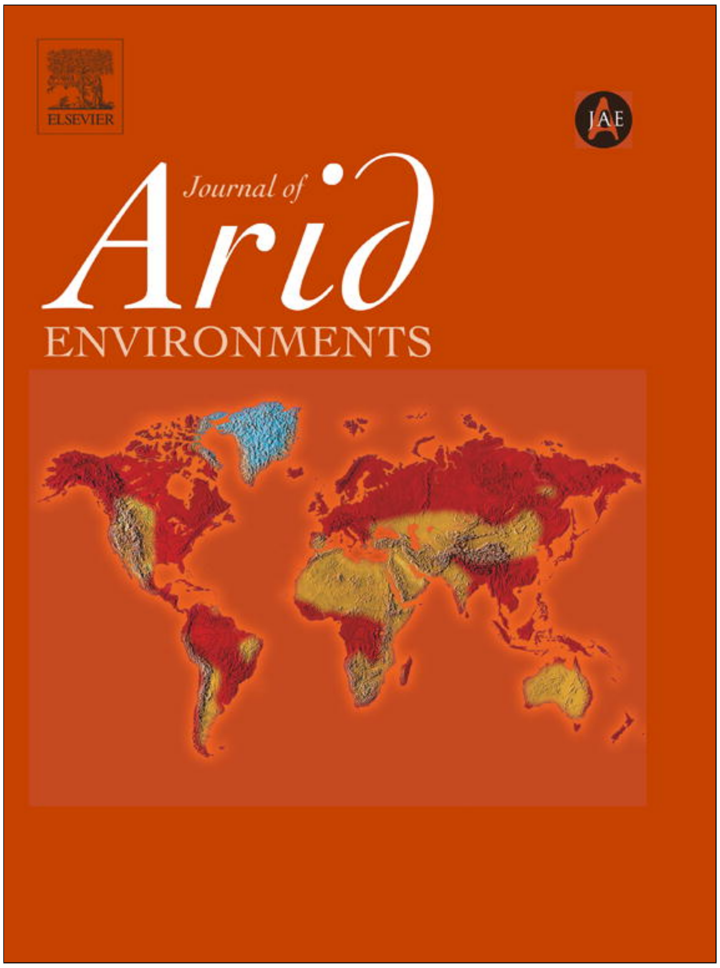
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Short communication

Diet and breeding success of long-eared owls in a semi-arid environment

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ABSTRACT

Only a few studies, and mostly in temperate climates in Europe, have examined the breeding and diet of long-eared owls (*Asio otus*) compared to studies of cavity-breeding owls, possibly because of the difficulties in reaching the nests of the former. Here we studied a population of long-eared owls, monitoring the diet of breeding owls and that of owls at a communal roost, every two to three months during 2006–2009, in a semi-arid region in Israel. It was found that the studied owls produced more young than in most countries in Europe. Diet was not associated with breeding parameters of the owls, whereas laying date was negatively correlated with both clutch size and number of nestlings. We found that more social voles (*Microtus socialis*) and fewer birds and house mice (*Mus musculus*) made up the diet at nests than that of adults at the roosts. The diet and breeding of long-eared owls in Israel differ from that in Europe, with birds and mice comprising an important part of the diet, in addition to voles.

Even though long-eared owls (*Asio otus*) are common over much of the Holarctic, most studies have concentrated strictly on the diet of these owls, due to the ease of pellet collection and analysis (Marti, 1976; see review; Birrer, 2009), while fewer studies have dealt with breeding (Korpimäki, 1992; Sergio et al., 2008; Tome, 1997; Village, 1981), most likely due to the difficulty in reaching their nests, compared to cavity-breeding owls that use nest boxes. In Europe, long-eared owls show strong numerical and functional responses in breeding numbers and diet to changes in vole density (Korpimäki, 1992; Korpimäki and Norrdahl, 1991; Sergio et al., 2008; Tome, 2003a; Village, 1981). Those studies that have dealt with variation in the diet of long-eared owls were carried out in Europe (Korpimäki, 1992; Korpimäki and Norrdahl, 1991; Nilsson, 1981), with a consequent need to study this owl's diet in other climates in order to determine whether a similar pattern of diet specialization and breeding occurs in other populations breeding in different climates and thousands of miles away from Europe. This is important because in regions where owls are highly specialized predators on one prey species, they may become more generalist in prey selection or nomadic when their preferred food is less available.

Unlike in Europe, where cold harsh weather may limit the breeding of owls (Altwegg et al., 2006; Lehikoinen et al., 2011), in semi-arid environments it is high temperatures that may affect diet and breeding (Charter et al., 2010b). Here we studied a population of long-eared owls that breed in a semi-arid region of the Middle East, in Israel, at a study site where temperatures can rise above 40 °C during the breeding season. In Israel, long-eared owl populations have increased during the last decade, probably because of a rise in the number of nest sites and greater availability of food in the region, as a result of the increased crow population (hooded crows, *Corvus corone*) and the modernization of agriculture, moving from mainly grazing to crop fields and plantations, which in Israel have larger rodent populations than in non-cultivated areas (Motro unpubl. data). However, owl diet has been little studied (Kiat et al., 2008; Leader et al., 2008) and breeding success even less so (Charter et al., 2010a) in the Middle East. Here we present a study on the diet of long-eared owls in a semi-arid area, specifically relating to whether the diet of adults and nestlings differs and whether diet is associated with breeding in long-eared owls. The study was performed in the Jezreel Valley, Israel (32°31′N, 35°15′E), 80–90 m above sea level, with a semi-arid climate. The site comprised mostly arable fields (sweet corn, alfalfa, oats and wheat), orchards (grape, almond plantations, olive groves, citrus), and scattered small villages.

Although long-eared owls bred in both nest baskets attached to eucalyptus trees (*Eucalyptus* sp.) (Charter et al., 2010a) and in natural crows nests, only the former were monitored during the 2007–2009 breeding seasons (18.1 %–31.6% of nest baskets were occupied). Active nests (defined as a nest in which eggs were

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laid) were determined by visits to the nest baskets. The nests were observed at least six times from February 1 to July 15, using an 8-m pole with a mirror attached to it, and a ladder when nestlings were banded at 19–20 d old. During the study, for each breeding attempt we recorded the clutch size and breeding success as the number of "branched" long-eared owls (19–22 d old), as long-eared owls leave the nest even before they can fly.

Pellets were collected from 41 breeding attempts during the 2006–2009 breeding seasons, while breeding data were collected only from 24 active nest baskets. Pellets were also collected from a communal roost. Adults at the roost were not marked so we do not know whether those owls were breeding or floaters. The minimum and maximum distance between the roost and nests was 100 m and 5 km respectively. The exact number of owls in the roost was also unknown because the owls were very sensitive to disturbance and would fly away when eye contact was made. During random counts we estimated the number to be between 10 and 40 owls per visit. The communal roost was located within a village (900 residents) among a stand of 15 pine trees (*Pinus pinea*), two field elms (*Ulmus minor*), and one pecan (*Carya illionensis*). We collected all the pellets during visits to the communal roost every two to three months from June 2006 to June 2009, and analyzed 100 pellets from each group (see Charter et al., 2009 for methods, using mandibles, skulls, and femurs). Pellets from the roost that were collected during the breeding season were only used for comparison with pellets collected at nests. To control for the possibility that pellets had been missed and remained from the previous visit, only fresh pellets were used in the analysis.

We performed multiple regression analyses to examine how diet may affect breeding. Pearson Chi-Square test was used to compare between the diet of long-eared owl adults at the roost and nestlings/parents at the nests, and seasonality of prey. Spearman's correlation was used to ascertain the relationship between laying date and breeding parameters. Statistical analyses were performed using SPSS for Windows version 20.

4724 prey specimens of long-eared owls were identified (Table 1). Social voles (*Microtus socialis guentheri*), house mice (*Mus musculus*), and birds were the most common prey specimens (Table 1). While rodents made up 81.8% of prey items, birds and bats combined made up 49.6%–82.6% of samples collected from June 24 to November 10, 2008 (Fig. 1). Thus, the diet of the studied owls is similar to that in Europe as rodents made up the majority of the diets. In Israel however, the owls also largely preyed on birds and bats when rodent numbers were low. In northern latitudes many species of owls rely on high rodent numbers to breed (Korpimäki et al., 2009), whereas the same owl species may prey on multiple prey species at lower latitudes, such as found in this study and also in the common kestrel (*Falco tinnunculus*; Charter et al., 2007).

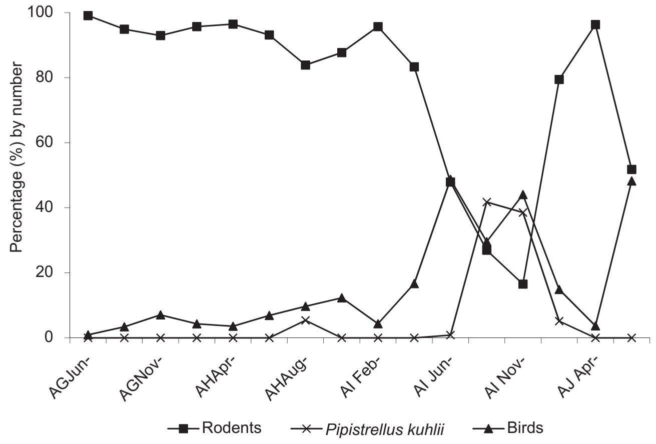

Fig. 1. Variation in the percentage of rodents, Kuhl's pipistrelle (bats) and birds in the diet of long-eared owls from a roost in the Jezreel Valley during 2006–2009.

Table 1
The diet of long-eared owls (roost and nest combined) breeding in a semi-arid region in Israel during 2006–2009.

Prey taxon	MNI[a]	%
Mammals		
Acomys cahirinus	3	0.06
Gerbillus sp.	1	0.02
Meriones tristrami	63	1.33
Microtus socialis guentheri	2879	60.94
Mus musculus	806	17.06
Rattus rattus	35	0.74
Spalax ehrenbergi	25	0.53
Unidentified rodent	50	1.06
Soricidae sp.	79	1.67
Pipistrellus kuhli	106	2.24
Birds	648	13.72
Reptilia		
Gekkonidae sp.	1	0.02
Invertebrates		
Dermaptera sp.	1	0.02
Coleoptera sp.	1	0.02
Gryllotalpa sp.	24	0.51
Unidentified	2	0.04
Total MNI	4724	

[a] MNI = minimum number of individuals.

Clutch size (range 2–7, mean = 4.63, SE = 0.3, $N = 19$), number of nestlings that reached branching age per laying pair (range 0–6, mean = 3.1, SE = 0.3, $N = 24$), number of nestlings that reached branching age per successful pair (fledged at least one young) (range 1–6, mean 3.4, SE = 0.3, $N = 22$), and laying date (range February 24 to May 17, mean = March 27, SE = 4.7, $N = 24$) were monitored during the 2006 to 2009 breeding seasons. Laying date was negatively correlated with both clutch size ($r_s = -0.59$, $n = 19$, $P < 0.01$) and the number of nestlings that reached branching age ($r_s = -0.44$, $n = 24$, $P < 0.05$). The breeding success of long-eared owls found in this study in the Middle East was on the higher side of that reported from Europe (mean = 3.0, SE = 0.6; Birrer, 2003; Korpimäki, 1992; Sergio et al., 2008; Tome, 1997, 2003b; Village, 1981). The diet of the long-eared owls was not related to their breeding parameters. Similar to other raptors in Israel, laying date was related to breeding parameters (Charter et al., 2007, 2010b).

To determine whether diet affects breeding we performed multiple regressions, backward model selection, comparing the three main prey species (*M. socialis guentheri*, *M. musculus*, and birds) to breeding parameters. The three prey species found in the diet were not related to laying date ($F_{3,20} = 0.78$, $P = 0.52$), clutch size ($F_{3,15} = 0.52$, $P = 0.67$), or number of nestlings ($F_{3,20} = 1.23$, $P = 0.32$). In comparison, in Europe the percentage of voles in the diet of long-eared owls was positively correlated to breeding parameters (Village, 1981; Sergio et al., 2008).

We compared the three major prey species (social voles, house mice, birds) of long-eared owls found in roosts with the total number of prey specimens found in nests during the same time period (June), to determine whether the adult owls in the roost preyed on different food items to those brought to the nest. It was found that long-eared owls preyed more on social voles in the nest than in the roost, and fewer birds and house mice in the former than in the latter (Pearson Chi-Square = 11.33, df = 2, $P < 0.01$, Fig. 2). Thus, the diet of the long-eared owls in roosts and nests

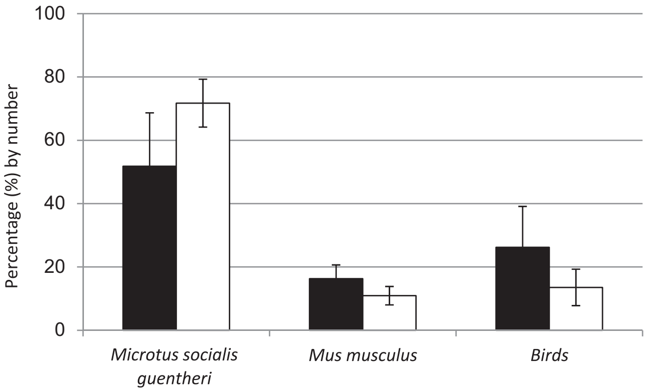

Fig. 2. Comparison between the percentage by number of social voles, house mice, and birds found in the diet of long eared-owls in roosts (black) and nests (white) during the study. Means ± s.e.

differed during the breeding season. Voles are commonly considered the long-eared owl's favorite prey throughout most of their range (Birrer, 2009), whereas birds are not. Birds are not only more difficult for owls to capture, but also to handle and eat. One possibility is that the adults preferred to bring voles to nests because a bird requires the parents to dismember it and provide it to the young, whereas voles can be swallowed whole. It is also possible that the owls in the roost were floaters, which may be less efficient hunters than mating adults, or which hunted in less attractive areas where fewer voles were available, such as within the villages. Similar results were found for the common kestrel, with more rodents found in the diet of nestlings of nests than at adults at roosts (Charter et al., 2007).

In this study we found that the diet of long-eared owls differs in the semi-arid region of Israel from that in Europe. The long-eared owls' large range makes it a unique species for study; but in order to understand the owls' breeding ecology it is important that future studies also concentrate on other regions of the world, and study additional breeding parameters to that of diet.

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