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# Implications of modern Barn owls pellets analysis for archaeological studies in the Middle East

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## Abstract

Situated at the crossroad between Africa, Asia and Europe, the Middle East is an important region for the knowledge of human and mammals migrations. Inside the mammals, fossil small mammals are good proxies for palaeoenvironmental reconstructions, and can also play the role of markers of prehistoric movements. In the aim to better characterize the origins and the palaeoecological signal delivered by the small vertebrate assemblages in Middle East archaeological sites, we performed a taxonomic and taphonomic study of the small mammal remains found in pellets from Barn owl (*Tyto alba*) from a poorly known region of South of Turkey at the Syrian border, east of Euphrates River. This will constitute the first available taphonomic referential for this region.

The studied sample constituted by more than 40 disintegrated pellets provided 2503 rodent skeletal elements. The most common preys are *Meriones tristami*, followed by *Mus musculus*. The taphonomic study showed that our assemblage fits well with a predator category of light modification. Regarding the preservation, our mean bone relative abundance reached 82% and the bone fragmentation showed that more than 77% of our sample is intact. The digested elements represented 22% and the low to moderate grades were dominant (83.5%). Implications for environmental and climatic reconstructions based on small mammal communities were also explored using *Bioclimatic model* and *Habitat Weighting* methods.

**Keywords:** Regurgitation Pellets, *Tyto alba*, South Anatolia, Bone modification, Environmental reconstruction.

## 1.Introduction

Birds of prey predate small mammals that they usually swallow in the whole and regurgitate bones, teeth, fur as compact pellets (Shad and Kakhki, 2014). The

1 studies of the pellets are really useful because they provide information about small  
2 mammal species occurrences in some regions, as well as the extent of bone  
3 modifications after the regurgitation process.

4 Our current understanding of small mammal distribution is based on the  
5 specimens found in zoological collections of the museums and most of them result of  
6 trapping surveys, scavenging of road killed individuals. More rarely museums host  
7 owl pellets assemblages while they can also provide useful information about the  
8 predatory birds diet, as well as rare prey-species abundance or distribution, habitat  
9 preferences, cyclic population dynamics, or seasonal changes (Boitani & Molur,  
10 2016; Kryštufek & Vohralík, 2009; Haddadian Shad et al. 2014). Consequently, pellet  
11 assemblages are often used as supplementary data for faunistic surveys, and a  
12 some studies have been performed in the Middle East (Abi-said, Shehab & Amr,  
13 2014; Jamshid Darvish et al. 2000; Kopij & Liven-schulman, 2013; Obuch &  
14 Khaleghizadeh, 2012; Haddadian Shad et al. 2014; Shehab et al. 2013).

15 For the archaeologists and palaeontologists, owl pellets assemblages are  
16 considered as the major source of fossilised accumulations (Andrews 1990). A  
17 taxonomic study of such fossil small mammal assemblages resulting from owl pellets  
18 represent an efficient tool for palaeoenvironmental reconstructions, but needs a  
19 preliminary taphonomic analysis to ensure that no major bias has altered the  
20 palaeoecological signal (e.g., Fernández-Jalvo et al. 2016; Stoetzel et al. 2011). In  
21 order to refine these taphonomic analyses and to better identify the origin of the  
22 accumulations, we need an exhaustive referential of modern avian predation for the  
23 study area (Eurasia, and more precisely Middle East). Indeed, each area has  
24 particular characteristics in term of predator and prey species, which may lead to  
25 different taphonomic signals.

26 The Barn owl is one of the major contributors to the fossil bone assemblages,  
27 specialized in taking a wide range of preys, including mostly rodents and insectivores  
28 (Andrews, 1990). Here we present the first combined taxonomic and taphonomic  
29 study of small mammals remains from *Tyto alba* pellets from South Turkey, in order  
30 to contribute to a better knowledge of the Middle East small vertebrate predators and  
31 their taphonomic impact on prey bones.

## 32 33 **2. Material and Methods**

### 34 35 **2.1. Sampling of the studied material**

36  
37 The studied pellets come from the region called Birecik (37°1'N, 37°58'E) in  
38 Turkey (Fig.1). The area is located at the west of Euphrates River, in the Southern  
39 Anatolia, close to Syria and Iraq border. Forty pellets have been collected by Jean  
40 Francois Noblet in June 2003, in a *Tyto alba* nest behind the breeding station of  
41 Northern bald Ibis (*Geronticus seremita*) installed in a valley near the Euphrates  
42 riverside, 3 km north of Birecik Şanlıurfa.

43 The pellets were disintegrated during handling and their contents were sorted by  
44 hand under microscope in order to identify and count the skeletal elements.

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## 2.2.Taxonomy

Bones were recovered manually and identified at a specific level when it was possible, following the established available identification keys (Boitani & Molur, 2016; Coşkun, 1999; Darviche et al. 2006; Darvish, 2011; Pavlinov, 2008; Kryštufek & Vohralík, 2009; Mamkhair et al. 2007; Momtazi et al. 2008; Musser & Carleton, 2005; Yicit & Çolak, 1996; Siahsarvie & Darvish, 2008; Tez 2000). Some measurements were done using Mitutoyo caliper (precision 0.01 mm) on the most complete elements of the skull and mandibles. Regarding the nomenclature and identification keys, for Soricidae we followed Kryštufek & Vohralík (2001), for Gerbillinae we followed Pavlinov (2008) and for Murinae Darviche et al. (2006).

The Minimal Number of Individuals (MNI) has been estimated using the most abundant skeletal element present in the assemblage, including cranial and postcranial elements.

## 2.3.Taphonomy

The taphonomic study focused upon bone representation, fragmentation and digestion of small mammal elements recovered from the pellets. For this we followed the methodology developed by Andrews (1990), Denys et al. (1996) and Fernández-Jalvo et al. (2016)

### 2.3.1.Skeletal element proportions

The differing proportions by which the various elements of the prey skeletons are represented in a predator assemblage are frequently used to distinguish different types of predators. The numbers of the skeletal elements are usually expressed to be present for a given number of prey individuals, which is usually the minimum number of individuals (MNI). This proportion is called the relative abundance (Andrews 1990).

$$R_i = N_i / (MNI \times E_i)$$

Where:

- R<sub>i</sub>= the relative abundance of the element i
- N<sub>i</sub>= the number of element i in the sample
- MNI= the Minimum Number of Individuals
- E<sub>i</sub>= the number of element i in the prey skeleton

For example, the number of bones found in the skeleton of an individual of a rodent like a mouse is: 1 skull, 2 maxillaries, 2 mandibles, 12 molars, 4 incisors, 2 femora, 2 humeri, 2 radii, 2 ulnae, 2 tibiae, 2 scapulae, 2 pelves, 2 astragali, 2 calcanei, 1 sacrum, 20 metapodials, 54 phalangias, 54 vertebrae, 24 ribs (Denys & Patou-Mathis 2014; Stoetzel et al. 2011).

The calculation is based on the notion that the predator consumes most or all of the body of the prey and modern samples indicate that predators have characteristic

1 patterns for the proportional abundances of prey elements. As a result, the MNI  
2 should approximate to the number of preys eaten.

3 Three indices have been used to compare the preservation of postcrania and  
4 crania elements. The first compares femora and humeri with the number of  
5 mandibles and maxillae  $((F+H)/(Md+Max)*100)$ . The second compares the number  
6 of all long bones with the major cranial elements and isolated molars  $([femora +$   
7  $tibiae + humeri + radii + ulnae]*16/([mandibles + maxillae + molars] *10)*100)$  and the  
8 third is the comparison between tibia and radii between femora and humeri  
9  $[(tibia+radii)/(femora+humeri)]$  (Andrews 1990; Stoetzel et al. 2011).

### 10 11 **2.3.2. Breakage**

12  
13 Breakage can also help to differentiate major groups of predators (Andrews 1990),  
14 notably the breakage of long bones, skulls and mandibles. But in our sample, most of  
15 the postcranial material cannot be identified at the species level, so we didn't analyse  
16 the breakage by taxa.

17 We also have to keep in mind that if in modern assemblages bone breakage can  
18 help identify the predator, in archaeological or palaeontological context many post-  
19 depositional processes may lead to an over-breakage of the material, and hide the  
20 "*predator signal*". Consequently, other taphonomic parameters (notably digestion)  
21 have to be taken into account for more reliable interpretations.

### 22 23 **2.3.3. Digestion**

24  
25 The corrosive effects of digestion on bones and teeth in the predator's stomach  
26 are well distinguishable from other alteration processes (e.g. Fernandez Jalvo et al.  
27 2014). Digestion is the most reliable parameter used to identify the predator type at  
28 the origin of a small mammal accumulation. It is based on both the degree of  
29 digestion and on the proportion of teeth and bones affected, considering that each  
30 type of predator has a different effect of digestion (Andrews 1990). In our study we  
31 have considered light, moderate and strong digestion grades following Andrews  
32 (1990) and Fernandez-Jalvo et al. (2016) on molars, incisors, femora and humeri.  
33 We precise that we have not found any postpredation modification in our sample.

34 Patterns of digestion, if they are well visible to the naked eye, are best  
35 distinguished using the Scanning Electron Microscope (SEM) (Andrews 1990;  
36 Demirel et al. 2011). In our study we used the SEM Hitachi SU 3500 from the *Service*  
37 *Commun de Microscopie Electronique du Museum National d'Histoire Naturelle*  
38 (MNHN-Paris), using secondary electron emission mode at an accelerating voltage of  
39 15 kV.

### 40 41 **2.4. Statistical analysis**

42  
43 Size differences have been investigated using Principal Component Analysis  
44 (PCA) between our sample and the references provided by the literature using the

1 statistical software XLSTAT 10.0. Skull measurements have been done, taking into  
2 account the condylo basal length, zygomatic breadth, maxillary tooth row and the  
3 tympanic bullae length (Fig. 2).

## 4 5 **2.5.Climatic reconstruction**

6  
7 Finally, we tried to evaluate the potential of small mammal associations coming  
8 from this owl to infer environmental and climatic parameters in using methods  
9 already developed for fossil mammal assemblages. The *Bioclimatic Model* (BM) was  
10 developed by Hernández-Fernández (2001) in order to reconstruct palaeoclimatic  
11 conditions based on faunal spectrum, in assuming that small- and large-mammal  
12 species can be ascribed to ten different climates (Hernández-Fernández, 2001;  
13 Hernández-Fernández & Peláez-Campomanes, 2003; Hernández-Fernández et al.,  
14 2007). We applied this method for the first time on an assemblage from South  
15 Anatolia. It was first necessary to calculate the Climatic Restriction Index ( $CRI_i = 1/n$ ,  
16 where  $i$  is the climatic zone where the species appear and  $n$  is the number of zones  
17 where the species is present) and the Bioclimatic Component ( $BC_i = (\sum CRI_i) 100/S$ ,  
18 where  $i$  is the climatic zone;  $S$  is the number of species). From the BC a  
19 mathematical model has been developed as a regression that allows us to calculate  
20 climatic parameters (see Appendix 1).

21 The different climatic groups defined by Hernández-Fernández (2001) and  
22 Hernández-Fernández et al. (2007) are: I *Equatorial*; II *Tropical with summer rains*;  
23 II/III *Transition tropical semiarid*; IV, *Subtropical with winter rains and summer*  
24 *droughts*; V, *Warm temperate with not very severe winters but high humidity*; VI,  
25 *Typical temperate with winters that are cold but not very long, but summers that are*  
26 *cool*; VII, *Arid-temperate with large temperature contrasts between winter and*  
27 *summer and VIII, Cold-temperate with cool summers and long cold winters (boreal).*

28 By means of the BM we are able to estimate the mean annual temperature (MAT),  
29 the mean temperature of the coldest month (MTC), the mean temperature of the  
30 warmest month (MTW) and the mean annual precipitation (MAP).

## 31 32 **2.6. Environmental reconstruction**

33  
34 The method used for the palaeoenvironmental reconstruction is the *Habitat*  
35 *Weighting* method (Evans et al., 1981; Andrews, 2006; modified by Blain et al., 2008;  
36 López-García et al., 2011), which is based on the current distribution of each taxon,  
37 in the habitat or habitats where it is possible to find each taxon nowadays. We  
38 adapted the method to our studied area, including the following types: Forest (Fo) a  
39 long area covered with trees, Shrubland (Sh) where the vegetation is dominated by  
40 shrubs; Grassland (Gr) an open area covered with grass, Desert (De) area with little  
41 precipitation and no vegetation cover and Wetlands (We) are normally use in  
42 agriculture (cereal fields).

## 43 44 **3.Results and discussion**

### 3.1. Taxonomic study

In total, 2503 identifiable skeletal elements were recovered from the studied pellets, belonging to only four small mammal taxa (Table 1). Rodents constituted the bulk of *T. alba* Birecik preys with 38 individuals and three genera (*Meriones*, *Nesokia* and *Mus*) followed by Eulipotyphla represented by one species (*Suncus etruscus*) and one individual. We present here some of the cranio-dental characters that allowed taxonomic identifications.

#### Order Eulipotyphla , Waddell et al. 1999

#### Family Soricidae, G. Fishcher, 1814

#### Genus *Suncus*, Ehrenberg, 1832

#### *Suncus etruscus* (Savi, 1822)

**Material:** 2; one right mandible and one left mandible (Fig.3.1).

**Description and discussion:** In Turkey four species of white-toothed shrews are documented (Kryštufek & Vohralík, 2001; Tez, 2000): *Crocidura leucodon*, *Crocidura suaveolens*, *Crocidura arispa* and *Suncus etruscus*. *Suncus* differs from *Crocidura* in having four upper unicuspid instead of three. In our material, the absence of maxillary prevents precise identification on this criterion. However, regarding mandibles, we can attribute our samples to *Suncus etruscus*, because of their smaller height of the coronoid process (Table 2).

**Habitat and distribution:** in the Mediterranean region *Suncus etruscus* prefers abandoned olive groves, vineyards, and other cultivated areas overrun by Mediterranean shrubs, but occurs also in gardens, low maquis, scrub, and open forest of Mediterranean oaks and pines. This species avoids sand dunes, dense forest and intensively cultivated land. It is more active during night than day. *Suncus etruscus* is distributed from Southern Europe, North Africa, parts of the Near East, Arabian Peninsula, Central Asia, South Asia and mainland Southeast Asia, to the island of Borneo in the east. It occurs from sea level to altitudes of 3000 meters above sea level (Aulagnier et al. 2017). In Turkey it was found mainly in the western and South Anatolia, especially in anthropogenic habitats up to 1200m (Kryštufek and Vorhalik 2001).

#### Order Rodentia Bowdich, 1821

#### Family Muridae Illiger, 1811

#### Genus *Nesokia*, Gray 1842

#### *Nesokia indica* (Gray, 1830)

**Material:** 2; one right maxillary fragment with M1 and one isolated Upper right M2.

**Description and discussion:** In our sample (Fig.3.2) we have identified a left upper M1 that belong to a large high-crowned Muridae, where we can observe on the tooth the three simple laminae that characterize it. We also found a second left upper

1 (M2) molar laminated and smaller in size with 2 laminae. Their relative size is typical  
2 of these Muridae, its first molar is the longest and the most complex and the last  
3 molar is shortest and the most simplified (Kryštufek et al. 2017). Both M1 and M2 are  
4 high-crowned, broad and transversely laminated. The first laminae of the M1 of  
5 Birecik pellets is wide and convex while in Gerbillinae the first lamina (or prelobe) is  
6 small and much narrower which allows us to distinguish it from *Tatera* and attribute  
7 this material to *Nesokia indica*.

8 **Habitat and distribution:** has a predominantly Palearctic distribution. It requires  
9 firm damp soil to dig in and succulent grass roots or underground bulbs to feed upon.  
10 It is found in humid areas in dry steppes, semi-deserts and deserts, but occurs  
11 mainly around permanent water bodies (Kryštufek and Vohralík, 2009). *Nesokia*  
12 *indica* is very widespread in south-western and Central Asia (Boitani and Molur,  
13 2016). In South Anatolia, *Nesokia indica* is mainly distributed near cultivated field and  
14 it is strictly limited to agricultural activities (Kryštufek and Vohralík, 2009).

15  
16 **Genus *Mus*, Linnée 1758**  
17 ***Mus musculus* (Linnaeus, 1758)**  
18

19 **Material: Skull:** one fragmented skull; **Mandibles:** 10; five complete right  
20 mandibles, five complete left mandibles; **Maxillae:** 4; one complete right maxilla,  
21 three complete left maxilla; **Isolated Teeth:** 4, one right lower m1, one left lower m1;  
22 two right Upper M2.

23 **Description and discussion:** Like in other Murinae, the first upper molar (M1)  
24 has three rows of cusps tubercles: the first (t1, t2, t3) and second (t4, t5 and t6)  
25 groups situated in the anterior part has three tubercles and the last group has two  
26 tubercles (t7 and t9) (Darviche et al., 2006). In South Turkey (Kryštufek and Vohralík,  
27 2009) both *Mus musculus* and *Mus macedonicus* may be found.

28 Our specimens from Birecik *T. alba* pellets fit well with *M. musculus* (Fig.3.3) in the  
29 upper M1 morphology: the lingual row of cusps (t1 and t4) is shifted posteriorly; cusp  
30 t7 is reduced to an enamel ridge; distal cusps t8 and t9 leave no space for posterior  
31 cingulum or postero-labial cusp t12. The second upper molar lacks cusp t3; t7 is  
32 suppressed to a mere enamel ridge; t9 is small. The anterior half of m1 has a  
33 symmetrical X pattern formed at the anterior portion of the tooth (Siahsarvie and  
34 Darvish, 2008). Dental elds of mesial and central cusps on 1st lower molars fuse  
35 early; mesiolabial cusp is small. Upper molar normally have three roots each, one  
36 lingual and two labial, lower molars are two rooted, each with anterior and posterior  
37 root (Kryštufek and Vohralík, 2009). We reported also an incisor with the notch that  
38 characterize *Mus musculus* (Kryštufek and Vohralík, 2009).

39 **Habitat and distribution:** is well distributed around all over the world, it is present  
40 over all continents, except Antarctica. They are found in a wide range of habitats but  
41 it not tends to be found in forest and deserts. *Mus musculus* is ecologically highly  
42 opportunistic but a weak competitor, it can cope with aridity and its expanding also in  
43 the desert (Kryštufek and Vohralík, 2009). It is found also on arid habitats along the



1 border with Syria and Iraq, in desert landscape and also near the Euphrates river  
2 (Kryštufek & Vohralík, 2009 and Musser et al. 2017).

3  
4 **Genus *Meriones*, Illiger 1811**  
5 ***Meriones tristami* (Thomas, 1892)**  
6

7 **Material: Skull:** 33 fragments; **Mandibles:** 75; 28 complete right mandibles, 29  
8 complete left mandibles; **Maxillae:** 57; 27 complete right maxilla, 30 complete left  
9 maxilla; **Isolated Teeth:** 96; nine right lower m1, six left lower m1; 14 right Upper M1;  
10 15 Left Upper M1, thirty two M2; twenty M3.

11 **Description and discussion:** The genus *Meriones* is one of the most diversified  
12 representative of the Gerbillini tribe in the Palaearctic region, particularly in arid  
13 regions of Asia (Darvish et al. 2011; Denys et al. 2017). The numbers of *Meriones*  
14 species reported in Turkey according to Kryštufek and Vohralík (2009) are: *Meriones*  
15 *tristami*, *Meriones vinogradovi*, *Meriones persicus*, *Meriones crassus*, *Meriones dahli*  
16 and *Meriones lybicus*. Although regarding their distribution the only one that is today  
17 present in Southern Anatolia is *Meriones tristami* (Kryštufek & Vohralík, 2009 and  
18 Sozen et al.,2017).

19 The Birecik molars attributed to *Meriones* display the typical morphology of the genus  
20 with hypsodont, prismatic triangles of enamel related by a longitudinal crest and no  
21 trace of cusps. In our sample we have identified first upper molars (M1) with three  
22 roots, so we could infer that it does not belong to *Meriones dalhi*, *Meriones lybicus* or  
23 *Meriones vinogradovi*, which present four roots on their M1 (Kryštufek & Vohralík,  
24 2009). Moreover, the dental morphology between *Meriones persicus* or *Meriones*  
25 *tristami* is similar. A PCA on skull measurements, taking into account the  
26 condylobasal length, zygomatic breadth, maxillary tooth row and the tympanic bullae  
27 length from our specimens compared with the data from Kryštufek and Vohralík  
28 (2009) (Fig.4 and Table 3) shows that size is not the main criteria to distinguish  
29 between both species.

30 Axis 1 and 2 explain respectively 81,64% and 8,3% of the total variance. Variables  
31 best correlated with Axis 1 are CBL (Condylo basal length), UTR (Upper tooth row)  
32 and ZB (Zygomatic Breadth), while TBL (Tympanic bullae length) is correlated with  
33 Axis 2. The Birecik samples fit well with *Meriones tristami* specimens but are also  
34 close to *Meriones persicus* ones. *Meriones tristami* has a wide size variability but  
35 comparing with Syrian specimens, these latter have relatively long tympanic bullae  
36 compared to a small CBL.

37 We provisionally attribute our specimens to *Meriones tristami* (Fig.3.4) pending a  
38 revision of the Middle East species of the genus.

39 **Habitat and distribution:** the genus *Meriones* is distributed in North Africa,  
40 Central Asia, Transcaucasia, Turkey and Pakistan (Darvish, et al. 2014, Stoetzel et  
41 al. 2017). They mostly live in dry steppes of short or tall grass, open hillside, among  
42 rocky outcrops in desolate steppes, or open dry meadows. *Meriones tristami* habitat  
43 is limited to 100 mm of rainfall annually and need well drained soil although it avoids

1 rocky situations. In Turkey it has been mainly found in dry steppe and short or tall  
2 grass (Kryštufek and Vohralík, 2009).

### 3 4 **3.2.Taphonomic study**

#### 5 6 **-Bone representation**

7 On the 2503 skeletal elements recovered in the Birecik *Tyto alba* pellets, a total of  
8 39 individuals (MNI) were counted, following the number of maxillae which were the  
9 most abundant elements. We found that all bones are present but in variable  
10 proportions. The most represented are maxillae (89%) and mandibles (87%) followed  
11 by tibiae (82%). On the other hand, the less represented elements (excluding the  
12 isolated molars) are the ribs (33%) and the calcanei (34%) (Table 4).

13 The mean representation percentage is 45.21% for all the taxa present in our  
14 assemblage, that is very close to the one proposed by Andrews (1990) for Barn owl  
15 from Africa (48.91%).

16 Some rodent bones are anatomically connected: nine femora connected with a  
17 tibiae (tibia+fibula) and also with the phalanges and three humeri linked with radii.

18 Regarding the taphonomic representation pattern, we can say that all elements  
19 are well represented, with small elements like foot bones, teeth and vertebrae lost  
20 during collecting.

21 Most skeletal elements are well preserved and unbroken, as expected from a barn  
22 owl assemblage, as we can see in our sample (Fig. 5). There is a preferential loss of  
23 some elements, as among which the distal parts or the limbs. The average relative  
24 abundances (the mean relative abundance for all skeletal elements, except the  
25 isolated teeth) vary from 33.01% to 89.06%, which means that between one or two  
26 thirds of the prey has been lost from the sample during ingestion and digestion  
27 (Andrews, 1990).

28 The table 5 presents the proportions of postcranial *versus* cranial elements. The  
29 ratios  $(f+h)/(m+max)*100$  reaches 108.85%, and 91.06% for the  $(t+r)/(f+h)+100$  ratio.  
30 There is a slight long bone over-representation compared with mandibles and  
31 maxillae.

#### 32 33 **-Fragmentation**

34 Our post-cranial sample presents a low percentage of fragmentation, with more  
35 than 77% of complete elements (Table 6). The preservation does not vary too much  
36 between the post-cranial bones, but the most broken ones in Birecik pellets are the  
37 pelvis (67.8%) and the scapulae (48.8%). The best preserved are the femora  
38 (98.3%).

39 In the case of *Suncus etruscus* we only have two mandibles, that are complete  
40 following the criteria established by Andrews (1990). For *Mus musculus* and  
41 *Meriones tristami*, most of the maxillae and mandibles are broken. Only 12% of the  
42 *Mus* skulls are partially complete, and in the case of *Meriones* almost 7%. For the  
43 mandibles, 37% are intact for *Mus* and 24% for *Meriones* (Table 7).

## 1 -Digestion

2 In total 22.51% of the studied elements (femur, humerus, molars and incisors) are  
3 digested (Table 8 and Figure 6) and the dominant grade of digestion is the light one  
4 (86.6%). The moderate grade was observed on one femur and one humerus, and  
5 strong digestion is only present in one femur. We observed also that the isolated  
6 molars are more digested than in situ ones, because of the exposition. This value is  
7 quite high for *T.alba* but the pellets came from a nest were digestion is slightly higher  
8 as highlighted by Denys et al.(2018).

9 For the elements in connexion we could find three femora harbouring light  
10 digestion upon free epiphysis.

### 11 3.2.1.Taphonomic implications

12  
13  
14 *Tyto alba* is an active hunter, especially at night, consequently nocturnal prey-  
15 species are taken more commonly than diurnal ones, which corresponds to what we  
16 found in the Birecik pellet assemblage. Moreover, the preferred hunting areas of the  
17 owl may be over-represented, notably the wetter and more open habitats (Mikola,  
18 1983). Compared to previous studies performed in the same region, our sample is  
19 not really diversified: we only have four species, mainly rodents (three species) and  
20 just one insectivore. In the others studies, were found a higher species diversity, as  
21 for example Shehad et al. (2013) where they identified twenty-three species,  
22 chiroptera (five species), rodents (eighteen species) (Appendix 2).

23 By the fact the lowest species diversity was found in our Birecik sample with three  
24 rodents and one shrew against six rodents and two shrews in Abi Said et al. (2014) in  
25 Lebanon. In some assemblages bats or birds were also identified as preys (Shehab  
26 at al. 2013, Maul et al. 2015) but we didn't recover any of these taxa in our  
27 assemblage. *Meriones* may be very abundant locally and represent a high biomass  
28 for the owl (Shehab et al. 2013), and considering the opportunistic diet of *Tyto alba*  
29 (Andrews, 1990), this may explain why *Meriones* are the most represented species in  
30 our material and why the owl did not diversified its diet spectrum. Another  
31 explanation may result from the low number of pellets analyzed here, or from the  
32 season of capture which both may favor a higher diversity. Also the predominance of  
33 *Meriones* can be explained as a hunting preference of barn owl (Andrews, 2018)

34 The pellets were collected in June 2003, in summer. Prey composition and  
35 digestion differed from month to month but the highest differences are between  
36 summer and winter (Andrews, 2018), our values are similar to the ones propose for  
37 the owls in summer. Although Barn Owls select one prey species at a particular time,  
38 they also exhibit an opportunistic feature (Tores et al. 2005).

39 The diet of *Tyto alba* from our collected pellets fits well with the other studies in  
40 Europe and Asia. The Barn owls' preys are small vertebrates, including a wide range  
41 of rodents and insectivores (Andrews, 1990).

42 *Tyto alba* is well known because it is widespread around the world and it was  
43 identified as one of the major accumulator of small mammal remains in several  
44 archaeological sites. Few studies were devoted to taphonomy in Pleistocene

1 archaeological contexts in the Middle East, notably in Iran, Israel and Syria (Bazgir et  
2 al., 2017; Demirel et al., 2011; Maul et al., 2015; Smith et al., 2015) . Most of the  
3 studies concluded that the origin of the accumulation was predation activity, mainly  
4 owls, but generally without any study of bone breakage or digestion.

5 Regarding the postcranial fragmentation most of our sample is intact, only a 21%  
6 is fragmented mainly in the proximal part. The best-preserved bone in our Birecik is  
7 the Femora. These values fit well with other *T. alba* assemblages, where around 80%  
8 is intact (Andrews, 1990).

9 Following the criteria established by Andrews (1990), our sample displays a good  
10 proportion of complete elements, corresponding to a category 1 predator where *Tyto*  
11 *alba* fits.

12 Few studies (Dauphin and Denys, 1992; Denys et al., 1996, 1992) have analyzed  
13 the differences in the fragmentation in different prey taxa, this is possible using skulls  
14 and mandibles because most of the post-cranial bones cannot be specifically  
15 identified here. Most of the skulls from *Mus musculus* and *Meriones tristami* are  
16 complete with a few skulls fragmented. This corresponds well with Denys et al.  
17 (1996) which showed a better skull preservation in favor of more robust rodents like  
18 *Meriones* spp. and some Dipodidae. The comparison between both species is not  
19 well correlated because we only have 16 *Mus* against 115 *Meriones* remains.  
20 *Meriones* are medium size rodents, which bones are generally more resistant  
21 compared to those of smaller species such as *Mus*. There is no correlation between  
22 the size and the preservation but we have seen that *Meriones* skull are more  
23 resistant as some studies suggest (Dauphin and Denys, 1992; Denys et al., 1996,  
24 1992). But the fact that we also found small species such as *Suncus etruscus*,  
25 indicates that shrews may also display a good resistance to fragmentation.

### 26 27 **3.3.Environmental and climatic remarks**

#### 28 29 **3.3.1.Climatic data**

30  
31 Redding (1978) pointed out that small vertebrates are more sensitive to the  
32 climatic changes than larger ones and are sources of more detailed and precise  
33 paleoenvironmental interpretations. Because predation can bias the faunistic  
34 composition of assemblages, it needs to be recognized before any paleoecological  
35 study of the taxonomic list (Fernandez-Jalvo et al., 2016). So in the archaeological  
36 assemblages the predator responsible for the accumulation should be identified as  
37 far as possible in order to identify potential bias of faunal and anatomical  
38 representation, and get a better picture of past environments and taphonomic history  
39 of the site (Demirel et al., 2011).

40 Barn owls have a restricted hunting area and are opportunistic predators, so their  
41 pellets represent a good picture of the relative availability of prey species and their  
42 contents are good indicator for knowing the environment if applied to archeological  
43 assemblages (Demirel et al. 2011).

1 Birecik is located in the Sanliurfa province, the centre of the South-eastern  
2 Anatolia. The altitude of the region is between 300-600 meters above the sea level  
3 and has a semiarid Mediterranean climate. Annual mean temperature is 18.5°C; the  
4 maximum mean temperature is 39°C and the minimum mean temperature is 2.7°C.  
5 Annual rainfall is about 458.1 mm and the precipitation regime is winter, spring,  
6 autumn, and summer. Birecik is characterised by a steppe vegetation (Vagi Atamov,  
7 2007).

8 For the climatic reconstruction we applied the *Bioclimatic model* (Table 10) directly  
9 upon the faunal list, in order to know if we could obtain the same results as the ones  
10 provided by the Vagif Atamov et al. (2007) and validate the methodology for South  
11 Anatolia.

12 Taking into account the Birecik rodent assemblage, nine of the different climatic  
13 groups defined by Hernández-Fernández (2001) and Hernández-Fernández et al.  
14 (2007) are represented (Table 9).

15 We can observe that there is a relatively good correspondence between the  
16 estimated means values of the *Bioclimatic model* and the current temperatures and  
17 precipitation taking into account the Standard Deviation. By the fact we obtain a  
18 mean annual temperature of 20.86°+/- 3.39 with the model against 18.5°C using  
19 meteorological surveys. Similarly, for the mean annual precipitation we found 432  
20 mm in average against 458 mm (Table 10).

21 We could see that there is a correspondence between the values obtained with the  
22 *Bioclimatic model* and the current ones.

### 24 3.3.2.Environmental data

26 Moreover the preys that we have, following the *Habitat Weighting*, where the value  
27 of 1 is divided between the habitats where it is possible to find the species at present  
28 (Table 11), indicate a steppe-like (Shrubland and grassland) environment which  
29 corresponds well to the one found in Birecik. Because it is mainly composed by a  
30 vegetation dominated by shrubs and grass but with low precipitation, It corresponds  
31 to a steppic environment.

32 *Mus musculus* is highly adaptable and found in all environments but *Meriones*  
33 *tristrami* is restricted only to habitat IV. *Nesokia indica* is also found in three different  
34 zones (II/III, III, IV, VII). Both taxa may be good palaeoenvironmental indicators in  
35 archaeological sites.

36 *Nesokia indica* and *Suncus etruscus* represent the just 5% of the fauna against  
37 *Mus musculus* 12,82% and *Meriones tristami* 82%, this two species making up 95%  
38 of the preys. *Habitat weighting* does not take in account the proportion of the species,  
39 just their representation. Following the percentage obtained with the *Habitat*  
40 *weighting* model the most represented environment is the Shrubland (vegetation  
41 dominated by shrubs) and Grassland (open area covered with grass), furthermore  
42 the desert percentage is the ones that follows. Combining this result we could said  
43 that with the *Habitat weighting* we obtained the same results as we could find

1 nowadays in the region (according to Vagif Atamov et al. 2007). All the species are  
2 represented in this three environments.

3 We have to keep in mind that that *Meriones* are the major preys in this faunal  
4 assemblage, which indicates a favourable dry open environmental condition for  
5 gerbils (steppes). Following the *Bioclimatic model* the results combined with the  
6 *Habitat weighting*, support an steppe environment.

7 We can thus conclude that *Tyto alba* pellets from the region represent good  
8 proxies for reconstructing environments and then it becomes possible to apply these  
9 inferences to the archaeological record in the Middle east.

#### 10 11 **4-Conclusions**

12  
13 This work presents the first combined taxonomic and taphonomic study of *Tyto*  
14 *alba* pellets in the Middle East. Our objective was to increase the modern referential  
15 for this predator in that region, contribute to a better understanding of small  
16 vertebrate accumulations in archaeological sites in the Middle East and to test the  
17 use of owl pellets faunal lists as proxies for paleoenvironmental reconstructions.

18 We have identified *Suncus etruscus*, *Nesokia indica*, *Mus musculus* and *Meriones*  
19 *tristami* in our sample, that combined with the *Bioclimatic model* and the *Habitat*  
20 *weighting*, showed that the values obtained for the temperatures and precipitations  
21 and also the reconstruction of the landscape allow us to test the potential of both  
22 methods upon an owl pellet assemblage and its validity for further archeological  
23 studies.

24 Such studies will serve as reference to better identify the origin of some fossil  
25 accumulation, before deposition and fossilization. The taphonomic study showed that  
26 our assemblage fits well with a predator category of light modification. Most skeletal  
27 elements are well preserved and unbroken, our mean bone relative abundance  
28 reached 82% and the bone fragmentation showed that more than 77% of our sample  
29 is intact. The digested elements represented 22% and the light moderate grade were  
30 dominant (83.5%) *Tyto alba* represents a major cause of small mammal  
31 accumulation in archaeological sites, especially in caves, all around the world, but is  
32 not the only predator at the source of such assemblages. In fossil assemblages, low  
33 digestion is associated with such faunal list may allow to identify a barn owl or a  
34 category 1 predator at the origin of the accumulation.

35 The emphasis of this article has remained on the nature of the modifications, and  
36 geographic variation (or lack of it) from one part of the world to another, as we could  
37 see, the modifications in this region are the same as we can find in other parts of the  
38 world produced by this predator. Further studies will allow to define the role and  
39 importance of avian predators and mammalian carnivores in the accumulations of  
40 small mammals in archeological sites of the Middle East.

41  
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7

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Figure 1: Geographic location of the studied area, Birecik (South Anatolia, Turkey).

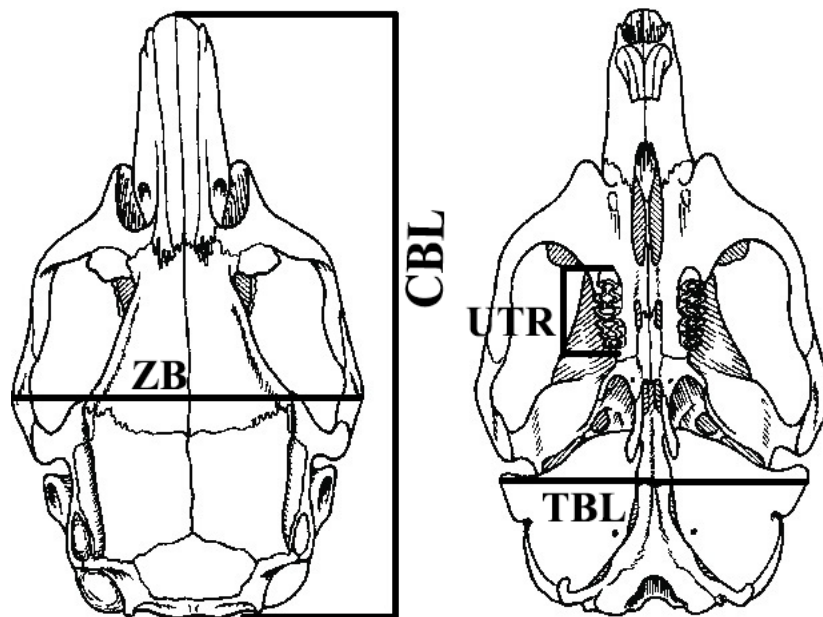


Figure 2: Skull measurements abbreviations. CBL: Condyllo-basal length; ZB: Bizygomatic breadth; UTR: Upper tooth row; TBL: tympanic bullae length. *Meriones* skull picture modified from Kryštufek and Vohralík (2009)

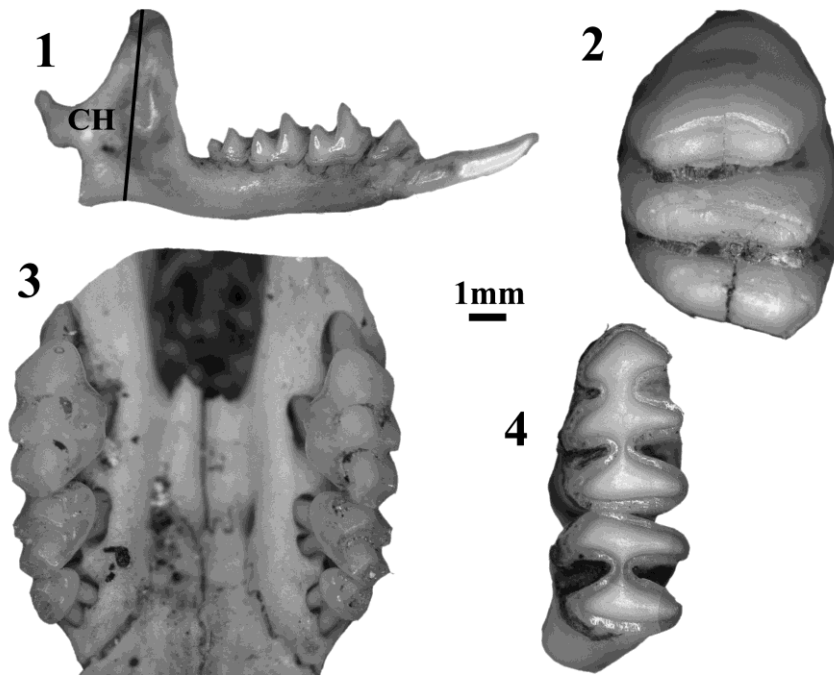


Figure 3:1-Right mandible *Suncus etruscus*, CH (Coronoid height); 2-Right Left Upper M1 molar *Nesokia indica*; 3-*Mus musculus* maxilla; 4-Left lower molar row with m1 and m2 of *Meriones tristami*.



Figure 4: PCA graph on skull measurements of *Meriones* spp (Axis 1, horizontal x Axis 2, vertical). Colours indicate the species. Green: *Meriones tristami*; brown: *Meriones vinogradovi*, Red: *Meriones persicus*, Blue: Birecik sample.

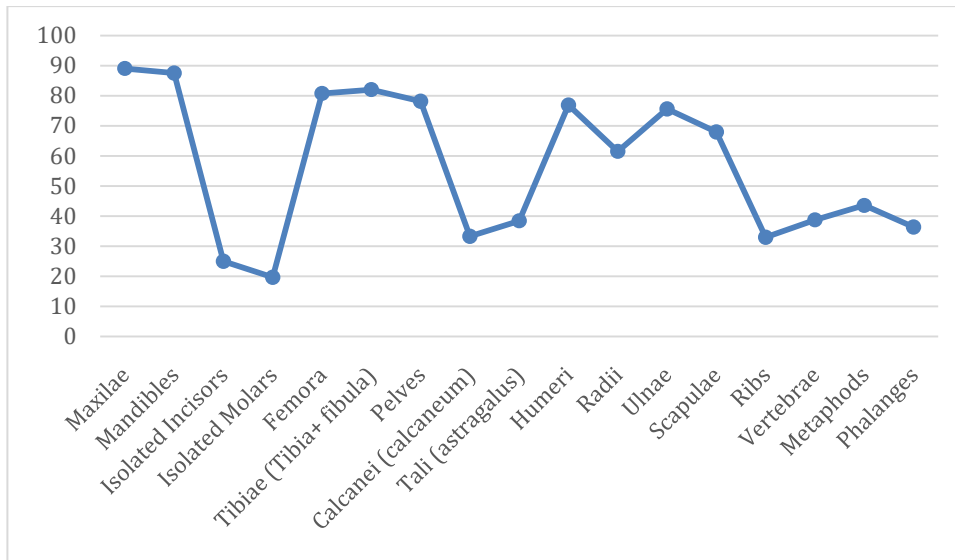


Figure 5: Profiles of representation percentage of the small mammal skeletal elements for Barn owl pellets from the sample from Birecik.

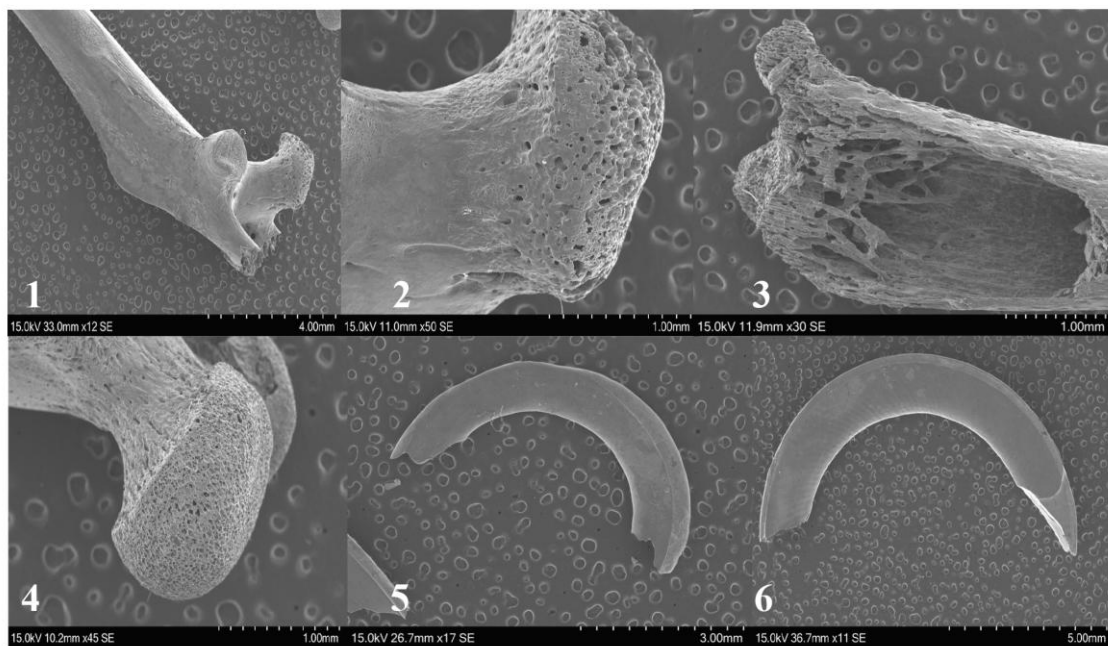


Figure 6: SEM pictures of digested rodent elements from the Birecik pellets. 1- Moderate digestion is observable on the trochanter and on the basis of the femoral head and 2- detail of the same femur; 3- Rodent distal femur with strong digestion, 4- Femur head with moderate digestion; 5- Rodent upper incisor with moderate digestion; 6- Incisor with light digestion at the tip.

<b>Species</b>	<b>MNI</b>	<b>%</b>
<i>Suncus etruscus</i>	1	2.56
<i>Nesokia indica</i>	1	2.56
<i>Mus musculus</i>	5	12.82
<i>Meriones tristami</i>	32	82.05
<b>Total</b>	<b>39</b>	<b>100</b>

Table 1: MNI: Minimal Number of Individual; %: percentage of relative abundance.

<b>Specimen</b>	<b>Coronoid Height</b>	<b>Number of specimens</b>	<b>Min-max</b>	<b>Mean</b>
Birecik sample	3.13- 3.25	2	3.13-3.25	3.19
<i>Crocidura leucodon</i>	4.3-5.9	63	4.3-5-9	4.92
<i>Crocidura suaveolens</i>	4.0-5.0	230	4.0-5.0	4.52
<i>Crocidura arispa</i>	4.1	2	4.1	4.1
<i>Suncus etruscus</i>	2.8-3.3	43	2.8-3.3	3.06

Table 2: Measurements of the coronoid height of the mandible in mm from Krystufek and Vorhalik (2001).

<b>Species</b>	<b>CBL</b>	<b>ZB</b>	<b>UTR</b>	<b>TBL</b>
<b>Birecik sample N=5</b>				
Mean	38.5	20.5	5.33	11.68
Max-Min	38.5	20.5	5.4-5.26	11.55-11.82
<b><i>Meriones tristami</i> N=22-34</b>				
Male	40.3	21	5.5	13.2
Female	36.3	20.2	5.2	13.2
<b><i>Meriones persicus</i> Turkey N= 4</b>				
Mean	39.5	22.5	6.5	12.7
Max-Min	37.4 – 40.8	21.7 – 23.0	6.1 – 6.8	11.8 – 13.6
<b>Armenia, Iran N=50</b>				
Mean	37.6	21.2	6.3	11.5
Max-Min	34.4 – 41.4	6.1 – 6.8	5.9-6.9	10.0-14.4

Table 3: Comparison between the measurements in the different *Meriones* species found in Syria, Armenia, Iran and Birecik pellets (after this work and Krsytufek & Vorhalik 2009). All measurements are given in millimetres. CBL: Condyllo-basal length; ZB: Bizygomatic breadth; UTR: Upper tooth row; TBL: tympanic bullae length.

Prey species	<i>Suncus etruscus</i> MNI=1			<i>Nesokia indica</i> MNI=1			<i>Mus musculus</i> MNI=5			<i>Meriones tristami</i> MNI=32		
	Ni	Ei	Ri%	Ni	Ei	Ri%	Ni	Ei	Ri%	Ni	Ei	Ri%
Skull						1						
Maxillae				2	2	100	6	10	60	57	64	89.06
Mandibles	2	2	100				10	10	100	56	64	87.5
IsolatedIncisors				1	4	25	1	20	5	39	156	25
IsolatedMolars				1	12	8.3	4			96	486	19.75
Femora										63	78	80.77
Tibiae (Tibia+ fibula)										64	78	82.05
Pelves										61	78	78.21
Calcanei (calcaneum)										26	78	33.33
Tali (astragalus)										30	78	38.46
Humeri										60	78	76.92
Radii										48	78	61.54
Ulnae										59	78	75.64
Scapulae										53	78	67.95
Ribs										309	936	33.01
Vertebrae										817	2106	38.79
Metaphods										340	780	43.59
Phalanges										284	780	36.41
Sacrum										14	39	35.9
<b>Total:</b>	2			4			21			2476	6113	<b>Mean: 45.21</b>
<b>MNI</b>	1			1			5			32		

Table 4: Anatomical representation of small mammal remains from the Birecik *Tyto alba* pellets (Ni: Number of elements in our sample; Ei: number of expected element i in the assemblage, Ri: Relative abundance in Percentage).

<b>Ratios</b>	<b>%</b>
$(\text{femora} + \text{humeri}) / (\text{mandibles} + \text{maxillae}) * 100$	108.85
$(\text{tibia} + \text{radii}) / (\text{femora} + \text{humeri})$	91.06
$([\text{femora} + \text{tibiae} + \text{humeri} + \text{radii} + \text{ulnae}] * 16 / ([\text{mandibles} + \text{maxillae} + \text{molars}] * 10) * 100)$	225.08

Table 5: Proportions of postcrania to crania elements (calculated according Andrews 1990).

<b>Element</b>	<b>Complete</b>	<b>Broken</b>			<b>Total</b>
		<b>Proximal</b>	<b>Distal</b>	<b>Shafts</b>	
Femora	58	1			59
Humeri	61	5			66
Tibiae (Tibia+Fibula)	59	1		3	63
Ulnae	48	9	1	1	59
Radius	47			1	48
Pelvis	13	48			61
Scapula	22	21			43
<b>Total (NR)</b>	<b>308</b>	<b>85</b>	<b>1</b>	<b>5</b>	<b>399</b>
<b>Percentage of fragmentation</b>	<b>77.19</b>	<b>21.30</b>	<b>0.25</b>	<b>1.25</b>	<b>100.00</b>

Table 6: Number of remains (NR) and percentage of broken postcranial elements of Birecik sample.

			<i>Suncus etruscus</i>		<i>Mus musculus</i>		<i>Meriones tristami</i>		
			N	%	N	%	N	%	
Skull	Complete				2	12.5	8	6.96	
	Broken	Isolated Maxilla with zygomatic				0		1	0.87
		Isolated Maxilla without zygomatic				0			0
		Maxilla molars loss			1	6.25	28	24.35	
		Maxilla incisors loss			3	18.75	22	19.13	
Mandible	Complete		2	100	6	37.5	28	24.35	
	Broken	Broken ascendant ramous			1	6.25	3	2.61	
		Ascendant ramous missing				0		6	5.22
		Missing and inferior border broken				0		4	3.48
		Fragment				0			0
		Mandible molar loss				0		11	9.57
		Mandible incisors loss				3	18.75	4	3.48
<b>Total</b>			<b>2</b>	<b>100</b>	<b>16</b>	<b>100</b>	<b>115</b>	<b>100</b>	
<b>Percentage of Fragmentation</b>				<b>100%</b>		<b>50%</b>		<b>68.7%</b>	

Table 7: Representation (N) and percentage of fragmentation (%) of the cranial elements.



Elements	Total	Total digested		No digestion		Low digestion		Moderate digestion		Strong digestion		In connexion Not digested		In connexion light digestion	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Isolated incisor	39	18	46.15	21	53.85	15	37.46	3	7.69						
In situ incisor	90	34	37.78	56	62.33	34	37.78								
Isolated molars	96	4	4.17	92	95.83	4	4.17								
In situ molars	84	3	3.57	81	96.43	3	3.57								
Femora	62	22	35.48	40	64.52	13	20.97	1	1.61	1	1.61	4	6.45	3	4.84
Humerii	60	16	26.67	44	73.33	12	20	1	1.67			3	5		
<b>Total</b>	<b>431</b>	<b>97</b>	<b>22.51</b>	<b>334</b>	<b>74.49</b>	<b>81</b>	<b>18.79</b>	<b>5</b>	<b>1.16</b>	<b>1</b>	<b>0.23</b>	<b>7</b>	<b>1.62</b>	<b>3</b>	<b>0.70</b>

Table 8: Representation (N) and Percentages of digestion (%) on cranial and post-cranial elements from the Birecik pellets.

Species	I	II	III/III	III	IV	V	VI	VII	VIII	IX
<i>Suncus etruscus</i>	0.333	0.333	0	0	0.333	0	0	0	0	0
<i>Nesokia indica</i>	0	0	0.25	0.25	0.25	0	0	0.25	0	0
<i>Mus musculus</i>	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0
<i>Meriones tristami</i>	0	0	0	0	1	0	0	0	0	0

Table 9: Distribution of species scores for the Bioclimatic Model of the Birecik assemblage (according to Hernández-Fernández, 2001; Hernández-Fernández et al., 2007).

	BM	SD	Current values
Annual Mean temperature	20.86 °C	3.39	18.5°C
Maximum mean temperature	27.61°C	4.77	39°C
Minimum mean temperature	11.45°C	4.66	2.7°C
Mean anual precipitation	431.98 mm	533.24	458.1mm

Table 10: Birecik sample *Bioclimatic model* results. SD (Standard Deviation).

	Fo	Sh	Gr	De	We
<i>Meriones tristami</i>		0.5		0.5	
<i>Mus musculus</i>		0.33	0.33		0.33
<i>Nesokia indica</i>	0.33	0.33	0.33		
<i>Suncus etruscus</i>	0.25	0.25	0.25	0.25	
<b>Total</b>	0.6	1.4	0.9	0.8	0.3

Table 11: Percentage of the palaeoenvironmental reconstruction for the Birecik sample, Fo (Forest), (Sh) Shrubland, (Gr) Grassland, (De) Desert and (We) Wetlands (*Habitat Weighting* model).