigeons or the grass served as a nesting material.

4.1.2. Pollen remains

The low arboreal pollen levels in the recent sample, together with the high Chenopodiaceae-Amaranthus pollen and *Artemisia* levels accord well with the present-day arid environment. As for the dung

Fig. 12. Pigeon bones from the floor of the pigeon tower.

Fig. 13. Complete pigeon skulls from the floor of the pigeon tower.

pollen, high *Olea* sp. (olive) ratios may indicate olive plantations near the site, while the relatively high *Quercus* sp. (oak) and *Pistacia* sp. (pistachio) pollen point to a possibly more humid period than today (even though they, too, could have been planted). The low *Artemisia* sp. percentages and the medium proportions of Chenopodiaceae-Amaranthus (some of which could derive from ruderal plant formations) also support a somewhat more humid climate. The origin of bank plants (*Typha* sp.) is not clear and they could have been used for matting or fencing at the site.

Evidently, one sample is not enough for a clear paleoenvironmental reconstruction or for the complete identification of the sources of plants used to feed the pigeons, apart from cereals. The possibility that *Olea* sp. pollen derived from "gefet" (waste from oil extraction composed of a mix of olive stones and pulp), on which the pigeons were fed, should not be ruled out (for olive pollen in ancient "gefet" see Galili et al., 1997).

4.1.3. Wood remains

It seems that some of the slender branches found in both strata of the dovecote (Str. I and II) originating of local shrubs and trees were brought into the building by humans as pigeon food, but that most were transported by pigeons for nest building. Another possibility is that the branches and pieces of un-worked wood were introduced by the pigeon breeders to construct perches for pigeons. These local shrub and tree species included *Zygophyllum dumosum*, *Gymnocarpos decander*, *Hammada negevensis*, *Tamarix* sp. (×5), *Phoenix dactylifera* and *Phragmites communis* and Chenopodiaceae family member. All are native to the environs of Shivta and the Negev and grew there also in the past. Other wood remains included tree species like *Cupressus sempervirens*, *Pinus nigra and Pinus brutia* which were used as construction timbers, e.g. roof beams, parts of ladders or other installations. These trees never grew native in the Negev desert. They could have been imported to Shivta from northern territories of the Byzantine Empire, maybe even from Turkey. The wild Cypress *Cupressus sempervirens* var. *horizontalis* which is characterized by a short trunk was cultivated by the Romans and was spread by them in the Middle East (Liphschitz, 2007, 2012).

4.2. Zooarchaeology

The study of the faunal material supports the importance of pigeon raising in the Byzantine Negev and provides excellent examples for comparative studies with respect to bone preservation, body-part distribution and demography of the main taxa found. In particular the high rate of bone preservation and completeness, and the age structure that fits a theoretical living structure. This observation strengthens the hypothesis that the dovecote was destroyed in a single and a rapid event, likely an earthquake as discussed in detail in Hirschfeld and

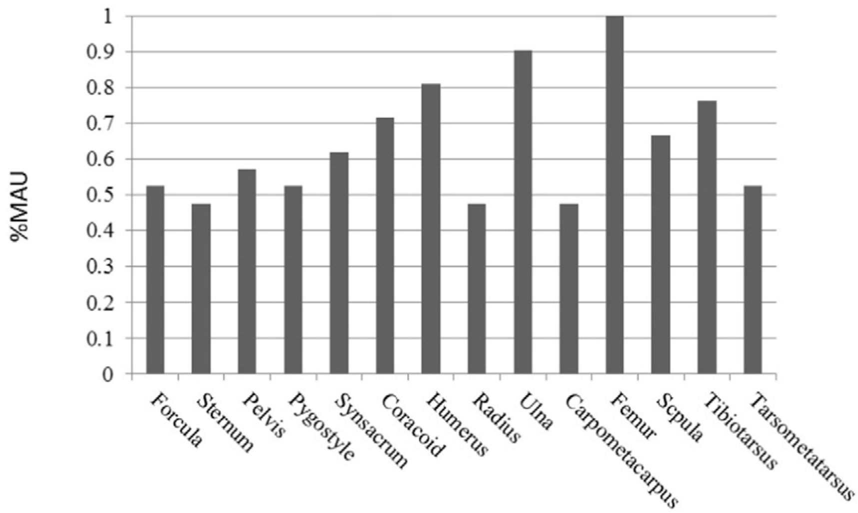

Fig. 14. Skeletal element representation of pigeon bones (based on MNE).

Tepper (2006). This observation also explains the relative equal distribution of skeletal parts. Following its destruction it was never restored and the materials remained sealed and protected from any post-burial and post-depositional attrition processes.

5. Conclusions

Written accounts, archaeological evidence and artistic depictions testify to the intertwined lives of pigeons and people in the Negev and the surrounding arid regions: pigeons were raised for the fertilizer they yielded and as a year-round source of meat. The results of our holistic research, examining botanical and zooarchaeological data provide information on how pigeon were raised, used and in particular how they were fed.

Clearly pigeon rearing was an integral part of the mixed husbandry agricultural regime that dominated the Negev region from at least the Roman period through the Byzantine period during a people of population increase and agricultural expansion. The structures that have been documented as related to the raising of pigeons (Tepper, 2007a) and the literary evidence of authors such as Pliny the Elder (1940–1963, *Natural History* 17.6), Varro (1934, *On Agriculture* 1.38) and Columella (1941, *De Re Rustica* 2.14) writing in the Roman period, attest to the importance of pigeons in the ancient society of the Mediterranean (Ramsay and Tepper, 2010). The analysis of pigeon dung in this study has provided direct evidence for pigeon diet in antiquity. It shows that the pigeons ate grapes, figs, olives and dates, as well as several weed species, like mezereon, canary grass and fat hen. The botanical remains recovered from the dung also illustrate that the environment around Shivta, which today is mostly barren desert, was likely much more verdant due to agricultural practices in antiquity.

Weed species identified are commonly found in agricultural fields, which would have surrounded the site in the past and are attested to by the presence of many hydraulic engineering features such as field walls and wadi barriers. Likewise, arboreal species like olive, pistachio and date were probably found around Shivta according to the pollen and wood evidence. The high ratio of cultivated trees (>15% olive, based on pollen reads) further demonstrate that they were grown in the area.

The composition of pigeons with their abundant nesting compartments and floral food remains suggest that the home range of the Shivta pigeons concentrated around the local agricultural fields. It further demonstrates their mutual benefits for the local agriculture. Their manure enabled to grow orchards in the nutrient-poor Negev soil and accordingly parts of these plants were brought back as nesting material. As such the dovecotes of the Negev provide a rare capsule with unique environmental information encoded in it.

This integrated examination from an agro-archaeological perspective illustrates the complexity of desert agriculture. By examining both the floral and faunal components of a collapsed pigeon tower we can demonstrate the holistic nature of arid environment farming in antiquity, which may be used to inform modern agricultural practices on arid landscapes.

Table 5
Summary of aging of pigeon remains from pigeon tower.

	Adult	Juvenile	Neonate	Total
Carpometacarpus	18	1		19
Coracoid	23	7		30
Humerus	28	13		41
Radius	25	8	2	35
Tarsometatarsus	20	2		22
Tibiotarsus	23	12		35
Ulna	28	10		38
Total	165	53	2	220
	75%	24%	1%	

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