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Comparative termporal prey use by barn owl (*Tyto alba*) and little owl (*Athene noctua*) in the Evros Delta, northeastern Greece

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The diets of barn owl (*Tyto alba*) and little owl (*Athene noctua*) were studied in the Evros Delta from 2002 to 2004 through pellet analysis. The barn owl preyed primarily on mammals (mainly *Microtus*, *Mus* and *Crocidura*), while birds and amphibians were much less important. Mean prey biomass ranged from 11.5 to 16.1 g. The median prey biomasses and mammalian prey use differed significantly during the study ($p < 0.001$). The diet of the little owl was primarily composed by insects (mainly Coleoptera, Orthoptera and Dermaptera) and mammals (mainly *Microtus* and *Mus*), although birds were also of some importance. Mean prey biomass ranged from 2.2 to 12.2 g. Overall, the median prey biomasses differed seasonally ($p < 0.001$). Between owls, the median prey biomasses mostly differed seasonally. Prey diversity and evenness were both higher in the little owl. The seasonal distribution of the main prey taxa differed significantly in the little owl being similar in the barn owl. In cluster analyses, diet was clumped mainly by owl species and study years, and secondarily by seasons. The same analysis for mammalian prey suggested common prey use based on their availability and differences were probably due to different behaviour of prey species and predators.

Key words: owls, diet, small mammals, Evros Delta.

INTRODUCTION

The barn owl, *Tyto alba* (Scopoli, 1769) and the little owl, *Athene noctua (*Scopoli, 1769) are sympatric over most of Europe and around the Mediterranean (Cramp, 1985). Their food habits have been widely studied, but there is a wide geographical variation in the prey composition of both species (Bunn *et al*., 1982; Mikkola, 1983; Cramp, 1985; Taylor, 1994). In the drier and warmer Mediterranean, their diet is different than that in middle European communities (Herrera & Hiraldo, 1976). Across the Mediterranean area, both species have been studied in continental areas and islands more than in wetlands where temporal comparative studies are lacking. In Greece both owl species are quite common all year round (Handrinos & Akriotis, 1997) and although a number of studies have been carried out on their diet (see Goutner & Alivizatos, 2003), seasonal dietary trends are known from only one study on the barn owl in mountain Hymettus of Attica (Tsounis & Dimitropoulos, 1992).

The aims of this study were: a) the description and comparison of the diets of the barn owl and little owl in the Evros Delta, b) intra- and interspecific seasonal comparisons of each species diet and c) comparison of the results with those from other areas.

MATERIALS AND METHODS

The Evros Delta (40° 84′ N, 26° 07′ E), is the easternmost Greek wetland protected by the Ramsar

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Convention. It includes a great variety of habitats, such as extensive saltmarshes, sand dunes, mudflats, lagoons, reedbeds, tamarisk and riparian forests, permanent and temporary freshwater marshes and extensive cultivations (Goutner & Kazantzidis, 1989).

Pellets were collected when found at known roosts of the two owl species at least monthly from the winter 2002-2003 to autumn 2004. The pellets were analyzed using reference books (Mammals: Lawrence & Brown, 1973; Chaline, 1974; Birds: Brown *et al*., 1987; Reptiles: Arnold & Burton, 1980; Insects: Chinery, 1981). Mean weight of each prey taxon was taken from the literature: (Mammals: Macdonald & Barrett, 1993; Birds: Perrins, 1987; Reptiles: Helmer & Scholte, 1985). Mice of the genus *Apodemus* were not separated by species due to the impossibility of distinguishing them by cranial characters in the study area (Vohralik & Sofianidou, 1992). Also, mice of the genus *Mus* were identified to species level only in the case of the barn owl, where relatively complete skulls were preserved, but not in the case of the little owl as in its pellets skulls were fragmented. Mean prey weight for each species in each period was estimated by multiplying the numbers of each prey item by its mean weight, adding the weights produced and dividing the sum by the total numbers of prey in each sample.

The diets of each species were analyzed for each field sample in terms of numbers and biomass. Due to low sample size in some visits, owing to the scarcity of pellets, data were compiled by season. For each species and year, samples from March to May were combined as "spring", from June to August as "summer", from September to November as "autumn" and from December to February as "winter".

Median prey biomasses were compared between different seasons within the same species and between species in the same season using box plot analyses and Kruskal-Wallis and Mann-Whitney tests, respectively. To locate interspecies differences among seasons, the Kruskal-Wallis tests were followed by Mann-Whitney tests between pairs of seasonal samples using Bonferroni corrected probability. To investigate seasonal trends in prey use, numerical data on the main prey were tested by contingency tables. For this analysis, prey of little owls was grouped as a) insects, b) mammals, and c) birds + other prey. In this species, tests were also carried out between seasons of different study years. For barn owls, prey was grouped as mammals and birds + other prey. In this species, data for seasonal tests were grouped as spring, summer and autumn to cope with expected values < 5. For testing differences in mammalian prey composition by the barn owl during the study, numerical data were combined as *Crocidura* spp., *Microtus rossiaemeridionalis*, *Mus* spp. and other mammals.

The trophic diversity (NB) of prey was estimated on a class level by using the antilog of the Shannon-Weiner index (Shannon & Weaver, 1963), while an evenness index was calculated (according to Simpson, 1949) in order to standardize the trophic diversity for seasonal comparisons within and between owl species. To compare the prey differentiation between owl species, cluster analysis based on the biomass proportions of all prey classes was performed. The same analysis was performed using only the proportions of mammalian prey of both species to investigate possible patterns in their use. For these analyses, the Primer 5.1.2 software was used with Bray-Curtis similarity as distance measure and group mean as linkage measure.

RESULTS

Barn owl

Pellets of barn owls were not found in the summer periods during the study. The diet of this owl consisted almost exclusively of mammals (10 species, over 97% by number), including only few birds (0.4-3.0% by number) and occasionally amphibians (0.0-1.7%) (Table 1). The main mammal species used were *Mus macedonicus* (21-45%), *Microtus rossiaemeridionalis* (10-46%) and *Crocidura suaveolens* (13-31%). These species were also the most important in terms of biomass in all seasons. Nevertheless the composition of the mammalian diet indicated significant seasonal changes through the study ($\chi^2 = 130.17$, df = 18, $p < 0.001$, Table 1). Anyway, on the level of most important prey types, the composition of the barn owl was uniform during the course of the study without significant seasonal trends ($\chi^2 = 0.499$, df = 2, $p > 0.05$).

Mean prey biomass ranged from 11.5 g (autumn 2003) to 16.1 g (autumn 2004). The median prey biomass differed significantly among the six seasonal samples (Kruskal-Wallis H = 84.78, df = 5, $p < 0.001$) because of a significantly higher median value in autumn 2004, while there were no differences between other seasons (Fig. 1). Both prey diversity and evenness were low (0.010-0.063 and 0.034-0.196, respectively). Prey diversity was highest in spring 2004, but evenness was highest in winter 2002-2003 (Table 1).

TABLE 1. Seasonal diet of the barn owl in the Evros Delta in % numbers (N) and % biomass (B), from winter 2002-2003 to autumn 2004

	Winter 2002-2003		Spring 2003		Autumn 2003		Winter 2003-2004		Spring 2004		Autumn 2004	
Prey	N	B	N	B	N	B	N	B	N	B	N	B
AMPHIBIA	–	–	1.7	3.6	–	–	–	–	–	–	–	–
AVES	3.0	9.7	1.1	3.6	1.8	4.8	0.4	1.7	1.1	0.5	0.7	1.6
MAMMALIA	97.0	90.3	97.2	92.7	98.2	95.2	99.6	98.3	98.9	99.5	99.3	98.4
Neomys anomalus	7.0	4.6	8.4	6.1	4.1	3.6	0.4	0.2	–	–	–	–
Crocidura leucodon	3.0	1.6	6.1	3.6	5.9	4.1	–	–	8.6	4.8	–	–
Crocidura suaveolens	14.6	5.5	26.5	11.6	30.5	15.9	18.9	7.7	17.2	7.2	12.7	4.7
Suncus etruscus	–	–	0.5	0.1	0.3	0.1	0.7	0.1	–	–	–	–
Microtus guentheri	3.0	11.9	–	–	–	–	1.4	5.8	–	–	–	–
Microtus rossiaemeridionalis	23.7	29.0	31.1	45.3	10.1	17.5	29.8	40.8	43.0	59.9	46.3	57.4
Microtus guentheri	–	–	–	–	–	–	0.4	0.7	–	–	–	–
Apodemus spp.	1.0	1.3	3.6	5.7	5.0	8.7	4.3	5.8	4.3	6.0	12.7	15.7
Rattus rattus	–	–	0.5	2.3	0.3	1.5	0.4	1.5	–	–	–	–
Mus macedonicus	44.6	36.4	20.6	18.0	42.0	43.8	43.3	35.6	25.8	21.6	27.6	20.5
Total number of prey	99	–	181	–	338	–	281	–	934	–	134	–
Prey diversity	0.059		0.063		0.039		0.010		0.026		0.019	
Evenness	0.196		0.132		0.129		0.034		0.086		0.063	

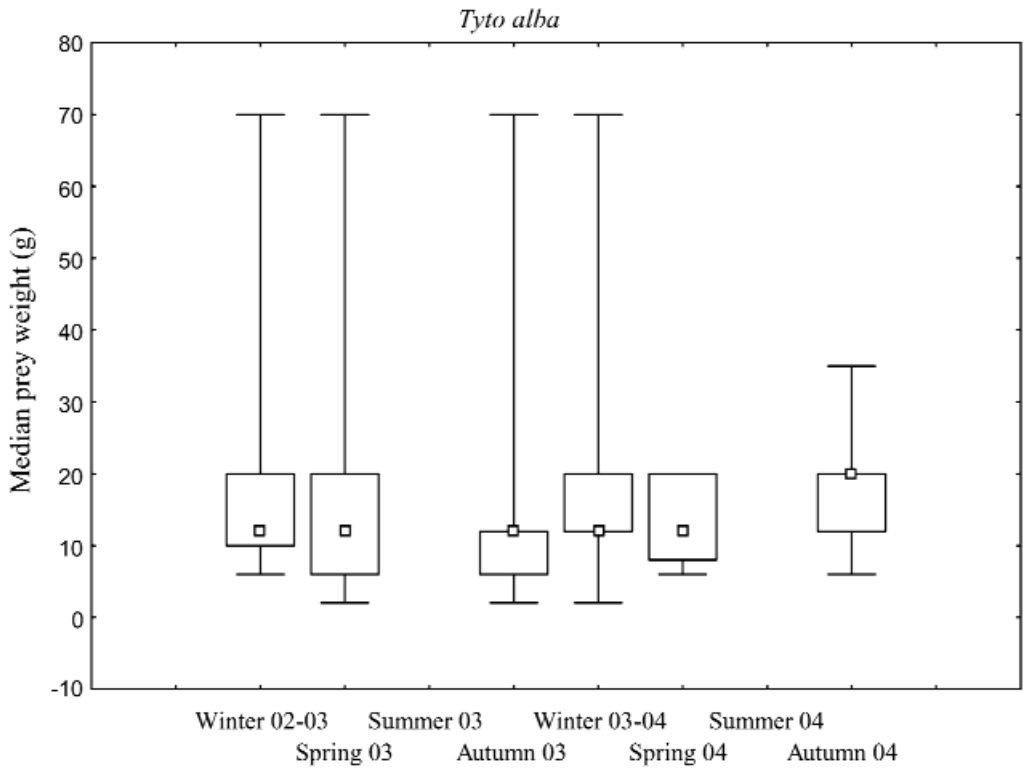

FIG. 1. Boxplots indicating seasonal median prey weights of the barn owl in the Evros Delta from 2002 to 2004. Small square: median; box: 25-75% of values; line: minimum and maximum. The gaps in summer data denote that no pellets were found.

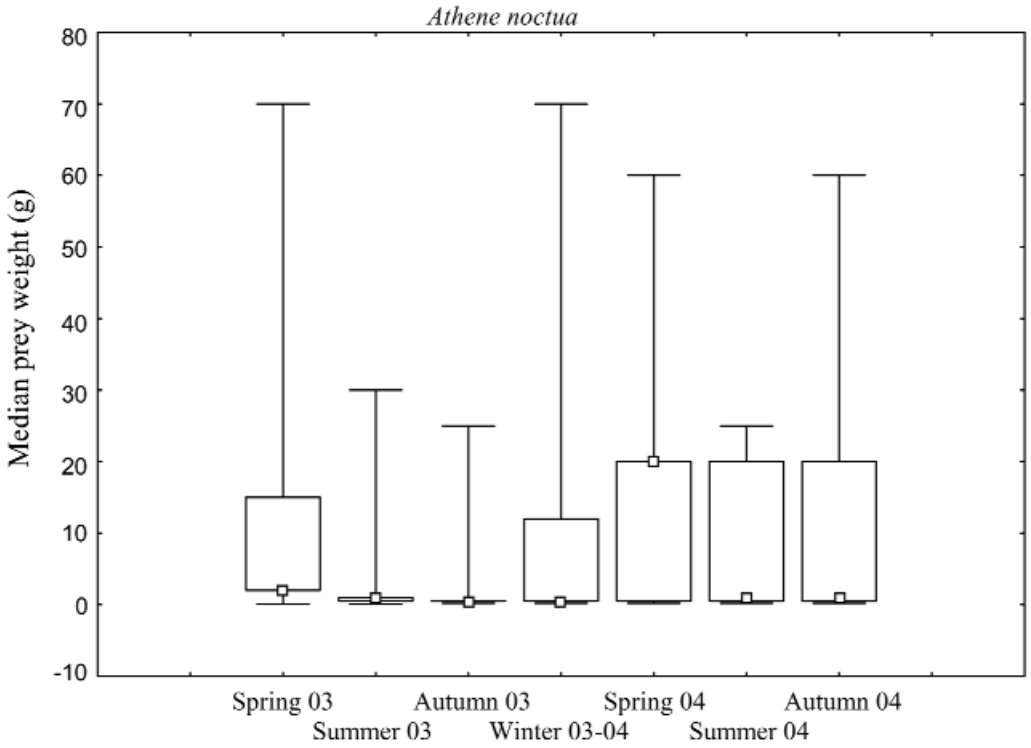

FIG. 2. Boxplots indicating seasonal median prey weights of the little owl in the Evros Delta from 2003 to 2004. Small square: median; box: 25-75% of values; line: minimum and maximum.

TABLE 2. Seasonal diet of the little owl in % numbers (N) and % biomass (B), in the Evros Delta from spring 2003 to autumn 2004

	Spring 2003		Summer 2003		Autumn 2003		Winter 2003-2004		Spring 2004		Summer 2004		Autumn 2004	
Prey	N	B	N	B	N	B	N	B	N	B	N	B	N	B
MOLLUSCA	0.3	< 0.1	–	–	–	–	–	–	–	–	–	–	–	–
ARACHNIDA	–	–	–	–	–	–	0.3	< 0.1	–	–	0.6	< 0.1	–	–
DIPLOPODA	–	–	–	–	–	–	0.6	0.1	–	–	–	–	–	–
CHILOPODA	–	–	1.9	0.6	0.8	0.7	–	–	2.1	0.2	0.6	0.2	–	–
INSECTA	59.3	11.2	81.2	19.1	85.5	19.6	54.5	3.6	30.8	1.3	62.5	5.7	57.0	4.8
Odonata	–	–	0.3	0.1	–	–	–	–	–	–	–	–	0.4	0.1
Orthoptera	2.6	0.2	33.1	10.9	4.4	1.7	6.7	0.5	2.1	0.2	22.7	3.1	19.7	1.7
Mantodea	0.6	0.1	0.3	0.1	2.5	1.1	1.2	0.1	–	–	–	–	6.1	0.8
Dermaptera	5.8	0.3	31.2	3.8	20.5	3.3	5.3	0.3	3.7	< 0.1	21.5	1.0	16.2	0.7
Coleoptera	49.0	10.5	15.3	4.2	24.8	5.6	40.1	2.6	23.0	1.0	18.4	1.6	14.0	1.6
Diptera	–	–	–	–	–	–	1.2	0.1	–	–	0.3	< 0.1	–	–
Lepidoptera	–	–	–	–	34.4	7.8	–	–	2.8	0.1	–	–	–	–
Hymenoptera	1.3	< 0.1	0.6	< 0.1	–	–	–	–	–	–	–	–	–	–
AMPHIBIA	–	–	0.3	3.1	–	–	–	–	–	–	–	–	–	–
REPTILIA	–	–	0.3	0.4	–	–	–	–	0.3	0.1	–	–	–	–
AVES	3.8	14.1	1.6	13.1	2.7	26.1	6.7	25.5	3.1	6.0	0.9	2.7	1.3	4.1
MAMMALIA	36.5	74.9	14.6	63.6	11.4	53.6	37.7	70.7	58.1	92.3	35.3	91.2	41.7	91.0
Crocidura leucodon	–	–	–	–	0.2	0.7	–	–	0.7	0.5	–	–	–	–
Crocidura suaveolens	4.5	3.4	3.8	7.5	3.1	8.4	4.7	3.5	0.7	0.4	1.8	1.6	2.2	1.7
Suncus etruscus	–	–	0.3	0.2	–	–	–	–	–	–	–	–	–	–
Pipistrellus spp.	0.3	0.3	0.3	0.7	1.0	3.0	–	–	–	–	–	–	0.4	0.4
Arvicola terrestris	0.3	2.4	–	–	–	–	–	–	0.3	1.8	–	–	–	–
Microtus rossiaemeridionalis	19.2	48.9	5.7	37.6	0.8	7.0	16.7	41.8	42.5	73.7	25.7	74.8	24.6	61.8
Apodemus spp.	0.6	1.6	–	–	–	–	0.6	1.5	2.1	3.6	0.9	2.6	2.6	6.6
Rattus sp.	–	–	–	–	–	–	–	–	–	–	–	–	0.4	3.3
Mus spp.	9.9	15.2	4.5	17.6	6.4	34.5	15.2	22.9	11.8	12.3	6.9	12.1	11.4	17.2
Rodentia indetermined	1.6	3.1	–	–	–	–	0.6	1.1	–	–	–	–	–	–
Total number of prey	312	–	314	–	517	–	341	–	263	–	331	–	228	–
Prey diversity	0.360		0.270		0.230		0.410		0.380		0.330		0.320	
Evenness	0.590		0.350		0.370		0.580		0.550		0.480		0.680	

Little owl

Little owls preyed mainly on insects and small mammals, and in much lower proportions, on birds, reptiles, amphibians, various arthropods and molluscs (Table 2). Insects were the most numerous prey type (31-86% by number), followed by mammals (11-58%). The insects most frequently found were Coleoptera (14-49%), Orthoptera (3-33%) and Dermaptera (4-31%), although in one sample (autumn 2003) Lepidoptera (larvae) reached 34%. Mammalian prey was represented by at least nine species, with *Microtus rossiaemeridionalis* (6-42%) and *Mus* spp. (5-15%) being the most numerous. In terms of biomass, mammals were the most important prey in all samples (54-92%), while birds (mostly small passerines) were more important than insects (3-26% *vs.* 1-20%).

Mean prey biomass ranged from 2.2 g (autumn 2003) to 12.2 g (spring 2004). The median prey biomasses were significantly different among the seven seasonal samples (Kruskal-Wallis $H = 350.74$, $df = 6$, $p < 0.001$), due to an outstanding increase in spring 2004, but not differing between pairs of other seasons (Fig. 2). The trends of the main prey groups presented significant seasonal differences ($\chi^2 = 320.63$, $df = 12$, $p < 0.001$, Fig. 3). Insect number proportions increased from spring to autumn in each year and mammals generally dropped. Also, the differences between seasons of the study years were highly significant (χ^2 tests, $p < 0.001$ in all three comparisons). Numerical changes were inconsistent with the respective biomass changes.

Both prey diversity and evenness were low (0.23-0.41 and 0.35-0.68 respectively, Table 2). Diversity was highest in winter 2003-2004, while evenness in autumn 2003.

Dietary comparisons between owl species

Mammalian prey was used more extensively by barn owls than little owls whereas in the latter, insects were numerically most important. Regarding mammalian prey, both owls preyed mainly on *Microtus* and *Mus*, while, for barn owls, species of the genus *Crocidura* were more important. Both prey diversity and evenness were higher in the case of the little owl (Tables 1 and 2).

Prey biomass was significantly different between the two species in the seasons where both were represented in the samples (Mann-Whitney tests, $p < 0.001$), except in spring 2004. A cluster analysis of percent biomasses revealed that from spring 2003 to winter 2003-2004 the little owl prey samples clustered separately from the rest of the samples (top cluster, Fig. 4). In the latter group, little owl samples generally differentiated from those of the barn owl. The barn owl samples from winter 2002-2003 to autumn 2003 clustered separately from those from winter 2003-

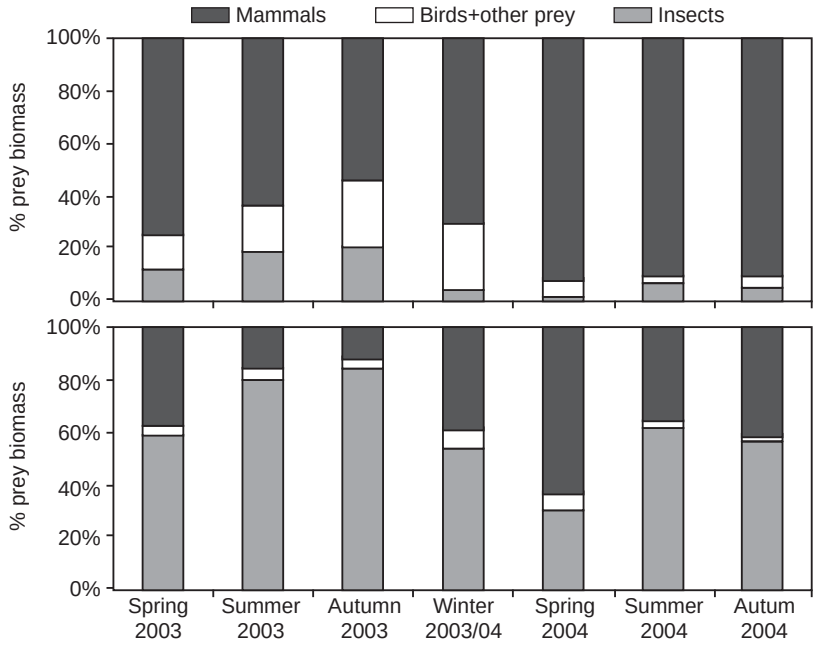

FIG. 3. Temporal changes in the main prey use of the little owl in the Evros Delta during the study.

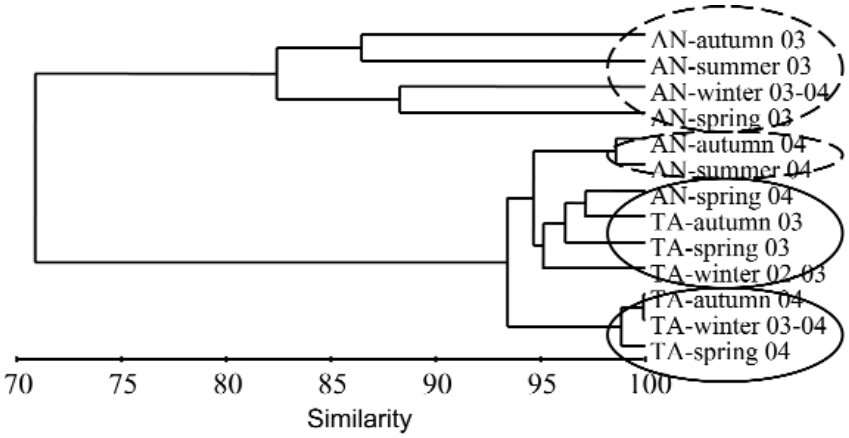

FIG. 4. Cluster analysis of percent biomass of prey of the little owl and barn owl in the Evros Delta. AN: *A. noctua*; TA: *T. alba*. Circles indicate groups of seasonal prey use by the different owl species.

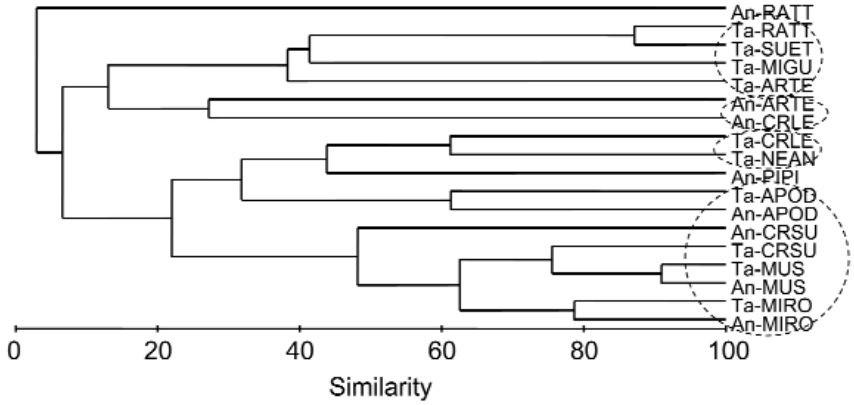

FIG. 5. Cluster analysis of seasonal percent numbers of mammalian prey of little owl and barn owl in the Evros Delta. Circles indicate groups of similarities in the use of different mammal species. An: *A. noctua*; Ta: *T. alba*; RATT: *Rattus* sp.; SUET: *Suncus etruscus*; MIGU: *Microtus guentheri*; ARTE: *Arvicola terrestris*; CRLE: *Crocidura leucodon*; NEAN: *Neomys anomalus*; PIPI: *Pipistrellus* spp.; APOD: *Apodemus* spp., CRSU: *Crocidura suaveolens*; MUS: *Mus* spp.; MIRO: *Microtus rossiaemeridionalis*.

2004 to autumn 2004. Thus, this analysis revealed a yearly prey biomass differentiation that was stronger in the little owl.

A cluster analysis of percent mammal prey use, revealed joint patterns for both owl species with regard to *Microtus rossiaemeridionalis*, *Mus* spp., *Apodemus* spp. and probably *Crocidura suaveolens* (Fig. 5). Some other clusters associated mammal prey use with one of the owl species: in one, *Arvicola terrestris* and *Crocidura leucodon* were associated only with the little owl. In another, *Neomys anomalus* and *Crocidura leucodon* were associated only with the barn owl and in another, *Rattus* sp., *Suncus etruscus*, *Microtus guentheri* and *Arvicola terrestris* were associated only with the barn owl (top of the cluster). The respective cluster analysis differentiated groups of mammalian prey use by the same species suggesting different seasonal prey activity.

DISCUSSION

Seasonal variation in the owls' diet

Although the main prey type of the barn owl was mammals, significant seasonal variation in the composition of this prey was found. Some other studies have also found seasonal variation in the diet of this species (e.g. Campbell *et al*., 1987; Tsounis & Dimitropoulos, 1992; Taylor, 1994; Goutner & Alivizatos, 2003), while in others the situation was unclear (e.g. Smith *et al*., 1972; Parker, 1988). Variations have been attributed to seasonal and yearly differences in availability and behavioural changes of mammalian prey (Webster, 1973; Brown, 1981; Goszczynski, 1981; Taylor, 1994). The differentiation in prey biomass use by each species in different years may also be due to yearly changes in prey availability; however appropriate data are lacking to support this assumption.

Regarding the little owl, its diet also showed significant seasonal and yearly variation. Other studies have also reported seasonal variation in the diet of this species (Zerunian *et al*., 1982; Mikkola, 1983; Cramp, 1985; Goutner & Alivizatos, 2003). These changes mostly reflect the increasing availability of insects during the warmer months of the year.

Interspecific variation in prey use

In the Evros Delta, the diet composition of the two owl species differed in that the little owl seized large numbers of invertebrates, so accordingly, the median prey weight of this species was significantly lower than that of the barn owl. Prey diversity and evenness was also higher in the former species. Other studies have also shown that the little owl often feeds largely on invertebrates (Bunn *et al*., 1982; Capizzi & Luiselli, 1995; Hounsome *et al*., 2004), which are only infrequently taken by the barn owl. Since mammals are the most important prey of both owl species in terms of biomass, a considerable overlap was noticed in this type of diet. Such an overlap has also been reported in other studies in assemblages where the two species coexist in the Mediterranean region (Herrera & Hiraldo, 1976; Delibes *et al*., 1984; Gotta & Pigozzi, 1997; Goutner & Alivizatos, 2003), but not in other parts of Europe (Mikkola, 1983; Cramp, 1985; Jaksic, 1988).

Regarding the dietary differences between the owl species, they are partly due to different morphological adaptations, hunting techniques and digestive efficiency of the two species (Bunn *et al*., 1982), as for example in the hovering capability of the little owl that facilitates insect capture. The seasonal differentiation between species may be due to their different energetic demands. Another difference in prey composition may arise due to the different activity patterns of these owls; the little owl is partly diurnal in contrast to the barn owl, which is nocturnal. Activity patterns also concern prey, thus affecting owls' prey use and capture success. Hence, in our area, the association revealed in the respective cluster analysis between *Crocidura suaveolens*, *Arvicola terrestris* and the little owl may be due to that both mammal species, especially the latter, are largely diurnal (Macdonald & Barrett, 1993). In contrast, mammalian prey, found to be associated with the barn owl, mainly have nocturnal habits. The similarity found in the use of species such as *Microtus rossiaemeridionalis*, *Mus* spp. and *Apodemus* spp. is probably due to the greater availability of these prey types, supported by the fact that these were the most abundant mammalian prey in the diet of both species.

Additionally, factors that affect the foraging activity of the barn owl by affecting the behaviour of their mammalian prey include moon phases, extreme weather conditions, and the presence of electric power lines that cause accidents to owls (Álvarez-Castañeda *et al*., 2004).

Comparisons with other studies

The number of mammalian species in the diet of the barn owl in this study is similar to those found in other studies, although the mean biomass (11.5-16.1 g) is among the lowest of those reported for this species (12.8-25.0 g) (Taylor, 1994; Pardiñas *et al*., 2005). In some areas, this has been attributed to a high proportion of shrews in the diet (Goszczynski, 1981; Bunn *et al*., 1982; Taylor, 1994) as is also the case for the Evros Delta. Higher mean biomass values were noticed where rats, gerbils and/or relatively large birds are taken (summarized in Goutner & Alivizatos, 2003).

In Greece, although barn owls are mainly small mammal predators, their main prey composition varies spatially and temporally. Thus, the composition of mammalian diet differs both between summer and winter and among wetlands of northeastern Greece, reflecting geographical particularities in prey composition (Goutner & Alivizatos, 2003). Differences in habitat structure, resulting in differences in prey availability and abundance in various mainland and island areas of Greece were reflected in differences in

barn owl diet (Alivizatos *et al*., 2005; Bontzorlos *et al*., 2005). Geographical particularities, suggesting that this species exploits prey opportunistically, probably according to local availability, are not unknown as in the case of the island of Crete where 11 species of bats were found in the barn owl's diet (Pieper, 1976).

The mammalian prey composition of the little owl in the Evros Delta ranged from 11.4 to 58.1% by numbers, with a mean for the whole study period of 30.4%. The numerically most important prey of the little owl in most Mediterranean countries (summarized in Goutner & Alivizatos, 2003) and elsewhere in Europe (summarized in Cramp, 1985) consists of invertebrates. In Greece, compared with the barn owl, information on the diet of little owls is relatively scarce. In island areas the dominant prey are insects whereas in most northeastern Greek wetlands small mammals are most important (Alivizatos *et al*., 2005). In certain areas, small mammals (particularly rodents) also form a considerably higher proportion of the diet (Moldavia 51.1%, Mikkola, 1983; Egypt 57.1%, Goodman, 1988; Sicily 16.4%, Lo Verde & Massa, 1988). A diet rich in mammals is more favourable than one dominated by insects and this may have considerable consequences for the biology of these populations, needing further investigation. The diet of little owl varies worldwide according to habitat, location and season also revealing particularities in the prey types used (Obuch & Krištín, 2004). Differences rather reflect opportunistic use than selection of prey (Jaksic & Marti, 1981; Zerunian *et al*., 1982).

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