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Diet of Pharaoh Eagle-Owl, *Bubo ascalaphus*, from Ara'r region, northern Saudi Arabia

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Abstract The diet of the Pharaoh Eagle-Owl, *Bubo ascalaphus,* was investigated based on 338 pellets collected from caves and underground caves in Ara'r region, northern Saudi Arabia. Small mammals constituted the highest number of consumed prey (75.75%), followed by arthropods (20%), birds (2.9%) and reptiles (1.26%). The Libyan Jird, *Meriones libycus*, was the most consumed rodent (26.46%) followed by Sundevall's Jird, *Meriones crassus* (20.47%), while the least were Cheesman Gerbil, *Gerbillus cheesmani*, and Wagner's Gerbil, *Gerbillus dasyurus*. At least three species of scorpions, *Androctonus crassicauda*, *Compsbuthus* sp. and *Scorpio* sp., and two species of reptiles *(Ptyodactylus hasselquistii* and *Trapellus agnetae)* were recovered. Study of owl pellet contents proved to be a valuable tool to study species composition in unexplored regions. Also, our findings substantiate the fact that the Pharaoh Eagle-Owl is an opportunistic species that adapts to available preys in its habitat.

Keywords: underground caves, biodiversity, vertebrates, feeding behaviour, Saudi Arabia

Összefoglalás Az egyiptomi uhu *(Bubo ascalaphus)* táplálék-összetételét az Észak-Szaúd-Arábiában fekvő Ara'ar régióban barlangokból és föld alatti üregeiből gyűjtött 350 köpet alapján vizsgáltuk. Az elfogyasztott zsákmány legnagyobb arányát a kisemlősök adták (75,75%), ezt követték az ízeltlábúak (20%), a madarak (2,9%) és a hüllők (1,26%). A legnagyobb arányban fogyasztott rágcsáló a sivatagi versenyegér *(Meriones libycus)* volt (26,46%), ezt követte a nagy versenyegér *(Meriones crassus)* (20,47%), míg a legkisebb arányban a Cheesman-futóegér *(Gerbillus cheesmani)* és a Wagner-futóegér *(Gerbillus. dasyurus)* került elő. A köpetekből továbbá három skorpiófajt (*Androctonus crassicauda*, *Compsbuthus* sp. és *Scorpio* sp.), valamint két hüllőfajt *(Ptyodactylus hasselquistii, Trapellus agnetae)* azonosítottunk. A köpetvizsgálat az eddig feltáratlan régiókban értékes eszköznek bizonyult a fajösszetétel tanulmányozásában. Eredményeink alátámasztják, hogy az egyiptomi uhu képes alkalmazkodni az élőhelyén nagyobb számban előforduló prédához.

Kulcsszavak: földalatti üregek, biodiverzitás, gerincesek, táplálkozási viselkedés, Szaúd-Arábia

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Introduction

Seven species of owls in two families are considered as resident in Saudi Arabia; Family Tytonidae: *Tyto alba* (Scopoli, 1769) and Family Strigidae: *Otus brucei* (Hume, 1873), *Otus pamelae* Bates, 1937, *Bubo ascalaphus* Savigny, 1809, *Bubo africanus* (Temminck, 1821), *Strix hadorami* Kirwan, Schweizer and Copete, 2015 and *Athene noctua* (Scopoli, 1769). Both *B. ascalaphus* and *A. noctua* are the most common species, with a wide range of distribution across the Arabian Peninsula (Jennings 2010, Boland & Al Suhaibany 2020). Another two species are considered as winter visitors, *Asio flammeus* (Pontoppidan, 1763) and *Otus scops* (Linnaeus, 1758) (Boland & Al Suhaibany 2020).

Little is known on the diet of owls inhabiting Saudi Arabia. Bauer (1988) reported on seven rodent species found in owl pellets, possibly of the Common Barn-owl, *Tyto alba,* in Summan Plateau, northeastern Saudi Arabia. Evans and Bates (1993) found at least two species of rodents, and two arachnids recovered from the Pharaoh Eagle-Owl, *Bubo ascalaphus,* pellets from Harrat al Harrah reserve. Jennings (2010) reported on prey items consumed by *B. ascalaphus* in Arabia, including rodents, hare, bats, birds and insects. Based on 112 pellets for *B. ascalaphus*, Abi-Said *et al.* (2020) found that rodents constituted the highest percentage of consumed prey items (91%), followed by scorpions (5.91%), other insects (2.96%) and birds (2.46%) from Wadi As Sulai, near Riyadh.

The diet of the Pharaoh Eagle-Owl was studied in Algeria (Biche *et al*. 2001, Benamor *et al*. 2021), Egypt (Goodman 1990, Sándor & Moldován 2010), Jordan (Amr *et al.* 1997, Rifai *et al.* 2000, Shehab & Ciach 2008, Obuch 2018), Qatar (Mohedano *et al.* 2014), and the United Arab Emirates (Cunningham & Aspinall 2001). These studies demonstrated that the Pharaoh Eagle-Owl is an opportunistic feeder preying on a wide range of animals including rodents, birds, reptiles and arthropods.

In this study, we report on the diet of the Pharaoh Eagle-Owl from Ara'r area, northeast of Saudi Arabia based on 338 pellets collected from 25 underground caves. This is the first work in the Middle East to study owl pellets from a large number of caves in an area that have never been studied. Also, our aim is to have an insight on the biodiversity of this little-known area.

Material and Methods

A total of 338 regurgitated pellets from at least six Pharaoh Eagle-Owls roost sites located at the entrance of 25 underground limestone caves or sinkholes in Ara'r region in northern Saudi Arabia were collected during July – December 2022 *(Table 1, Figure 1, 2)*. These underground caves vary in diameter and length, ranging from 15 × 12 m wide entrance for the largest cave, to 2–3 m wide entrance for small ones *(Figure 2)*. The owls were seen near the caves or sitting on the ledges surrounding the caves *(Figure 1)*. The caves are located in flat rocky areas surrounded by gravel and sand. The studied area is barren desert with no farmlands or human settlements.

The length and width of the collected 159 intact pellets were measured by a digital calliper. Each pellet was soaked in warm water and teased using a pair of forceps and a

Table 1. List of caves from which pellets were collected in Ara'r region
1. táblázat A bagolyköpetek gyűjtési pontjainak listája az Ara'r régióban

No.	Cave name	No. of pellets collected	Coordinates of localities	
			N	E
1	Luga Al Dahal	20	41.44351	29.41716
2	Sanar Al Ra'an 1	42	41.44358	29.41697
3	Sanar Al Ra'an 2	30	41.44358	29.41697
4	Al Boom	20	42.1773	29.45498
5	Al Boom Sanar Al Ra'an	64	41.47038	29.41297
6	Thraia' Al Ra'an	6	41.24977	23.57355
7	Al Habaka south	4	42.18391	29.45453
8	Al Fohood	8	42.27269	29.47229
9	Al Akrab	10	42.18535	29.46127
10	Al Habaka west 1	1	42.13951	29.50143
11	Al Habaka west 2	6	42.12763	29.52148
12	Um Al Hammam	2	41.2844	29.52281
13	Sanar Al Ra'an 3	29	41.44372	29.41702
14	Sanar Al Ra'an 4	44	41.42288	29.4156
15	Na'jan	5	42.0472	29.35767
16	Sanar Al Ra'an 5	14	41.48966	29.4102
17	Al Habaka west 3	2	42.12628	29.5018
18	Jal Al Thour	3	42.08812	30.01453
19	Al Markouz	2	44.230543	30.00126
20	Al Habaka north 2	4	42.21049	29.49322
21	Al Habaka north 1	5	42.16095	29.57066
22	Al Habaka north 3	3	42.16581	29.57621
23	Mehthem Al Raka'a	2	42.34089	29.42472
24	Al Habaka north 4	1	42.17764	29.56311
25	Jal Al Mazwa	23	42.64605	29.785189

needle to separate prey remains for identification. Recovered items from each pellet were placed in a Petri dish. For each species, lower and upper jaws were cleaned and preserved. Prey remains were identified using distinctive morphological characteristics of body and/or skull parts (e.g. mouthparts, mandibles, dentaries) described based on previous collections from the region (Amr 2012) as well as Iyad Nader small mammals collection kept at the National Center for Wildlife (NCW). Arthropod remains were identified to the family level.

Diet composition was expressed by the Minimum Number of Individuals (MNI) and percentage (number of individuals divided by the total number of prey individuals). The total number of prey individuals in a pellet was determined using the total number of mandibles and/or skulls found. In addition, average prey biomass (body weight in grams)

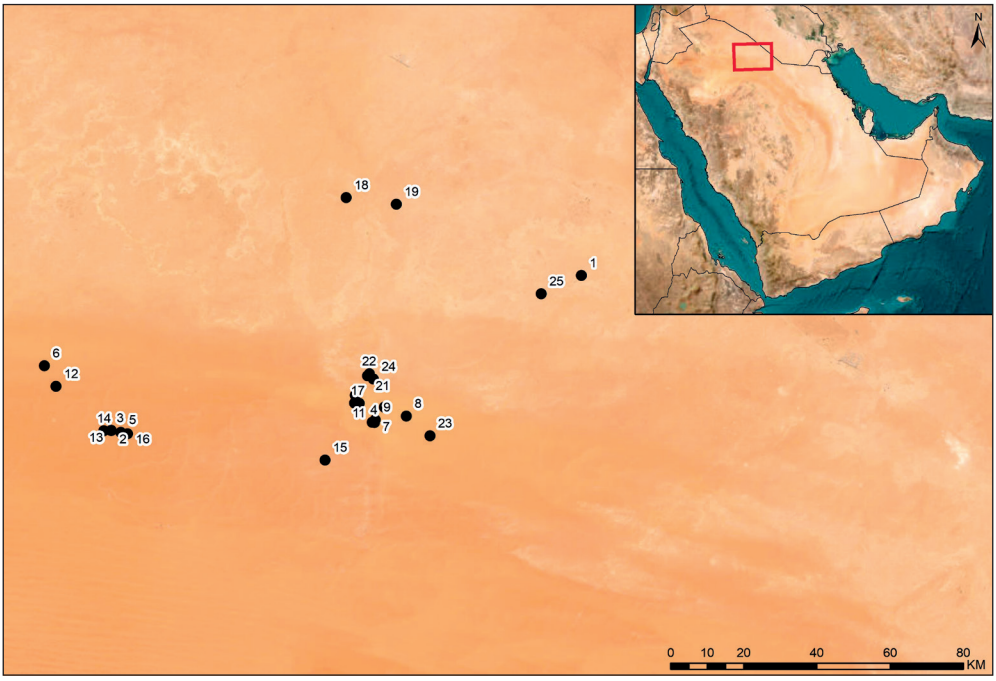

Figure 1. Map of Saudi Arabia showing locations of the investigated underground caves (NCW)
1. ábra Szaúd-Arábia térképe a vizsgált földalatti üregek helyével (NCW)

Figure 2. Underground caves in Ara'r region
2. ábra Földalatti üregek az Ara'r régióban

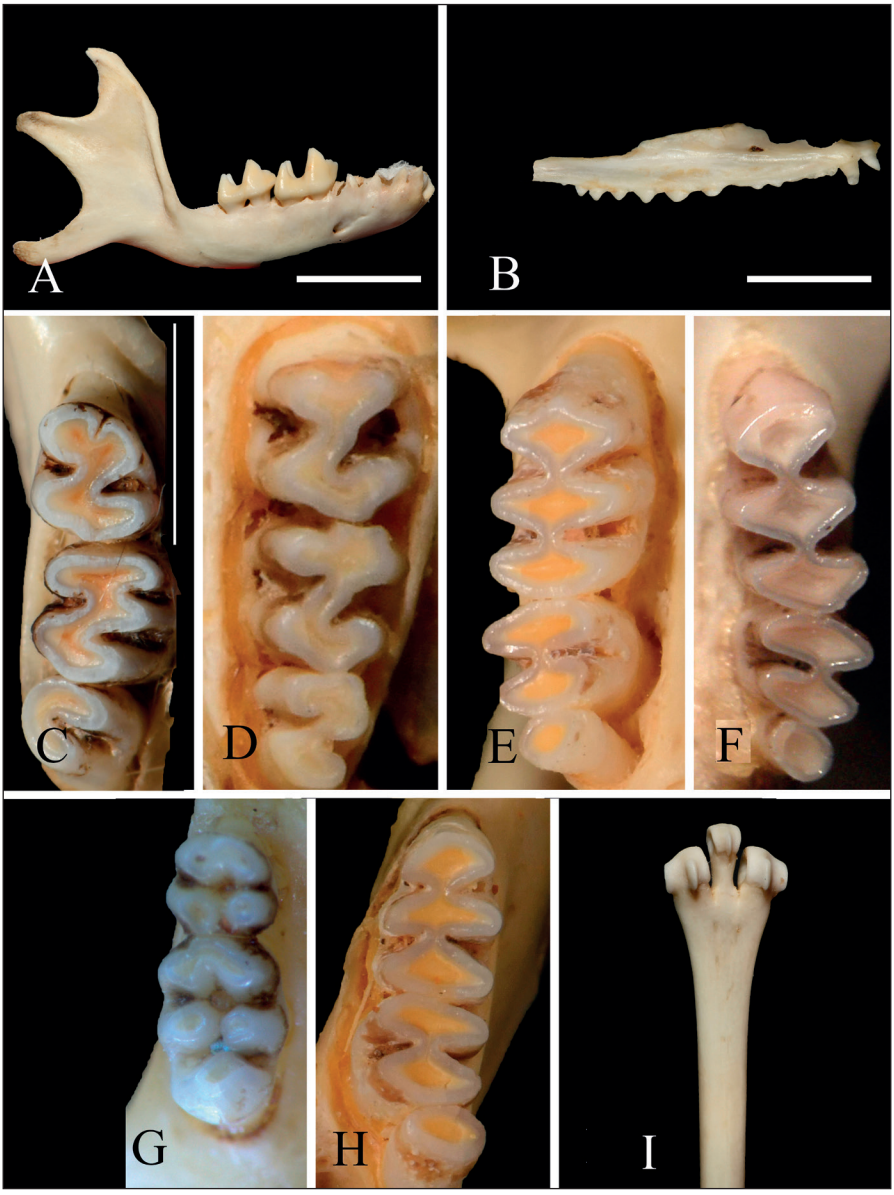

Figure 3. Bone remains recovered from the Pharaoh Eagle-Owl pellets. A. mandible of *Paraechinus aethiopicus* (Scale bar 1 cm). B. *maxilla* of *Trapellus agnetae*. C. *maxilla* of *Scarturus euphratica* (Scale bar 5 mm). D. *maxilla* of *Jaculus loftusi.* E. upper maxillary teeth of *Meriones libycus.* F. *maxilla* of *Meriones crassus.* G. *maxilla* of *Gerbillus nanus.* H. *maxilla* of *Gerbillus dasyurus*. I. *metatarsus* of *Jaculus loftusi*

3. ábra Az egyiptomi uhu köpeteiből meghatározott csontmaradványok. A. *Paraechinus aethiopicus mandibula* (a fehér csík 1 cm-t jelöl). B. *Trapellus agnetae maxilla*. C. *Scarturus euphratica* állcsonti fogak (a fehér csík 5 mm-t jelöl). D. *Jaculus loftusi* állcsonti fogak. E. *Meriones libycus* állcsonti fogak. F. *Meriones crassus* állcsonti fogak. G. *Gerbillus nanus* állcsonti fogak. H. *Gerbillus dasyurus* állcsonti fogak. I. *Jaculus loftusi metatarsus*

was estimated using previous collections and reports (e.g. Harrison & Bates 1991, Amr 2012). Spearman's rank correlation test (Microsoft Excel for Mac, version 16.66.1) between the prey body weight and its percentage in the rodent data was used to assess for weight-dependent predation.

Results

Pellets were cylindrical in shape with an average length of 52.74±11.64 mm (mean±SD) and 28.52±4.79 mm in width. *Figure 3* shows the morphology of bone remains for the recovered vertebrates from owl pellets. Both *Scarturus euphratica* and *Jaculus loftusi* have a very distinctive *metatarsus (Figure 3I)*.

A total of 635 individuals were recovered from all studied pellets, representing nine mammals, birds, at least two species of reptiles and arthropods *(Table 2)*. Small mammals constituted the highest number of consumed prey (n=481, 75.75%), followed by arthropods (n=127, 20%), birds (n=19, 2.9%) and reptiles (n=8, 1.26%). The Libyan Jird, *Meriones libycus*, was the most consumed rodent (26.46%) followed by Sundevall's Jird, *Meriones crassus* (20.47%), while the least were the Baluchistan Gerbil, *Gerbillus nanus*, and Wagner's Gerbil, *Gerbillus dasyures*. The percentage of prey item in the pellets correlated

Table 2. Food composition of the Pharaoh Eagle-Owl, *Bubo ascalaphus,* from Ara'r region in terms of number of prey items and percentages

2. táblázat Az egyiptomi uhu *(Bubo ascalaphus)* Ara'r régióban gyűjtött köpeteiben azonosított zsákmányelemek száma és biomassza értéke, illetve ezek százalékos megoszlása

Species	No. of individuals (MNI)	%	Individual weight in grams	Biomass in grams	Biomass %
Jaculus loftusi	62	9.76	57	3,534	10.54
Scarturus euphratica	24	3.78	52	1,248	3.73
Gerbillus sp.	41	6.46	25	1,025	3.05
Gerbillus nanus	6	0.94	26	156	0.46
Gerbillus dasyurus	4	0.63	25	100	0.29
Meriones crassus	130	20.47	80	10,400	31.02
Meriones libycus	168	26.46	70	11,760	35.08
Paraechinus aethiopicus	12	1.89	280	3,360	10.03
Unidentified rodent	34	5.35	30	1,020	3.04
Birds	19	2.99	25	475	1.44
Reptiles	8	1.26	15	120	0.35
Scorpions	42	6.61	5	210	0.63
Solifugae	20	3.15	2	40	0.12
Tenebrionidae	55	8.66	1	55	0.16
Scarabaeidae	10	1.57	2	20	0.06
	635	**100**		**33,523**	**100**

Table 3. Number and composition of prey items per pellet consumed by the Pharaoh Eagle-Owl, *Bubo ascalaphus*

3. táblázat Az egyiptomi uhu *(Bubo ascalaphus)* által köpetenként elfogyasztott zsákmányállatok száma és összetétele

No. of prey items	Frequency	Prey items recovered from pellets
1	46	1 *M. crassus*
	44	1 *M. lybicus*
	19	1 *J. loftusi*
	4	1 *S. euphratica*
	5	1 *P. aethiopicus*
	5	1 *Gerbillus* sp.
	17	1 Unidentified rodent
	4	1 Bird
	2	1 Lizard
	3	1 Tenebrionid
	1	1 Scorpion
	1	1 Solifugid
2	20	2 *M. crassus*
	16	2 *M. lybicus*
	5	2 *J. loftusi*
	1	2 *S. euphratica*
	3	1 *M. crassus*, 1 *Gerbillus* sp.
	1	1 *M. crassus*, 1 *S. euphratica*
	8	1 *M. crassus*, 1 *J. loftusi*
	7	1 *M. crassus*, 1 scorpion
	3	1 *M. crassus*, 1 solifugid
	5	1 *M. crassus*, 1 tenebrionid
	1	1 *M. crassus*, 1 bird
	5	1 *M. lybicus*, 1 *J. loftusi*
	3	1 *M. lybicus*, 1 *G. dasyurus*
	2	1 *M. lybicus*, 1 *G. nanus*
	1	1 *M. lybicus*, 1 *S. euphratica*
	4	1 *M. lybicus*, 1 *P. aethiopicus*
	2	1 *M. lybicus*, 1 bird
	2	1 *M. lybicus*,1 lizard
	3	1 *M. lybicus*, 1 scorpion
	6	1 *M. lybicus*, 1 tenebrionid
	1	1 *Gerbillus* sp., I bird
	1	1 *Gerbillus* sp., 1 scorpion
	2	1 *J. loftusi*, 1 *S. euphratica*
	1	1 *J. loftusi*, 1 *P. aethiopicus*
	1	1 *J. loftusi*,1 *Gerbillus* sp.
	2	1 *J. loftusi*, 1 tenebrionid
	1	1 *J. loftusi*, 1 solifugid
	1	1 *S. euphratica*, 1 Unidentified rodent
	2	1 *S. euphratica*, 1 bird
	1	1 *G. nanus*, 1 Unidentified rodent
	1	1 *P. aethiopicus*, 1 scorpion
	5	1 Unidentified rodent, 1 tenebrionid
	3	1 Unidentified rodent, 1 scorpion

No. of prey items	Frequency	Prey items recovered from pellets
3	1	3 *Gerbillus* sp.
	1	3 *M. lybicus*
	2	2 *M. crassus*, 1 *J. loftusi*
	1	2 *M. crassus*, 1 *Gerbillus* sp.
	1	2 *M. crassus*, 1 *M. lybicus*
	1	2 *M. crassus*, 1 *G. dasyurus*
	1	2 *M. crassus*, 1 scorpion
	1	2 *M. crassus*, 1 solifugid
	1	2 *M. crassus*, 1 tenebrionid
	1	2 *M. lybicus*, 1 *J. loftusi*
	1	2 *M. lybicus*, 1 *S. euphratica*
	1	2 *M. lybicus*, 1 *G. nanus* 1
	1	2 *M. lybicus*, 1 tenebrionid
	1	2 *M. lybicus*, 1 bird
	1	2 *M. lybicus*, 1 scorpion
	1	2 *M. lybicus*, 1 *Gerbillus* sp.
	1	2 *G. nanus* 1, *M. lybicus*
	1	2 *Gerbillus* sp., 1 *M. crassus*
	1	2 *J. loftusi*, 1 bird
	1	1 *M. lybicus*, 1 *J. loftusi*, 1 tenebrionid
	1	1 *M. lybicus*, 1 *J. loftusi*, I bird
	1	1 *M. lybicus*, 1 lizard, 1 tenebrionid
	2	1 *Gerbillus* sp., 2 scorpions
	1	1 *M. crassus*, 1 *J. loftusi*, 1 tenebrionid
	1	1 *M. crassus*, 1 *J. loftusi*, 1 solifugid
	2	1 *M. crassus*, 1 scorpion, 1 tenebrionid
	1	1 *M. lybicus*, 1 *S. euphratica*, 1 lizard
	1	1 *M. lybicus*, 1 *M. crassus*, 1 tenebrionid
	1	1 *M. lybicus*, 2 scorpions (1)
	1	1 *M. lybicus*, 1 *J. loftusi*, 1 bird
	1	1 *M. lybicus*, 1 tenebrionid, 1 scorpion
	1	1 *G. nanus*, 1 tenebrionid, 1 scorpion
	1	1 *M. lybicus*, 1 *Gerbillus* sp., 1 tenebrionid
	2	1 *J. loftusi*, 1 *G. dasyurus*, 1 solifugid
	1	1 *J. loftusi*, 1 *M. crassus*, 1 tenebrionid
	1	1 *J. loftusi*, 1 *Gerbillus* sp., 1 solifugid
	1	1 *J. loftusi*, 1 tenebrionid, 1 scorpion
	1	1 *S. euphratica*, 1 tenebrionid, 1 scorpion
	2	1 *Gerbillus* sp., 1 tenebrionid, 1 scorpion
	1	1 Unidentified rodent, 2 scorpions
	2	1 Unidentified rodent, 1 tenebrionid, 1 scorpion

No. of prey items	Frequency	Prey items recovered from pellets
4	1	4 *Gerbillus* sp.
	1	3 *J. loftusi*, 1 *S. euphratica*
	1	2 *M. lybicus,* 1 *J. loftusi* 1, *P. aethiopicus*
	1	2 *M. lybicus,* 1 tenebrionid, 1 Unidentified roden
	1	2 *M. crassus,* 2 *Gerbillus* sp.
	1	2 *M. lybicus,* 1 *Gerbillus* sp., 1 scorpion
	1	2 *M. lybicus,* 1 tenebrionid, 1 scorpion
5	1	3 *M. lybicus,* 2 solifugid
	1	2 *M. lybicus,* 2 *Gerbillus* sp., 1 *J. loftusi*
	1	2 *M. lybicus,* l bird, 2 tenebrionid
	1	2 *M. lybicus,* l bird, 1 solifugid, 1 undetermined rodent
	1	2 *G. dasyurus,* 1 *M. lybicus,* 1 *J. loftusi,* 1 solifugid
	1	2 *M. lybicus,* 1 *P. aethiopicus,* 1 lizard, 1 tenebrionid
	1	1 *M. crassus*, 3 scorpions, 1 tenebrionid
6	1	3 *M. lybicus,* 1 solifugid, 1 tenebrionid, 1 undetermined rodent
7	1	2 *M. crassus,* 1 lizard, 1 tenebrionid, 3 solifugid
	1	3 *M. crassus,* 1 *S. euphratica,* 1 *P. aethiopicus,* 1 tenebrionid, 1 scorpion
8	1	3 *M. crassus,* 2 *Gerbillus* sp., 1 *P. aethiopicus,* 1 bird, 1 tenebrionid
9	1	4 *M. crassus,* 2 *Gerbillus* sp., 1 *P. aethiopicus,* 1 *J. loftusi,* 1 tenebrionid
10	1	3 *M. lybicus,* 2 tenebrionid, 2 scorpions, 1 bird, 1 *J. loftusi,* 1 *S. euphratica*

significantly with its average body weight (Spearman's rank correlation rs=0.72, P<0.05), suggesting significant selection by the Pharaohs Eagle-Owls for larger prey.

Number of individuals per pellet ranged from 1 to 10 (1.9±54.46). Most pellets contained one prey item (n=150), while pellets with 10 items were the least (n=1). *Table 3* shows the frequency of each category of prey items per pellet.

The average biomass of prey per pellet was 59.4 g, ranging between 10–270 g.

Scorpions represented at least three species, *Androctonus crassicauda*, *Compsbuthus* sp. and *Scorpio* sp. The first is characterized by its heavy tail granulation, the second by its thin metasomal segments, while the third can be recognized by its lobster-like pedipalps. At least two species of reptiles were found, *Ptyodactylus hasselquistii* and *Trapellus agnetae*. Only two species of tenebrionids and scarabids were identified to the species level, *Prionotheca coronata* and *Scarabaeus sacer,* respectively.

Discussion

Owl pellets are excellent indicators for the abundance of rodent species in their feeding grounds. This helps to understand species richness and abundance especially for desert rodents (Heisler *et al.* 2016). The proportions of the small mammal's species in owl pellets demonstrate the abundance for these species in their habitat (Andrade *et al.* 2016).

In the study site, both *M. crassus* and *M. libycus* were the most abundant, followed by species of the genus *Gerbillus*. This study shows clearly that the Arabian Jerboa, *J. loftusi* is more common than the Euphrates Jerboa, *S. euphratica*. Abi-Said *et al.* (2020) found that both *M. crassus* and *M. libycus* were the prey items most consumed by *B. ascalaphus*

in Eastern Saudi Arabia. Similar findings were reported by Bauer (1988) on the feeding behavior possibly of the Barn Owl, *Tyto alba,* in the Summan Plateau. He also indicated that the Euphrates Jerboa was more common in owl pellets than the Arabian Jerboa.

The Libyan Jird, *M. libycus,* and Sundevall's Jird, *M. crassus,* were the prey items most consumed by *B. ascalaphus*. Both are common species that exist together across the deserts of the Arabian Peninsula and the surrounding arid region of Jordan and Iraq (Harrison & Bates 1991, Amr 2012). Moreover, *S. euphratica* is considered rare in Saudi Arabia with distribution limited to the northeastern part of the country, compared to the more common *J. loftusi* (Harrison & Bates 1991). The Pharaohs Eagle-Owl is the largest owl in the area, and the results suggest that it has nocturnal, opportunistic feeding habits, it prefers larger, more profitable rodent prey items (*M. crassus* and *M. libycus*), but smaller (*Gerbillus* sp.) are also hunted. Rifai *et al.* (2000) and Obuch (2018) recorded similar prey items in the diet of *B. ascalaphus* in the Eastern Desert of Jordan including *M. crassus, M. libycus* and *J. loftusi*. Four mammals (*M. crassus*, *J. loftusi, Gerbillus* sp., *Lepus capensis*), one bird *(Merops persicus)*, 1 reptile, and scorpions were recovered from *B. ascalaphus* in Qatar (Mohedano *et al.* 2014). This indicates that this owl is dependent on relatively large-sized murids as *M. crassus* and *M. libycus* as main food items, to meet its bioenergetic demand. In contrast, the feeding behavior of this owl in wetlands in the close proximity of urban areas showed a distinctive pattern. It fed mainly on the Lesser White-toothed Shrew, *Crocidura suaveolens*, and the House Mouse, *Mus musculus* in the Azraq wetland in Jordan (Amr *et al.* 1997). In the urban Hurghada area in Egypt, 78.05% of its diet consisted of commensal rodents: *Rattus norvegicus* and *M. musculus* (Sándor & Moldován 2010). Rodents (i.e. *M. libycus, Meriones shawi,* and *M. musculus*) were the most consumed prey items in Algeria (Biche *et al.* 2001, Benamor *et al.* 2021). Smaller and diurnal owls, such as Little Owl, *Athene noctua*, fed mainly on reptiles (35.5%) in the Eastern Desert of Jordan (Al-Melhim *et al.* 1997).

Obuch (2014) listed 56 mammal and more than 100 species of birds, in addition to amphibians, reptiles, fishes and invertebrates as part of the Eurasian Eagle-Owl, *Bubo bubo* diet across different habitats in Iran. This suggests that this species is highly opportunistic and feeds on a variety of prey items as they occur in its habitat.

Further studies on the diet composition of other owl species in Saudi Arabia should be conducted to better understand their feeding behavior. Underground caves in the desert of eastern Arabia represent valuable refuge sites for the terrestrial wildlife that may be used for nesting and/or shelter in the open desert habitats, these sites should be mapped and monitored to better understand their importance as subterranean habitats (Culver & Pipan 2019).

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