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Foraging habitat selection and differentiation among coexisting raptors across an estuarine landscape (Evros Delta, northern Greece)

Ekaterini Bobola[a], Vassilis Goutner[a], Vasilios Liordos[b,*]

[a] Department of Zoology, School of Biology, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece
[b] Department of Forestry & Natural Environment Management, Eastern Macedonia & Thrace Institute of Technology, P.O. Box 172, 66100, Drama, Greece

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ABSTRACT

Knowledge of habitat preferences is critical for understanding the needs of and interactions among sympatric avian species and for implementing successful management and conservation projects. The common buzzard, western marsh harrier, hen harrier and black kite are the commonest raptors of Greece during the non-breeding season. Therefore, the availability, use and selection of cover types by these foraging raptors were recorded in the Evros Delta, Greece, along a 40-km x 1-km road transect, using the road transect method. A total of 14 surveys (2–4 a month) were conducted during the non-breeding season, from November 2002 to March 2003. Eight cover types were identified within the transect, with agricultural land being the most abundant, followed by saltmarshes, freshwater marshes and lagoons. Each raptor species was more likely to use one or more cover types more than expected and other types less than expected. Overlap in cover type use was higher between common buzzards, western marsh harriers and black kites, and lower between these species and hen harriers. Common buzzards more strongly selected freshwater marshes, rivers and canals, grassland and reedbeds as foraging habitats. Foraging western marsh harriers more strongly selected reedbeds, freshwater marshes and saltpans, hen harriers mostly preferred grassland and saltmarshes, whereas black kites showed a strong selection for rivers and canals, freshwater marshes and reedbeds. Analysis revealed preferences, similarities and differences in habitat use and selection among four diurnal medium-sized raptors across the Evros Delta. Particularities in habitat preferences by raptors suggested that they were adapted to the available features in this area. This study provided important information on the foraging behavior of raptor species that could help assess the importance of certain sites and habitats and improve management strategies to benefit birds.

1. Introduction

Habitat is defined as a distinctive set of physical environmental factors that a species uses for its survival and reproduction (Block and Brennan, 1993). Habitat use is the way in which an individual or species uses habitats to meet its life history needs, whereas habitat selection refers to a hierarchical process of behavioral responses that may result in the disproportionate use of habitats to influence survival and fitness of individuals (Block and Brennan, 1993; Hutto, 1985). Habitat use patterns represent the actual distribution of individuals across habitat types, being the end result of habitat selection processes (Jones, 2001). Habitat selection by animals is an important determinant of survival and fitness and understanding the patterns of habitat use is necessary for the formulation of effective habitat management plans and habitat suitability indices (Garshelis, 2000). Knowledge of how interacting species differentiate habitat use may also be critical for the understanding of the coexistence of sympatric species (Pita et al., 2011).

Foraging of diurnal raptors is assumed to be guided mainly by vision (Potier et al., 2016) and foraging theory predicts that it is not prey abundance but prey availability that determines where predators hunt (Stephens and Krebs, 1986). Overskaug et al. (1997) found that fat accumulation in raptors was higher in winter than in summer, a strategy probably adopted to increase survival during harsh conditions in the non-breeding season and, especially for females, to cope with the high energy demands of breeding. Therefore, knowledge and conservation of habitats used during non-breeding seasons may be critical for securing the complexity of food webs (Begon et al., 2006).

Wetlands are critical habitats for the fulfillment of the foraging, resting and breeding requirements of many avian species. Despite their importance, almost half of the world's natural wetlands have disappeared in the last century due to anthropogenic activities, while the

* Corresponding author.
E-mail address: liordos@teiemt.gr (V. Liordos).

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other half have been variously affected (Shine and Klemm, 1999). The high biological diversity of wetlands, combined with the threats they are facing, have rendered their protection and restoration a major conservation priority (Keddy, 2010).

One of the major causes of alteration is the conversion of wetlands to agricultural land. This conversion and the subsequent agricultural intensification have been linked to decreases in biodiversity and abundance of several avian species (Tucker and Heath, 1994). Conversely, some bird species have benefited from creation of new foraging or breeding habitat in managed lands, such as artificial ponds and irrigated crops that replaced natural wetlands (Moreno-Mateos et al., 2009; Sebastián-González et al., 2010). Estuaries are large, flat and fertile areas that have long been inhabited and cultivated by humans, and include a high diversity of habitats, both natural and those modified by humans. As such, they represent favorable foraging grounds for certain raptors, offering conditions conducive to detecting and capturing diverse prey, including birds, insects, rodents, reptiles and amphibians (Bildstein, 2017).

As knowledge of habitat use, selection and niche overlap by animals is necessary for their effective conservation, numerous studies have been carried out for European populations of diurnal raptors associated with open habitats (e.g. Alves et al., 2014; Arroyo et al., 2009; Baltag et al., 2013; Rodríguez et al., 2010; Tanferna et al., 2013). However, most of these studies concerned single raptor species, lagoon and estuaries were underrepresented, whereas none of these concerned Greek ecosystems. Here we present the first description and analysis of foraging patterns by the four commonest diurnal medium-sized raptors, the common buzzard *Buteo buteo*, western marsh harrier *Circus aeruginosus*, hen harrier *Circus cyaneus* and black kite *Milvus migrans migrans* found in the Evros Delta, a major estuary in Greece, during the non-breeding season. More specifically, a) measured habitat availability, recorded foraging habitat use and estimated habitat selection by each species, and b) examined how the use of habitats differed among species in a mosaic of cover types across an estuarine landscape.

2. Materials and methods

2.1. Study area

The Evros Delta (Fig. 1) at the Greece-Turkey border (40°27′-40°38′N, 22°33′-22°52′E) is an extensive area (190 km^2) that has been designated as a National Park, a Ramsar site and an important bird area due to its ornithological importance. Agricultural land is the predominating habitat, occupying most of the upper half of the delta (Goutner and Kazantzidis, 1989). Wheat is the major crop in the area, other crops including sweet corn, cotton, barley, rye, oats, alfalfa and potatoes (Zalidis and Mantzavelas, 1994). Freshwater marshes, saltmarshes and lagoons are the main natural features of the delta. Natural grasslands, grazed by cattle, are dispersed in the delta. Saltpans are human-modified habitats found at the lower half of the delta, close to the lagoons.

The common buzzard, western marsh harrier, hen harrier and black kite are the most common raptors in Greece during the non-breeding season, with considerable populations in the Evros Delta (Hellenic Ornithological Society, 1994). The common buzzard is the commonest and most widespread medium-sized raptor, with approximately 5000 pairs nesting in Greece. Also being the commonest in the Evros Delta during the non-breeding season, it disperses to forested habitats to breed. Approximately 80 marsh harrier pairs breed in Greece, a few of which in Evros, with population influxes during winter and migration periods (Goutner and Kazantzidis, 1989). Hen harriers occur in the delta as winter visitors and migrants, being more common in winter and spring. Black kites are rare but resident in Greece, where approximately 10–30 pairs breed, with two or three pairs known to nest along riparian woodland in the Evros region. During the non-breeding season birds from distant populations also use the delta (Literák et al., 2017). Other medium-sized raptors, including the red kite *Milvus milvus*, honey buzzard *Pernis apivorus* and long-legged buzzard *Buteo rufinus*, are rare occurrences in the Evros Delta, mainly during spring and autumn migration.

2.2. Data collection

We conducted 14 surveys (2–4 a month; Table 1) during the non-breeding season, from November 2002 to March 2003, and data were collected using the road transect method (Ellis et al., 1990; Herremans and Herremans-Tonnoeyr, 2000; Meunier et al., 2000). This method is appropriate for the collection of accurate and precise data in all seasons, in large areas of open vegetation and for conspicuous species (Fuller and Mosher, 1981; Millsap and LeFranc, 1988). Three persons participated in each survey; the observer, a driver and a data recorder. Surveys were carried out from a car, at 20–25 kmph, along a 40-km route on the main accessible road, from which all deltaic habitats could be sampled (Fig. 1). The direction of driving was alternated in successive visits to eliminate potential bias in visibility from one side of the route to the other (Meunier et al., 2000). Preliminary investigations did not suggest differences between time of day and number of individuals or habitat use for any of the four studied species. Meunier et al. (2000) also did not find a time effect in numbers or habitat use for common buzzards and black kites. Surveys started between 9.00 and 11.00 h, took c. 120 min and were performed by the same person (E. Bobola) to eliminate variation among investigators. During the surveys, an area 500-m-wide on each side of the road (a total of 40 km^2) was scanned using 10 × 50 binoculars. Any raptor seen was identified and its foraging behavior was recorded in three classes, adapted from Masman et al. (1988): (1) perching, (2) walking or alighting on the ground, (3) flight-hunting. Any of these behaviors was recording as foraging only when resulted to strikes or attacks on prey. Soaring or high flights were not considered hunting attempts (Garner and Bednarz, 2000). The foraging behavior, habitat and position of each bird, visually estimated with the help of permanent features, were recorded on a 1:30000 map. Field data were used together with orthorectified Landsat 7 ETM+, acquired from the global land cover facility (GLCF) website, and Google Earth images (Fig. 1) to confirm the accuracy of habitat estimation.

Pellets were collected from roosts of common buzzards and black kites and analyzed to evaluate potential association of diet composition with the raptors' foraging habitats (see Goutner and Alivizatos, 2003 for methods). Relative information on the diet of the western marsh harrier was available from Alivizatos et al. (2011) based on material collected in the winter of 2005.

Eight cover types were identified (Table 2) and their availability was measured on orthorectified Landsat 7 ETM + images with the help of field data. The tidal range in Greece is small (c. 0.4 m; ESEAS: European Sea Level Service) and visual comparison of satellite images from 2002 to 2003 did not allow for the detection of any substantial changes in the extents of the 8 habitat classes. Furthermore, changes due to precipitation (e.g. temporary ponds) were not traceable on satellite images. Habitat measurements are considered therefore suitable for use throughout the study period.

2.3. Statistical analysis

Habitat selection was studied by comparing the use and availability of each habitat class, using the selection ratio (Manly et al., 2002). For design I studies (the animals are not identified; the habitat use and availability are measured at the scale of the population), this approach is implemented by the function *widesI* of the *adehabitatHS* R package (Calenge, 2006, 2015). This function allows for testing two levels of habitat selection by each species. First, the function determined whether raptors used all the available habitats randomly with an overall test statistic (log-likelihood χ^2). Second, selection ratios were computed for each habitat and the differences between selection ratios were tested

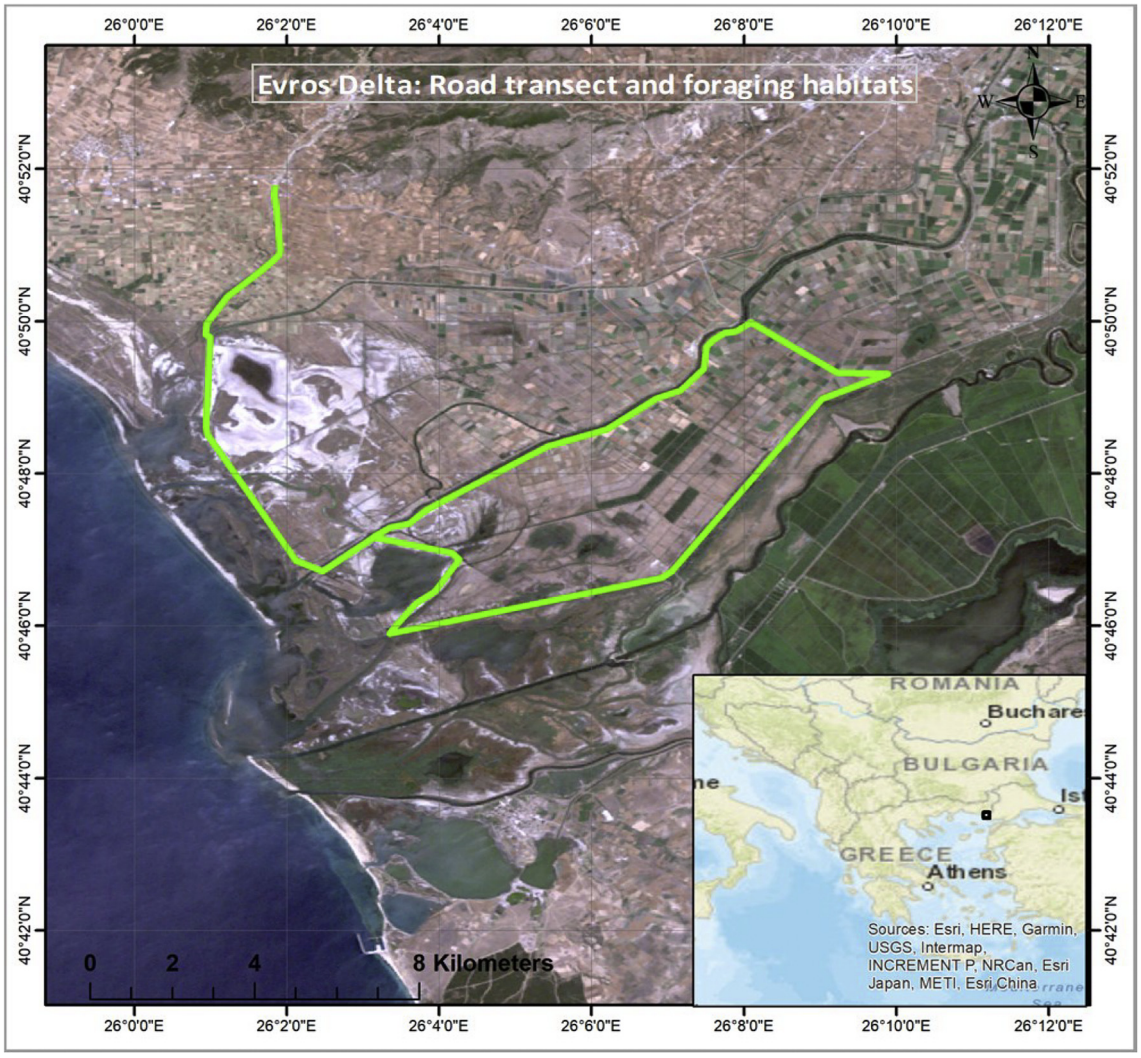

Fig. 1. Road transect used for studying diurnal raptors in the Evros Delta, Greece (40-km-long green line). Landsat TM satellite image (acquired on 26/6/2002 and downloaded from the USGS). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Monthly breakdown of foraging observations (N) of four diurnal raptors in the Evros Delta, Greece, during the non-breeding season.

Month	Mumber of surveys	Common buzzard		Western marsh harrier		Hen harrier		Black kite	
		N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
November	3	35	11.7 ± 0.9	67	22.3 ± 1.8	14	4.7 ± 0.7	6	2.0 ± 0.6
December	4	116	29.0 ± 2.3	135	33.8 ± 6.3	12	3.0 ± 0.6	10	2.5 ± 0.9
January	2	44	22.0 ± 4.0	83	41.5 ± 4.5	10	5.0 ± 1.0	11	5.5 ± 0.5
February	2	70	35.0 ± 4.0	60	30.0 ± 3.0	4	2.0 ± 1.0	9	4.5 ± 1.5
March	3	150	50.0 ± 11.5	137	45.7 ± 8.5	26	8.7 ± 2.3	31	10.3 ± 6.8
Total	14	415	29.6 ± 4.3	482	34.4 ± 3.3	66	4.7 ± 0.8	67	4.8 ± 1.5

with pairwise Bonferroni tests. This allowed for the ranking of the relative selection of habitats by each raptor species.

Overlap (O) in habitat use between raptor species was calculated using Pianka's niche overlap index (Pianka, 1974). Overlap indices were computed by the *piankabio* function and the 95% Confidence Intervals (CI) of estimates were assessed using 1000 permutations by the *piankabioboot* function of the *pgirmess* R package (Giraudoux, 2017). Habitat differentiation was further explored by comparing the use of each habitat between species using pairwise two-tailed t-tests (Zar, 1999). After applying the Bonferroni correction for multiple comparisons, t-tests with $p < 0.0083$ were considered significant. This enabled the ranking of species by use within each habitat.

Analyses were performed in program R 3.4.1 (R Development Core Team, 2017). Significance level was set at $\alpha = 0.05$, unless otherwise stated.

3. Results

3.1. Foraging observations

Raptor numbers. The number of foraging individuals was higher during spring migration in March for all four species (Table 1). The interaction of month with cover type use was not significant in all four species (factorial ANOVAs, $F < 2.07$, $p > 0.10$). Monthly foraging

Table 2
Cover types identified in habitat mapping to study foraging habitat selection and differentiation among four coexisting diurnal raptors in the Evros Delta, Greece, during the non-breeding season.

Cover type	Description
Agricultural land	Ploughed and cultivated land, extended mainly over the "upper" delta that is the area not affected by underground salinity
Freshwater marshes	Wet areas surrounding freshwater bodies, periodically flooded and covered mainly with grasses and sedges
Rivers and canals	River bodies and irrigation canals, running through the delta
Grassland	Extensive open areas at the upper and lower delta, covered with herbaceous vegetation and used as grazing land for cattle
Reedbeds	Tall riparian herbaceous vegetation, mainly composed by *Phragmites* sp. and/or *Thypha* sp., being particularly extensive at the fringes of some fresh or brackish water bodies
Saltpans	Limited, seasonally flooded, saline and vegetation-free areas, extending at some parts of the lower delta, near the sea
Lagoons	Areas of the lower delta where the sea penetrates to land from narrow openings, used as extensive fishponds and non-hunting reserves
Saltmarshes	Areas dominated by halophytes, bordering coastal areas and lagoons, directly affected by seawater through tidal flooding

observations were therefore pooled together for subsequent analyses.

Foraging techniques. Most common buzzards were observed using a perch to locate prey (60.0%), followed by flight-hunting (37.6%) and other activities (2.4%; including walking on the ground and feeding) ($\chi^2_2 = 209.8$, $p < 0.001$). On the other hand western marsh harriers, hen harriers and black kites were observed flight-hunting (85.6%, 87.9%, and 82.1%), and to a lesser degree hunting from a perch (12.6%, 7.6%, and 17.9%) or other (1.7%, 4.5%, not observed for black kites) activities ($\chi^2_2 > 27.6$, $p < 0.001$; all comparisons).

Cover type availability and use. Agricultural land was the most abundant cover type of the study area, followed by saltwater marshes, freshwater marshes and lagoons (Fig. 2). Common buzzards most often foraged on freshwater marshes, agricultural land and saltmarshes. Western marsh harriers were mostly seen on freshwater marshes and saltmarshes. Hen harriers used mostly saltmarshes, grassland and agricultural land. Black kites mostly foraged on freshwater marshes and agricultural land.

Raptor diet. The analysis of pellet contents revealed that the diet of common buzzards, western marsh harriers and black kites mostly consisted birds and mammals, both by numbers and biomass (Table 3). The contribution of waterbird prey was high in the diet of western marsh harriers.

3.2. Habitat selection

Non-random use. The analysis of selection ratios showed non-random use of foraging cover types by common buzzards (log-likelihood $\chi^2 = 160.9$, $p < 0.001$), western marsh harriers, (log-likelihood $\chi^2 = 298.2$, $p < 0.001$), hen harriers (log-likelihood $\chi^2 = 31.4$, $p < 0.001$) and black kites (log-likelihood $\chi^2 = 66.4$, $p < 0.001$).

Cover type selection. Relative to availability, the most preferred cover type for common buzzards was freshwater marshes, followed by rivers and canals, grassland and reedbeds (Fig. 2, Table 4, online Supplementary Material Table S1). Saltmarshes and lagoons were used far less than was available. Foraging western marsh harriers more strongly selected reedbeds, freshwater marshes and saltpans, while they avoided saltmarshes, lagoons and to a higher degree agricultural land. Grassland was the most preferred foraging cover type by hen harriers, followed by saltmarshes, whereas other habitats were undesirable, more so agricultural land and reedbeds. Black kites showed a strong selection for

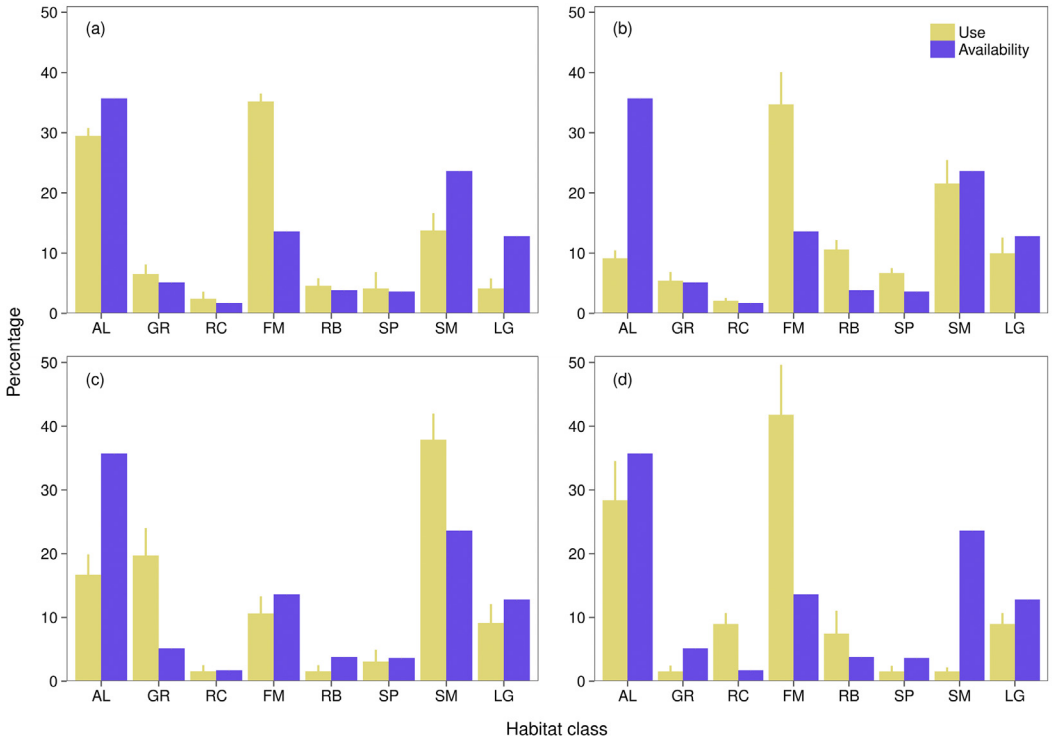

Fig. 2. Comparison of mean foraging cover type use (+1 SE) and availability by (a) common buzzard, (b) western marsh harrier, (c) hen harrier and (d) black kite in the Evros Delta, Greece, during the non-breeding season. AL: agricultural land; GR: grassland; RC: rivers and canals; FM: freshwater marshes: RB: reedbeds; SP: saltpans; SM: saltmarshes; LG: lagoons.

Table 3
Percent relative abundance by numbers and biomass of the prey found in the pellets of diurnal raptors in the Evros Delta, Greece, during the non-breeding season.

Prey taxa	Commom buzzard		Western marsh harrier[a]		Black kite	
	% numbers	% biomass	% numbers	% biomass	% numbers	% biomass
Aves	42.5	83.4(13.0[b])	27.7	63.2(44.1[b])	51.3	81.5(4.5[b])
Mammalia	23.7	9.4	66.6	36.6	31.6	15.9
Reptilia	2.5	6.3	–	–	1.3	2.2
Insecta	31.3	0.9	5.7	0.2	15.8	0.4
Total prey numbers	80		141		76	

[a] Data from Alivizatos et al. (2011).
[b] Numbers in parentheses indicate percentage of waterbird prey.

Table 4
Manly's selection ratio (wi ± SE) of eight cover types used by four coexisting diurnal raptors in the Evros Delta, Greece, during the non-breeding season. Cover types were compared against each other and ranked in order of selection strength. See Table S1 for detailed analyses and explanation of ranking method.

Cover type	$w_i \pm SE$	Rank
Common buzzard		
Freshwater marshes	2.591 ± 0.173	1
Rivers and canals	1.390 ± 0.434	2
Grassland	1.281 ± 0.238	2
Reedbeds	1.196 ± 0.268	2
Saltpans	1.128 ± 0.268	6
Agricultural land	0.825 ± 0.063	2
Saltmarshes	0.578 ± 0.071	6
Lagoons	0.321 ± 0.076	8
Western marsh harrier		
Reedbeds	2.764 ± 0.366	1
Freshwater marshes	2.552 ± 0.160	2
Saltpans	1.828 ± 0.312	3
Rivers and canals	1.197 ± 0.375	4
Grassland	1.062 ± 0.203	4
Saltmarshes	0.908 ± 0.079	4
Lagoons	0.780 ± 0.107	7
Agricultural land	0.256 ± 0.037	8
Hen harrier		
Grassland	3.878 ± 0.964	1
Saltmarshes	1.594 ± 0.251	2
Rivers and canals	0.874 ± 0.868	3
Saltpans	0.835 ± 0.581	3
Freshwater marshes	0.781 ± 0.289	5
Lagoons	0.712 ± 0.277	5
Agricultural land	0.468 ± 0.129	8
Reedbeds	0.396 ± 0.393	5
Black kite		
Rivers and canals	5.154 ± 0.963	1
Freshwater marshes	3.071 ± 0.443	2
Reedbeds	1.945 ± 0.837	3
Agricultural land	0.794 ± 0.154	3
Lagoons	0.700 ± 0.273	5
Saltpans	0.410 ± 0.207	5
Grassland	0.293 ± 0.291	5
Saltmarshes	0.063 ± 0.063	8

rivers and canals, freshwater marshes and reedbeds, with other cover types not preferred for foraging, especially saltpans, grassland and saltmarshes.

3.3. Habitat differentiation

Ranking of species by cover type use. Pairwise comparisons showed that agricultural land was used more by common buzzards than western marsh harriers (Table 5). Common buzzards also used freshwater marshes more than hen harriers. Western marsh harriers used reedbeds more than hen harriers. Saltmarshes were used more by hen harriers and western marsh harriers than black kites and also by hen harriers than common buzzards. Differentiation in the use of grassland, rivers and canals, saltpans and lagoons was not observed.

Table 5
Foraging cover type differentiation among four diurnal raptors in the Evros Delta, Greece, during the non-breeding season. Species are pairwise compared with two-tailed *t*-tests and ranked in descending order of use of each cover type.

Cover type	Species ranking by habitat use
Agricultural land	CB^a > BK > HH > MH^a
Grassland	HH > CB > MH > BK
Rivers and canals	BK > CB > MH > HH
Freshwater marshes	BK > CB^a > MH > HH^a
Reedbeds	MH^a > BK > CB > HH^a
Saltpans	MH > CB > HH > BK
Saltmarshes	HH^{ac} > MH^b > CB^a > BK^{bc}
Lagoons	MH > HH > BK > CB

Species sharing a common letter differ significantly in the use of each cover type ($p < 0.0083$ after Bonferroni adjustment for multiple testing).
CB: Common buzzard; MH: Western marsh harrier; HH: Hen harrier; BK: Black kite.

Table 6
Pairwise Pianka's niche overlap indices of four diurnal raptors foraging in the Evros Delta, Greece, during the non-breeding season (means and 95% CI's) after 1000 permutations.

Species pairs	Pianka's index
Common buzzard – Western marsh harrier	0.879 (0.652–0.940)
Common buzzard – Hen harrier	0.669 (0.417–0.855)
Common buzzard – Black kite	0.944 (0.756–0.973)
Western marsh harrier – Hen harrier	0.725 (0.443–0.927)
Western marsh harrier – Black kite	0.818 (0.789–0.915)
Hen harrier – Black kite	0.440 (0.201–0.683)

Niche overlap. Interspecific overlap in cover type use was higher between common buzzards, western marsh harriers and black kites, and lower between these species and hen harriers in pairwise comparisons (Table 6). Cover type differentiation between hen harriers and the other raptors resulted to a large extent from the much higher use of saltmarshes and the lower use of freshwater marshes and reedbeds by hen harriers (Fig. 2, Table 5).

4. Discussion

Agricultural land, saltmarshes, freshwater marshes and lagoons were the dominant cover types, among the eight identified, within the studied area. Diurnal raptors used all cover types during the non-breeding season, although a few of them in high proportions. Vision dependent raptors selected foraging habitat non-randomly, seemingly hunting where accessibility to 'higher value' prey was enhanced, as predicted by foraging theory (Stephens and Krebs, 1986). Bird species use a variety of foraging habitats along environmental gradients in the Mediterranean, primarily depending on the availability of prey (Farinós-Celdrán et al., 2017).

Common buzzards use open habitats with low vegetation, both

natural and humanized (Cramp and Simmons, 1980), to hunt for their favorite prey, mainly medium and small-sized rodents and birds (Reif et al., 2001, 2004; Rooney and Montgomery, 2013; Sergio et al., 2002). Graham et al. (1995) reported that birds usually constitute alternative prey of common buzzards in shortage of mammals. During the non-breeding season and throughout their European range, common buzzards are commonly associated with meadows and agricultural land with some trees (Baltag et al., 2013; Cramp and Simmons, 1980; Wuczyński, 2005). Furthermore, being a typical perch-hunting predator (Meunier et al., 2000; Palomino and Carrascal, 2007), they predominately use areas with natural perches (trees or bushes; Baltag et al., 2013; Wuczyński, 2005). In the Evros Delta, common buzzards selected grassland for foraging, however they did not prefer agricultural land. They mostly used perches to hunt, although they also engaged to a considerable number of hunting flights. Agricultural land was the most available cover type and although not preferred it was highly used for foraging, being second only to freshwater marshes. Trees and bushes, suitable perching sites for common buzzards, mainly occur along the river and its branches, and irrigation canals, being scarce on grassland and agricultural land. Pellet analysis suggested a high proportion of non-waterbird avian prey, therefore it might be that, in the absence of perches, common buzzards resorted to flight-hunting over cultivations in pursuit of flocks of small land birds where they congregate to exploit seeds left behind after the harvest. On the other hand, the availability of perching sites along waterbodies might be a critical factor for the strong preference for rivers and canals with their associated freshwater marshes.

Although western marsh harriers and hen harriers commonly used and selected a variety of cover types, their respective patterns differed, probably reflecting differences in the use of foraging niches. Prey types are also expected to differ between the two species due to their difference in size (with the western marsh harrier being heavier; Cramp and Simmons, 1980). Buij et al. (2012) found generally comparable patterns of habitat use among coexisting harriers wintering on Sahelian grounds, apart from the significant avoidance of dry grasslands by western marsh harriers and Montagu's harriers *Circus pygargus*. Furthermore, they reported that heavier western marsh harriers took heavier prey items with greater frequencies. Significant differences were also observed between the winter diets of the two species in a Dutch saltmarsh, where marsh harriers specialized on ducks and hen harriers targeted a broader diet of smaller-sized prey (Clarke et al., 1993). Natural habitats such as reedbeds are key foraging habitats for western marsh harriers (Alves et al., 2014), although they have been found to tolerate and even benefit from humanized environments by exploiting agricultural crops both during the breeding (Cardador et al., 2011) and wintering period (Alves et al., 2014). Hen harriers avoided agricultural land in the Evros Delta, however they strongly selected grasslands for foraging, which might be suggestive of a diet based on small mammals and birds. Western marsh harriers preferred natural habitats such as reedbeds and freshwater marshes, avoiding at the same time humanized environments. In addition, small to medium-sized waterbirds contributed a considerable proportion to the birds' diet (Alivizatos et al., 2011). Diet composition is in agreement with the use of aquatic habitats and also with foraging trends observed elsewhere (Alves et al., 2014; Clarke et al., 1993). However, sympatric harriers seem to avoid agricultural land in the Evros Delta, opposing to findings from other areas (Alves et al., 2014; Cardador et al., 2011).

Tanferna et al. (2013) found that black kites in Doñana National Park (south-western Spain) selected open habitats suitable for their aerial foraging modes and avoided woodland and farmland. Meunier et al. (2000) reported that in an intensive arable plain in western France almost all black kites seen in motorway verges were flying above and along the road, obviously looking for carrion. In the Evros Delta black kites mostly preferred flight-hunting along linear features such as rivers and canals with their associated freshwater marshes and reedbeds. In doing so, they mostly fed on avian prey, predominantly land birds as suggested by pellet analysis. Furthermore, black kites' habitat use, selection and diet composition did not reveal associations with humanized environments known from other areas, where birds are attracted by food availability at urban waste disposal sites (Blanco, 1997; De Giacomo and Guerrieri, 2008; Mazumdar et al., 2016).

A generally high overlap in the use of cover types was observed, especially between common buzzards, western marsh harriers and black kites. High niche overlap suggests competition between members of different species for the same resources (Peterson and Holt, 2003). Coexistence of raptors in the Evros Delta might be allowed by prey differentiation, as was found with the consumption of more waterbirds and small mammals by western marsh harriers in comparison to common buzzards. Interspecific competition between raptors might be further reduced in the delta by the high availability of prey or the use of different microhabitats, although the validity of these hypotheses has to be tested.

5. Conclusion and management implications

Habitats greatly reflect their management regime in the delta. Extensive and generally uncontrolled grazing modified vegetation on grasslands and also on freshwater and saltmarsh habitats (Gerakis and Kalburtji, 1998). Out of the breeding season the spatial variation of harriers and buzzards is influenced by the distribution and/or density of their prey (Thirgood et al., 2003). Vegetative cover affects prey vulnerability and thus the availability of small mammals such as rodents (Bechard, 1982; Garner and Bednarz, 2000; Preston, 1990). The continued over-grazing of the delta's grasslands and other habitats could further modify vegetation and thereby affect the occurrence and distribution of the raptors' mammalian prey. The control of grazing and the maintenance of conservation grasslands have proved effective actions for the increase of hen harrier populations (Amar and Redpath, 2005; Wilson et al., 2010). Extensive cultivations, having long ago replaced natural habitats, cleared potential perching sites confining them at peripheral natural areas with trees and bushes. Increasing the availability of trees and bushes in cultivations, and also grasslands, would most likely increase the frequency and efficiency of perch-hunting by common buzzards. Mowed intensive herbaceous crops might also be advantageous to raptors by increasing the availability of small mammals (Cardador et al., 2011). Furthermore, vegetation managed in road verges and along rivers and canals to provide an undisturbed edge-habitat would be favorable to small mammals, valuable prey for raptors (Meunier et al., 2000). So far no measures have been undertaken in the delta for the conservation of medium-sized raptors. These management interventions suggest that a mosaic of habitats could be preserved in the delta to the benefit of these top predators.

The studied raptor species are open ground foragers throughout their range (Baltag et al., 2013; Buij et al., 2012; Tanferna et al., 2013) and, similarly to our findings, common buzzards prefer to hunt from natural perches (Baltag et al., 2013), western marsh harriers prefer hunting in habitats such as reedbeds (Alves et al., 2014), hen harriers are often associated with grasslands (Buij et al., 2012), whereas foraging black kites often forage along linear landscape features (Meunier et al., 2000). Our findings and management implications could be therefore applicable for the management of sites elsewhere, especially Mediterranean coastal areas, lagoons and estuaries.

Overall, results provided important information on the foraging behavior of diurnal raptors, determining critical foraging grounds and suggesting measures for their management and conservation. As such, they could be used as a basis for temporal, within the delta, and spatial comparisons, with other areas, that might also enable us to better identify the importance of certain sites and habitats and to improve management strategies to benefit birds. Further research should focus on the indirect effects of grazing and vegetation management on the distribution of raptors and their prey, especially on grassland, agricultural land and linear habitats. More information is also needed on

the adequacy of perching sites for common buzzards on agricultural land. The potential distribution and foraging of raptors on other habitats close to the delta, especially urban areas such as garbage dumps should also be examined.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ecss.2018.08.009.

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