Journal of Biological Research-Thessaloniki **10**: 181 – 189, 2008
J. Biol. Res.-Thessalon. is available online at http://www.jbr.gr
Indexed in: WoS (Web of Science, ISI Thomson), CAS (Chemical Abstracts Service) and DOAJ (Directory of Open Access Journals)

Seasonal variation in the diet of the long-eared owl (*Asio otus*) in a northeastern agricultural area of Greece

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Received: 22 February 2008 Accepted after revision: 1 September 2008

The diet composition of the long-eared owl (*Asio otus*) was studied in New Orestiada, Greece from 2005 to 2007 by pellet analysis. The species preyed primarily on mammals (mostly *Mus*, *Apodemus*, and *Microtus*), birds followed, while insects and amphibians were less important as prey. Average prey biomass ranged from 12.7 ± 8.02 (summer 2006) to 15.5 ± 8.29 g (winter 2005-2006). The diet showed significant seasonal variations of both general prey types and mammalian prey ($p < 0.001$). Mammals comprised the majority of prey items as well as biomass in all seasons, followed by birds, and the proportion of insects by number in the diet significantly increased in the summer. Prey diversity was higher in summer, so was prey evenness, which was higher than in the other seasons. Between winters, comparisons showed that species diet over the severe winter of 2005-2006 was more diverse in contrast to the following milder winter.

Key words: owl, trophic diversity, small mammals, diet, Greece.

INTRODUCTION

As high predators in many ecosystems, owls may be valuable indicators of the environmental health of those ecosystems (Oliphant, 1994). Owls are sensitive to a number of environmental factors among which prey is of outstanding importance (Gutiérrez *et al*., 1984; Noble *et al*., 1993). Therefore, detailed and long-term studies on their diet can be instrumental to their conservation (Galbraith *et al*., 1992). Knowledge on the species' food habits has contributed to a better understanding of their ecology and behaviour, as well as to the proper management of their habitat (Petty *et al*., 2000; York *et al*., 2002; Tsahalidis *et al*., 2004; Marchesi & Sergio, 2005).

Being an opportunistic species, owls primarily rely on the abundance and easy capture of their prey, which means that their prey choice is not only dependent on spatial factors but is also temporary (habitat and season of the year) (Jaksić & Marti, 1981; Seckin & Coskun, 2006). Seasonal variation in their prey has been attributed to seasonal changes in vegetation cover that may make some species susceptible to owl predation (Fairley, 1967; Marti, 1974). Alternatively, prey variation may be due to the seasonal variation in the abundance and activity of the small mammals (Taylor, 1994).

The long-eared owl, *Asio otus* (Linnaeus, 1758) is present in almost the entire northern hemisphere (North America, Eurasia, and North Africa). It prefers tree clusters or edges of coniferous forests and parks adjacent to open agricultural areas and meadows, which are important hunting habitats for the species (Mikkola, 1983; Cramp, 1989). In Greece, the species winters and breeds in many mainland areas and on some large islands (Handrinos & Akriotis, 1997). Although its food habits have been widely studied in northern and central Europe, only a few published studies have addressed this issue in the south of the continent (Alivizatos & Goutner, 1999; Rubolini *et al*., 2003; Alivizatos *et al*., 2005).

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The purpose of this study was to describe the seasonal diet variation of the long-eared owl and its seasonal variation in an agro-forested area of northeastern Greece (New Orestiada, hereafter named N. Orestiada), located near the borders with Turkey. There is a lack of information about this part of Greece; an area with a considerable habitat mosaic where this owl has not been investigated so far.

MATERIALS AND METHODS

Study area

The area of N. Orestiada (41°51′ N, 26°53′ E) consists of a mosaic of agricultural systems (with a large number of irrigation canals), scattered tree clusters, poplar plantations (*Populus* sp.) and natural hedgerows. In the east of the area, the Evros River (border with Turkey) and its riparian vegetation constitute suitable habitats for a large number of species of small mammals and birds (Vohralik & Sofianidou, 1992; Heath & Evans, 2000). Human activities are intensive and include extensive corn (from April to October) and cereal (from October to July) crops as well as poplar logging.

Collection of pellets

The diet of predators can be studied using several methods including: a) direct observation of birds catching or consuming prey, b) collection and identification of prey remains, and c) pellet collection and analysis (Huang *et al*., 2006). Analysis of pellets is the most popular method for the study of owl diet composition (Marti, 1974; Mikkola, 1983). Pellets were collected between December 2005 and February 2007. From October to April pellets were collected from a roost occupied by 50-70 long-eared owls, located on the east edge of the city of N. Orestiada, in a small park with pine trees (*Pinus halepensis subsp. brutia*). During the rest of the year, samples were collected from all around the park area used by the owls for nesting (six to eight pairs remained in the area for breeding) as well as by young owls that remained and rambled close to their parental locality after their independence. Pellets were collected two to four times per month. They were placed in plastic bags and transferred to the laboratory where they were air-dried at room temperature.

Prey identification

Each pellet was treated as a single sample. Dry pellets were opened by hand and with the use of forceps. After hairs and feathers were removed, the remaining prey items were identified using reference books mainly from the remains of sculls and bills, but also from other bones (jaws, thighs, etc.), as well as from fur of mammals and feathers of birds (mammals: Lawrence & Brown, 1973; Chaline, 1974; birds: Brown *et al*., 1987; amphibians: Arnold & Burton, 1980; insects: Chinery, 1981). Insects were identified using remains that included heads, legs, and other identifiable hard parts (Marti, 1974). Prey was identified at class or family level, if species identification was impossible.

Remains from the same sample were combined to "reconstructed" individuals and then counted. The left and right jawbones of each prey species were paired and the larger number of jaws (left or right) was considered as the number of individuals of the particular species. Single unpaired bones, useful for species or class identification, were treated as an individual of a given species (Raczynski & Ruprecht, 1974; Yom-Tov & Wool, 1997). A simple count of skulls or jaws in pellets indicates the relative numerical importance of different mammal species in the predator's diet. However, this takes no account of body size of prey items (Morris, 1979).

The diet of the long-eared owl was analyzed for each season in terms of the number (N) and biomass (B) of prey items. For each year, seasons were determined as spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). To calculate the biomass of consumed prey, the number of individuals of each prey type was multiplied by the average body mass of each species. The body mass of mammals and birds was taken from the literature (mammals: McDonald & Barrett, 1993; birds: Perrins, 1987) and that of insects and amphibians from Alivizatos (personal communication). Samples were analyzed for all seasons and for each season separately.

Data analysis

In each season, average prey biomass was calculated by dividing the seasonal total biomass by the number of individuals. The relative participation of each taxon (species, family or class) in the diet of the long-eared owl was estimated using the following equation:

$$W\% = \frac{n_i \times w_i}{\sum_{i=1}^{m} (n_i \times w_i)} \times 100$$

where W% is the relative percentage of consumed biomass, m is the number of total taxa in prey, n_i is the number of individuals in each taxon of prey, and w_i is the biomass of each taxon in prey.

To investigate the seasonal variation in prey, numerical data on the main prey were tested using contingency tests. For these analyses, prey was grouped as a) mammals, and b) birds and other prey. For testing the seasonal differences in the composition of the mammalian prey in particular, mammal numerical data were combined as *Mus macedonicus*, *Apodemus sylvaticus*, *Microtus rossiaemeridionalis*, *Crocidura* sp., and other mammals. Summer was excluded from this analysis due to the small sample size.

Food Niche Breadth (FNB) was estimated using Levins' index (Levins, 1968) calculated by the equation $FNB = 1/\sum p_i^2$, where p_i is the proportion of prey i in the diet of the long-eared owl. This index incorporates both richness (number of prey types in the diet) and evenness (uniformity of prey types in the diet), and it varies from 1 to N, with the higher values reflecting a wider dietary breadth (Marti, 1987). This index was applied because it is commonly used in comparative studies on raptor diets (Marks & Marti, 1984; Marti *et al*., 1993; Marti & Kochert, 1995).

Diet diversity was additionally calculated using the standardised Levins' index (FNBsta) (Colwell & Futuyma, 1971): $FNBsta = (FNB - 1)/(n - 1)$, where FNB is the Levins' index and n is the total number of prey species (lowest niche breadth = 0; highest niche breadth = 1). This estimate is independent of the number of prey types included in the sample, and is useful for comparing the diets among different areas and seasons that may vary in number of prey types available (Ganey & Block, 2005). The overlap in diet composition among seasons was estimated using Pianka's index (Pianka, 1973): $O = \sum p_i q_i / (\sum p_i^2 \sum q_i^2)^{1/2}$, where p_i is the proportion of prey type i in a diet sample representing a season and q_i is the proportion of the same type in another diet sample representing a different season. Pianka's index ranges from 0 (no overlap in the diet) to 1 (complete overlap). The diet overlap was estimated a) at species level, and b) at class level (mammals, birds, insects, amphibians).

RESULTS

Description of diet and summary statistics

The diet of the long-eared owl comprised of small mammals, birds, insects, and amphibians in order of decreasing numerical abundance (Appendix 1). From a total of 1086 prey items identified, small mammals (eight species) comprised 91% of the diet by number (90.4% by biomass). The main species were *Mus macedonicus* (56.8% by number and 46.6% by biomass), *Apodemus sylvaticus* (16.9 and 23%, respectively) and *Microtus rossiaemeridionalis* (8.6 and 11.7%, respectively). Birds (12 species) constituted 7.6% by number and 9.3% by biomass of the prey items. The commonest species was *Fringilla coelebs* (1% by number and 1.4% by biomass), while > 50% were undetermined passerines (4 and 4.1%, respectively). Insects and amphibians constituted only a small percentage of the diet. The total average prey biomass was 14.6 ± 6.60 g (range 1-80 g).

Seasonal composition of prey

Seasonal median prey biomass was 12 g for all the seasons. Mammals were the most important prey type in all seasons, both in terms of number (range 60-96.1%) and biomass (range 61.9-96.7%) and were represented by at least four species in each seasonal sample (Table 1 and Fig. 1). The most abundant mammalian prey species were *M. macedonicus*, *A. sylvaticus*, and *M. rossiaemeridionalis* (Table 1). In summer, *Crocidura suaveolens*, an insectivore, reached 15% by number, becoming the second most abundant prey species in this season. In autumn and winter, *Micromys minutus* was more abundant than in other seasons, whereas *M. rossiaemeridionalis* was more abundant in winter. The seasonal variation in mammalian prey composition was significant ($\chi^2 = 100.82$, df = 16, $p < 0.001$). Seasonal variation remained significant even after the removal of the summer sample ($\chi^2 = 49.06$, df = 12, $p < 0.001$). On the level of general prey types, the owl's diet also showed significant seasonal trends including all seasons and precluding summer ($\chi^2 = 75.1$, df = 4, $p < 0.001$; $\chi^2 = 30.18$, df = 3, $p < 0.001$, respectively).

Birds were the second most important prey type both in terms of number and biomass and were represented by many passerine species, although species composition varied seasonally (Table 1). Insects generally constituted a small proportion of prey in terms of biomass (< 1%), except for summer, when they

TABLE 1. Seasonal diet composition of the long-eared owl by % numbers (N) and % biomass (B), in N. Orestiada from 2005 to 2007

	Winter 2005-2006		Spring 2006		Summer 2006		Autumn 2006		Winter 2006-2007	
Prey	N (%)	B (%)	N (%)	B (%)	N (%)	B (%)	N (%)	B (%)	N (%)	B (%)
MAMMALIA	**83.9**	**84.0**	**88.0**	**85.9**	**60.0**	**61.9**	**96.1**	**96.7**	**95.4**	**94.7**
Mus macedonicus	43.8	34.0	52.3	40.9	22.5	21.3	67.8	59.1	61.3	50.6
Apodemus sylvaticus	15.3	19.9	18.8	24.5	12.5	19.7	18.3	26.5	15.7	21.6
Rattus spp.	1.5	5.7	0.4	1.5	–	–	0.4	1.9	0.7	3.0
Micromys minutus	2.2	1.0	–	–	–	–	3.5	1.8	3.6	1.7
Microtus rossiaemeridionalis	13.1	17.0	8.3	10.8	5.0	7.9	3.0	4.4	10.7	14.7
Arvicola terrestis	0.7	2.8	0.4	1.5	–	–	–	–	–	–
Crocidura suaveolens	4.4	1.7	1.1	0.4	15.0	7.1	–	–	0.7	0.3
Crocidura leucodon	2.2	1.1	0.4	0.2	–	–	0.4	0.3	–	–
Muridae indet.	0.7	0.7	6.0	5.9	5.0	5.9	2.6	2.8	2.4	2.5
Rodendia indet.	–	–	0.4	0.4	–	–	–	–	0.2	0.2
AVES	**14.6**	**15.9**	**11.3**	**13.3**	**22.5**	**35.5**	**2.6**	**3.2**	**4.1**	**5.3**
Fringilla coelebs	2.2	2.8	2.3	2.9	5.0	7.9	–	–	–	–
Phylloscopus collybita	–	–	1.1	0.5	–	–	–	–	–	–
Coccothraustes coccothraustes	–	–	0.4	1.2	–	–	–	–	–	–
Carduelis carduelis	1.5	1.4	0.8	0.7	–	–	0.4	0.5	–	–
Turdus sp.	–	–	0.4	1.7	–	–	–	–	–	–
Turdus merula	–	–	–	–	–	–	–	–	0.2	1.3
Serinus serinus	0.7	0.5	–	–	–	–	–	–	0.2	0.2
Parus sp.	0.7	0.6	0.4	0.3	–	–	–	–	–	–
Parus caeruleus	0.7	0.6	–	–	–	–	–	–	0.5	0.4
Galerida cristata	–	–	–	–	2.5	7.9	–	–	–	–
Emberiza sp.	2.2	3.5	–	–	2.5	4.9	0.4	0.8	0.2	0.4
Erithacus rubecula	-	–	–	–	–	–	–	–	0.2	0.2
Passer sp.	0.7	1.2	–	–	–	–	–	–	–	–
Aegithalos caudatus	0.7	0.4	–	–	–	–	–	–	–	–
Passeriformes indet.	5.1	5.0	6.0	5.9	12.5	14.8	1.7	1.9	2.7	2.7
INSECTA	**1.5**	**0.1**	**0.4**	**0.02**	**17.5**	**2.6**	**1.3**	**0.1**	**0.5**	**0.03**
Gryllotalpa gryllotalpa	–	–	–	–	15.0	2.4	–	–	–	–
Tettigoniidae indet.	0.7	0.05	–	–	–	–	0.4	0.03	–	–
Coleoptera indet.	0.7	0.05	0.4	0.02	2.5	0.2	0.9	0.1	0.5	0.03
AMPHIBIA	–	–	**0.4**	**0.7**	–	–	–	–	–	–
Anura sp.	–	–	0.4	0.7	–	–	–	–	–	–
Total No of prey	137	–	266	–	40	–	230	–	413	–
FNB	5.16		4.04		7.34		2.36		3.06	
FNBsta	0.15		0.11		0.23		0.05		0.07	

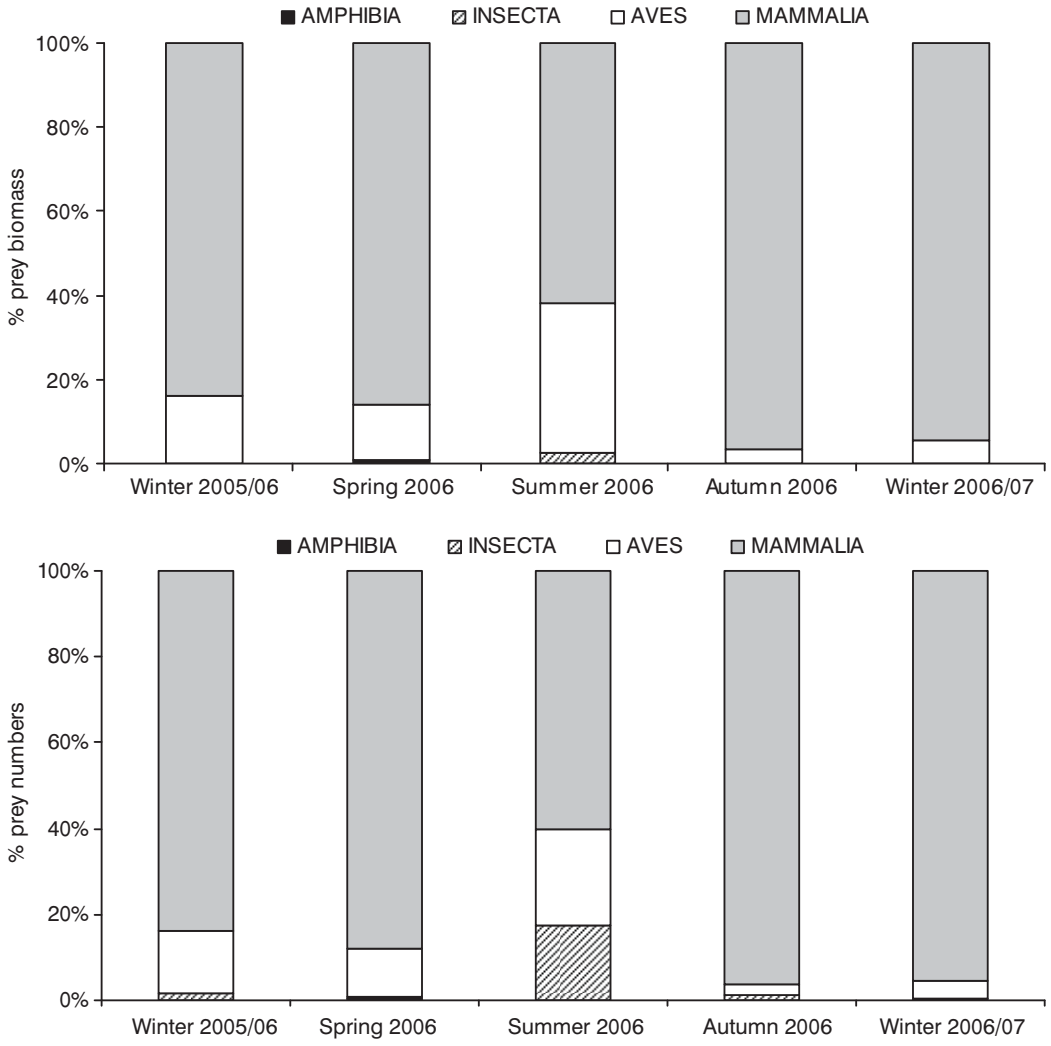

FIG. 1. Seasonal changes in the proportion of biomass and number of main prey type of the long-eared owl in N. Orestiada during 2005-2007.

TABLE 2. Food niche overlap (O) expressed as Pianka's index between the five seasons studied: a) calculations based on proportions of biomass of prey species consumed, and b) calculations based on proportions of biomass of taxa consumed. W1: Winter 2005-2006, SP1: Spring 2006, SU1: Summer 2006, AU1: Autumn 2006, W2: Winter 2006-2007

	Pianka index	
	$O^{(a)}$	$O^{(b)}$
W1/SP1	0.98	0.99
W1/SU1	0.77	0.95
W1/AU1	0.96	0.98
W1/W2	0.98	0.99
SP1/SU1	0.76	0.94
SP1/AU1	0.98	0.99
SP1/W2	0.99	0.99
SU1/AU1	0.69	0.91
SU1/W2	0.71	0.91
AU1/W2	0.99	0.99

reached 2.6% by biomass (Table 1 and Fig. 1). Amphibians appeared only in spring and comprised a very low proportion of the diet (Table 1).

Trophic diversity and overlap

Seasonal trophic diversity was very low because of the dominance of small mammals in the owl's diet in all seasons. However, the summer diet was more variable ($FNB_{STA} = 0.23$) compared with the other seasons because of the higher proportion of birds and insects (Table 1). Trophic overlap was almost similar across seasons (Table 2). The only exception appeared in summer, when prey type variation increased. However, this may be due to the low summer sample size (Table 2).

DISCUSSION

In the region of N. Orestiada, the diet of the long-eared owl contained 24 species overall (eight mammals, 12 birds, three insects, and one amphibian). The study species consumed a wider range of food types in our area compared with other areas of southern Europe (Pirovano *et al*., 2000; Alivizatos *et al*., 2005).

The mosaic of habitats in the study area may account for the considerable diversity as they provide micro-habitats that are suitable for a large number of species of small mammals and birds (Vohralik & Sofianidou, 1992; Heath & Evans, 2000), which are the main prey of the long-eared owl (Cramp, 1985; Taylor, 1994). *Mus macedonicus* was the main species of prey (56.8% of its total diet by number), as it is known from other areas of Greece (Alivizatos & Goutner, 1999; Alivizatos *et al*., 2005). *Mus macedonicus* is the most common small mammal species in the lowland regions of Thrace. It occurs in habitats that range from dry regions with isolated bushes to water channels, but it is not found in forests or buildings (Vohralik & Sofianidou, 1992). The considerable presence of *Apodemus sylvaticus* in the owl's diet (16.9% by number) may be explained by the fact that it hunts in areas covered by trees (Cramp, 1985; Alivizatos & Goutner, 1999). This mammal is the second most widespread species in Thrace, which is largely dominated by forested areas (Vohralik & Sofianidou, 1992; Bousbouras, 1999).

In northern Europe, microtine rodents predominate in the diet of the long-eared owl (Herrera & Hiraldo, 1976; Mikkola, 1983; Korpimäki, 1992; Roulin, 1996; Tome, 2003; Balciauskiene *et al*., 2006). However, in northern Greece, rodent proportion in the diet of the long-eared owl varies, probably depending on changes in the population cycles or the habitat (Alivizatos *et al*., 2005). In the present study, the mammal prey species constituted only a small proportion of the diet (8.6% by number), while in other studies it has been reported as the most important, constituting more than 40% by number (Alivizatos *et al*., 2005). As also confirmed in our study (2.1%), shrews are not preferred by the long-eared owl (Bunn *et al*., 1982; Mikkola, 1983) and they rarely exceed 2% of its diet in biomass (Alivizatos & Goutner, 1999).

Birds comprise a significant proportion of the species' diet, reaching 7.6% by number. In Greece, as in other areas of Europe, birds are often an important prey for the owl and in certain areas the long-eared owl's diet is based on them (Amat & Soriguer, 1981; Mikkola, 1983; Alivizatos & Goutner, 1999). Insects also constitute an important food source for the species particularly in the summer, because of their increased availability during the warmer months of the year (Alivizatos *et al*., 2006). Amphibians are represented by very small proportions in the owl's diet (only in spring), while no reptiles were found; a fact which is in agreement with previous studies in other areas of Greece (Alivizatos & Goutner, 1999; Alivizatos *et al*., 2005).

There is seasonal variation in the proportion of different taxa present in the owl's diet. Seasonal diet fluctuations have also been reported in other studies (Fairley, 1967; Glue & Hammond, 1974; Nilsson, 1981; Mikkola, 1983; Wijnandts, 1984; Cramp, 1989; Rubolini *et al*., 2003). Winter climatic conditions are an important factor resulting in these seasonal fluctuations (Korpimäki, 1981; Rubolini *et al*., 2003). Long-eared owls seem to adopt a more generalistic pattern in their winter diet, feeding on a wider range of prey species, especially if unfavourable weather conditions predominate (low temperatures, snowfall) (Rubolini *et al*., 2003). The diet composition of the owl in N. Orestiada in the winter of 2005-2006, when adverse weather conditions dominated, became more diverse compared with the winter of 2006-2007 (FNB: 5.16 *vs* 3.06). In agreement with our results it has been reported that, during prolonged periods of snowcover and very low temperatures, the proportion of birds and riparian rodents increase in the species' diet (Wijnandts, 1984; Canova, 1989). In addition, a riparian rodent (*Arvicola terrestris*) was also present in the owl's diet, but was not present in the following winter (Table 1).

A small increase in the presence of mammals in the diet was found in the autumn and winter of 2006-2007 compared with the other seasons (Table 1). Variation in the composition of mammalian species in the diet of nocturnal birds has been attributed to various climatic factors, to seasonal population cycles, to seasonal variation in abundance and activity of small mammals, and to changes in vegetation cover during the year, particularly in agricultural areas, where annual agricultural cycles cause major changes to the soil surface (e.g. tillage, harvesting, cereals in summer, cotton in autumn) (Marti, 1974; Taylor, 1994; Rubolini *et al*., 2003; Bontzorlos *et al*., 2005).

Mus numerically increased in the autumn, with a significant decrease in the *Microtus* species. The increased proportion of *M. macedonicus* in the autumn could be explained by the fact that in the study area at the start of this season, cultivations are burnt following harvest. *Mus macedonicus* is a species which invades post-fire habitats in the first stages of habitat recovery (Haim *et al*., 1999) and the owl preys on small mammal species (Canova, 1989). In spring, there was an increase in the presence of *Apodemus sylvaticus* in the owl's diet, with a decrease in the *Mus* and *Microtus* species, which may be due to the fact that *A. sylvaticus* starts to breed in March (McDonald & Barrett, 1993). Marti (1974) has reported that when prey individuals are seeking mates and when young disperse, many of them are found in unfamiliar areas and are probably more vulnerable to predation. The increase of *Microtus* in the owl's diet during the winters of 2005-2006 and 2006-2007, may also be attributed to the fact that over this period its capture is easier due to the lack of vegetation cover following harvest, or because these mammals are heavier than other prey, providing a larger amount of food per hunting trip (Pirovano *et al*., 2000).

In spring, very few owls remain in the area to breed and young owls remain close to their natal area for some months after their independence (Cramp, 1989). During this period, mammal numbers significantly decrease. The observed small number of *Microtus* sp. during the summer is probably due to their lower detectability by the owls in the dense cover of the cultivations. However, a large increase in the proportion of birds and insects was observed. The increased proportion of the latter may be due to their increased availability during the warmer months of the year (Alivizatos *et al*., 2006).

ACKNOWLEDGEMENTS

The authors are grateful to Dr. H. Alivizatos for his support in prey identification. We also wish to thank Dr. E. Papadatou and L. Sidiropoulos for their valuable comments.

REFERENCES

Alivizatos H, Goutner V, 1999. Winter diet of the barn owl (*Tyto alba*) and long-eared owl (*Asio otus*) in northeastern Greece: a comparison. *Journal of raptor research*, 33: 160-163.

Alivizatos H, Goutner V, Zogaris S, 2005. Contribution to the study of four owl species (Aves, Strigiformes) from mainland and island areas of Greece. *Belgian journal of zoology*, 135: 109-118.

Alivizatos H, Goutner V, Athanasiadis A, Poirazidis K, 2006. Comparative temporal prey use by barn owl (*Tyto alba*) and little owl (*Athene noctua*) in Evros Delta, northeastern Greece. *Journal of biological research-Thessaloniki*, 6: 177-186.

Amat JA, Soriguer RC, 1981. Analyse comparative des regimes alimentaires de l'Effraie *Tyto alba* et du Moyen-Duc *Asio otus* dans l'ouest de l'Espagne. *Alauda*, 49: 112-120.

Arnold EN, Burton JA, 1980. *A field guide to the reptiles and amphibians of Britain and Europe*. Collins, London.

Balciauskiene L, Jovaisas A, Narusevicius V, Petraska A, Skuja S, 2006. Diet of tawny owl (*Strix aluco*) and long-eared owl (*Asio otus*) in Lithuania as found from pellets. *Acta zoologica lituanica*, 16: 37-45.

Bontzorlos VA, Peris SJ, Vlachos CG, Bakaloudis DE, 2005. The diet of barn owl in the agricultural landscapes of central Greece. *Folia zoologica*, 54: 1-14.

Bousbouras D, 1999. A study of *Apodemus sylvaticus* and *Apodemus flavicolis* habitat occupation at the Dadia Forest Reserve: Contribution to issues concerning the conservation of raptors. *Biologia gallo-hellenica*, 25: 3-14.

Brown R, Ferguson J, Lawrence M, Lees D, 1987. *Tracks and signs of the birds of Britain and Europe*. Helm, London.

Bunn DS, Warburton AB, Wilson RDS, 1982. *The barn owl*. Poyser, Calton.

Canova L, 1989. Influence of snow cover on prey selection by long-eared owls *Asio otus*. *Ethology ecology & evolution*, 1: 367-372.

Chaline J, 1974. *Les prois des rapaces*. Doin, Paris.

Chinery M, 1981. *Collins guide to the insects of Britain and Western Europe*. Collins, London.

Colwell RK, Futuyma DJ, 1971. On the measurement of niche breadth and overlap. *Ecology*, 52: 567-576.

Cramp S, 1985. *The birds of the western Palearctic, Vol. 4*. Oxford University Press, Oxford.

Cramp S, 1989. *Handbook of the birds of Europe, the Middle*

East and North Africa: the birds of the western Palearctic. Vol. IV. Terns to woodpeckers. Oxford University Press, Oxford.

Fairley JS, 1967. Food of long-eared owls in northeast Ireland. *British birds*, 60: 130-135.

Galbraith CA, Taylor IR, Percival S, 1992. *The ecology and conservation of European owls*. JNCC, UK.

Ganey JL, Block WM, 2005. Dietary overlap between sympatric Mexican spotted and great horned owls in Arizona. Research Paper RMRS-RP-57WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 9p.

Glue DE, Hammond GJ, 1974. Feeding ecology of the long-eared owl in Britain and Ireland. *British birds*, 67: 361-369.

Gutiérrez RJ, Solis DM, Sisco C, 1984. Habitat ecology of the spotted owl in northwestern California: implications of management. In: *Proceedings of the convention of the Society of American Foresters*. 16-20 October 1983, Portland: 368-373.

Haim A, Shabtay A, Arab Z, 1999. The thermoregulatory and metabolic responses to photoperiod manipulations of the Macedonian mouse (*Mus macedonicus*), a post-fire invader. *Journal of thermal biology*, 24: 279-286.

Handrinos G, Akriotis T, 1997. *The birds of Greece*. A & C Black, London.

Heath MF, Evans MI, 2000. *Important bird areas in Europe: priority sites for conservation. Vol. 2: Southern Europe*. BirdLife Conservation Series No. 8, Cambridge.

Herrera CM, Hiraldo F, 1976. Food-niche and trophic relationships among European owls. *Ornis scandinavica*, 7: 29-41.

Huang KY, Lin YS, Severinghaus LL, 2006. Comparison of three common methods for studying the diet of nestlings in two *Accipiter* species. *Zoological studies*, 45: 234-243.

Jaksić FM, Marti CD, 1981. Trophic ecology of *Athene* owls in Mediterranean-type ecosystems: a comparative analysis. *Canadian journal of zoology*, 59: 2331-2340.

Korpimäki E, 1981. On the ecology and biology of Tengmalm's owl (*Aegolius funereus*) in southern Ostrobothnia and Suomenselkä western Finland. *Acta universitatis ouluensis series A*, 118: 1-84.

Korpimäki E, 1992. Diet composition, prey choice, and breeding success of long-eared owls: Effects of multiannual fluctuations in food abundance. *Canadian journal of zoology*, 70: 2373-2381.

Lawrence MJ, Brown RW, 1973. *Brown mammals of Britain. Their tracks, trails and signs*. Blandford Press, Dorset.

Levins R, 1968. *Evolution in changing environments: some theoretical explorations*. Princeton University Press, Princeton, New Jersey.

MacDonald D, Barrett P, 1993. *Mammals of Britain and Europe*. Harper Collins, London.

Marchesi L, Sergio F, 2005. Distribution, density, diet and productivity of the Scops Owl *Otus scops* in the Italian Alps. *Ibis*, 147: 176-187.

Marks JS, Marti CD, 1984. Feeding ecology of sympatric barn owls and long-eared owls in Idaho. *Ornis scandinavica*, 15: 135-143.

Marti CD, 1974. Feeding ecology of four sympatric owls. *Condor*, 76: 45-61.

Marti CD, 1987. Raptor survey techniques. In: Giron Pendleton BA, Millsap BA, Cline KW, Bird DM, eds. *Raptor management techniques manual*. National Wildlife Federation, Washington: 67-80.

Marti CD, Kochert MN, 1995. Are red-tailed hawks and great horned owls diurnal-nocturnal dietary counterparts? *Wilson bulletin*, 107: 615-628.

Marti CD, Korpimäki E, Jaksić FM, 1993. Trophic structure of raptor communities: a three-continent comparison and synthesis. In: Power DM, ed. *Current ornithology, Vol. 10*. Plenum, New York: 47-137.

Mikkola H, 1983. *Owls of Europe*. T & AD Poyser, London.

Morris P, 1979. Rats in the diet of the barn owl (*Tyto alba*). *Journal of zoology*, 189: 540-545.

Nilsson IN, 1981. Seasonal changes in food of the long-eared owl in southern Sweden. *Ornis scandinavica*, 12: 216-223.

Noble DG, Elliott JE, Shutt JL, 1993. *Environmental contaminants in Canadian raptors. Technical Report Series No. 91*. Canadian Wildlife Service, Environment Canada, Ottawa.

Oliphant L, 1994. A report on results of national and regional ornithological surveys in Canada. *Bird trends*, 4: 1.

Perrins C, 1987. *New generation guide to the birds of Britain and Europe*. Collins, London.

Petty SJ, Lambin X, Sherratt TN, Thomas CJ, Mackinnon JL, Coles CF, Davison M, Little B, 2000. Spatial synchrony in field vole (*Microtus agrestis*) abundance in a coniferous forest in northern England: the role of vole-eating raptors. *Journal of applied ecology*, 37: 136-147.

Pianka ER, 1973. The structure of lizard communities. *Annual review of ecology and systematics*, 4: 53-74.

Pirovano A, Rubolini D, Brambilla S, Ferrari N, 2000. Winter diet of urban roosting long-eared owls *Asio otus* in northern Italy: the importance of the brown rat *Rattus norvegicus*. *Bird study*, 47: 242-244.

Raczynski J, Ruprecht AL, 1974. The effect of digestion on the osteological composition of owl pellets. *Acta ornithologica*, 14: 25-38.

Roulin A, 1996. Wintering diet of the barn owl (*Tyto alba*), long-eared owl (*Asio otus)*, hen harrier (*Circus cyaneus*) and kestrel (*Falco tinnunculus*). *Bulletin de la société vaudoise des sciences naturelles*, 84: 19-32.

Rubolini D, Pirovano A, Borghi S, 2003. Influence of seasonality, temperature and rainfall on the winter diet

of the long-eared owl, *Asio otus*. *Folia zoologica*, 52: 67-76.

Seckin S, Coskun Y, 2006. Mammalian remains in the pellets of long-eared owls (*Asio otus*) in Diyarbakyr Province. *Turkish journal of zoology*, 30: 271-278.

Taylor I, 1994. *Barn owls. Predator-prey relationships and conservation*. Cambridge University Press, Cambridge.

Tome D, 2003. Functional response of the long-eared owl (*Asio otus*) to changing prey numbers: a 20-year study. *Ornis fennica*, 80: 63-70.

Tsahalidis E, Paralikidis N, Tsiompanoudis A, 2004. Diet and food habitat of the European (common) quail (*Coturnix coturnix coturnix*) in the areas of Evros. In: *First Panhellenic Environmental Conference*, New Orestiada, Greece: 159-168.

Vohralik V, Sofianidou TS, 1992. Small mammals (Insectivora, Rodentia) of Thrace, Greece. *Acta universitatis carolinae biologica*, 36: 341-369.

Wijnandts H, 1984. Ecological energetics of the long-eared owl (*Asio otus*). *Ardea*, 72: 1-92.

Yom-Tov Y, Wool D, 1997. Do the contents of barn owl pellets accurately represent the proportion of prey species in the field? *Condor*, 99: 972-976.

York MM, Rosenberg DK, Sturm KK, 2002. Diet and food-niche breadth of burrowing owls (*Athene cunicularia*) in the Imperial Valley, California. *Western north american naturalist*, 62: 280-287.

APPENDIX 1. The diet of the long-eared owl in N. Orestiada in total from 2005-2007 (n = 477 pellets)

Prey	N	N (%)	B (%)
MAMMALIA	988	91.0	90.4
Mus macedonicus	617	56.8	46.6
Apodemus sylvaticus	183	16.9	23.0
Rattus spp.	7	0.6	2.6
Micromys minutus	26	2.4	1.1
Microtus rossiaemeridionalis	93	8.6	11.7
Arvicola terrestis	2	0.2	0.8
Crocidura suaveolens	18	1.7	0.7
Crocidura leucodon	5	0.5	0.3
Muridae indet.	35	3.2	3.3
Rodendia indet.	2	0.2	0.2
AVES	82	7.6	9.3
Fringilla coelebs	11	1.0	1.4
Phylloscopus collybita	3	0.3	0.1
Coccothraustes coccothraustes	1	0.1	0.3
Carduelis carduelis	5	0.5	0.5
Turdus sp.	1	0.1	0.4
Turdus merula	1	0.1	0.5
Serinus serinus	2	0.2	0.1
Parus sp.	2	0.2	0.2
Parus caeruleus	3	0.3	0.2
Galerida cristata	1	0.1	0.3
Emberiza sp.	6	0.6	0.9
Erithacus rubecula	1	0.1	0.1
Passer sp.	1	0.1	0.2
Aegithalos caudatus	1	0.1	0.1
Passeriformes indet.	43	4.0	4.1
INSECTA	15	1.4	0.1
Coleoptera indet.	7	0.6	0.0
Gryllotalpa gryllotalpa	6	0.6	0.1
Tettigoniidae indet.	2	0.2	0.0
AMPHIBIA	1	0.1	0.2
Anura sp.	1	0.1	0.2
Total prey items	1086		