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Research Article

Dietary niche comparison of raptors in northeastern Iran asan important zoogeographic zone

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Abstract

Diet analysis is one of the most basic requirements for understanding species' ecological niches and determining their feeding relationships in an ecosystem. Pellets are common material for investigating diets. In this study, to investigate the diets and food niche overlap of coexisting raptors in NE Iran, a total of 344 pellets were collected during 2017–18. The pellets belonged to common buzzard (*Buteo buteo*), long-legged buzzard (*Buteo rufinus*), a little owl (*Athene noctua*), common kestrel (*Falco tinnunculus*), golden eagle (*Aquila chrysaetos*), and Eurasian sparrowhawk (*Accipiter nisus*) from the Binalud protected area. Analysis of prey percent frequency showed that the pellets were predominantly composed of the remains of rodents, followed by birds and reptiles. The most frequently captured rodents were jirds (*Meriones libycus* and *M. persicus*), followed by a vole (*Microtus arvalis*). Although the raptors generally utilized small mammalian prey, they showed species-specific preferences and seasonal variations in prey species' share. According to three niche overlap indices, the most extensive food overlaps were found between long-legged buzzard with a common buzzard and golden eagle with a common buzzard. The smallest food overlap was found between the little owl and golden eagle. Seasonal comparison for common buzzard, common kestrel, and little owl showed that richness in the prey items was the highest in summer, followed by autumn. In addition to providing valuable

information in terms of raptors' food habits and biodiversity, this study's results can be leveraged in conservation and management programs.

Keywords: Biodiversity, diet, feeding behavior, overlap index, pellets

Introduction

Iran is characterized by great habitat diversity, making it one of the most important countries for conserving biodiversity in the Middle East and West Asia (Firouz, 2005). Since the loss of just one species may affect many other species, greater species diversity in an ecosystem and more complex food webs make an ecosystem more sustainable and self-regulated. Thus, the overall reduction of biodiversity caused by human activities has a destructive impact on ecosystem sustainability and biological resilience (Mitchell et al., 2002).

As an essential part of biodiversity, birds have evolved over millions of years (Kristin, 2004). So far, 49 species of birds of prey have been recorded among the 520 native and migratory bird species in Iran. However, several factors, such as hunting, habitat degradation, and pollution, have reduced these species' diversity and numbers (Khaleghizadeh et al., 2017).

Obtaining dietary information is necessary to determine the status of a species in biological communities and achieve adequate protection (Bradley et al., 2007). In ecological and taphonomic studies, diet analysis is one of the most basic requirements for understanding species' biology and determining their nutritional relationships and roles in the ecosystem (Royer et al., 2018, Redpathet al., 2001, Deagle et al., 2005). Furthermore, more detailed knowledge of species' diets might be used to properly set up protective strategies (Marrero et al., 2004). Hence, the topic of dietary habits has found a special place in conservation.

Dietary studies are essential in understanding the different aspects of feeding ecology in raptors, and the results of such studies are often used for conservation and management purposes (Marti et al., 2007). One of the most common methods for investigating the diet of wildlife is the examination of pellets. Among traditional diet studies, pellet analysis is one of the best methods for determining raptors' diet composition, especially for species that cannot be hunted due to legal restrictions since pellet analysis is non-invasive and indirect (Khaleghizadeh & Javidkar, 2010; Hámori et al., 2017).

Pellets are mainly spindly or oval-shaped, containing the undigested parts of the birds' food suchas bones, teeth, claws, and hair. These materials are regurgitated through the mouth and are entirely different from droppings. Therefore, by collecting and analyzing pellets, it is possible to determine prey items. For raptors, this method provides extensive information about the food composition, prey species diversity, dominant prey, food preferences, archaeology, ecotoxicology, and differences in food habits (Ghiasyi 1996; Zerunian et al., 1982; Carevic et al., 2003; Van den Brink et al., 2003; Shao et al., 2008; *Charter* et al., 2012; Pocora et al., 2012; Rajaei et al., 2014; Rey-Rodríguez et al., 2019). Additionally, this method can provide information on the distribution of small mammals as prey species, the impact of annual and seasonal changes in prey availability, fluctuations in the relative abundance of prey populations, and the niche overlap among raptors in a region.

For instance, Goutner et al. (2003) studied the diet of the barn owl (*Tyto alba*) and little owl (*Athene noctua*) in the wetlands of northeastern Greece and found the greatest niche overlap in the summer, mainly in mammalian prey items. Romanowski and Lesiński (2020) compared the trophic niches of sympatric raptors in central Poland and showed that the niches and hunting habitats of coexisting kestrels and long-eared owls overlapped almost completely. Zhao (2011) studied the dietary overlap between little owls and long-eared owls in northwestern China, demonstrating that the main prey items overlapped extensively. Kitowski (2013) investigated food niche overlap between barn owls and long-eared owls in Poland and discovered an 83.2% overlap between the two wintering species in main prey items. Numerous studies on the diet of birds of prey have been published worldwide during the last few decades with various aims. However, such studies have been rare in Western Asia and the Middle East. Rey-Rodríguez et al. (2019) performed a modern analysis on barn owl pellets in the Middle East. Ghiasyi (1996), Obuch and Kristin (2004), and Rajaei et. al. (2014) also determined food composition for little owl (*Athene noctua*) in Iran, Syria, and Egypt. The pellets were collected from 34 roosting sites, 17 of which were located in Iran. Obuch and Khaleghizadeh (2011) identified rodent fauna based on one raptor species' pellets (*Tyto alba*) in Iran, finding remarkable differences in the 26 studied prey taxa. In 1996, Ghiasyi studied the rodent fauna of northern Khorasan based on nearly 500 pellets collected from near the cities of Sarakhs, Torbate Jam, Dargaz, and Quchan.

Niche overlap is the shared use of a resource by two or more species (Varasteh et al., 2017). Niche overlap can be relevant to species density and the community structure (Rajaei et al., 2014). There are several methods for measuring niche overlap (Krebs, 2001; Romanowski & Lesiński, 2020). Most previous studies on the diet of sympatric raptors have been carried out on two bird species. Although a comprehensive investigation of several sympatric raptors' diets based on pellets has been undertaken by Romanowski and Lesiński (2020) in Poland, no such research has been conducted in Iran so far. In contrast with previous studies in Iran, which included one or two species (e.g., Varasteh et al., 2017; Anushiravani & Sepehri Roshan, 2017), in the present study, dietary niches of several coexisting raptors were investigated in NE Iran (Binalud protected area in Khorasan Razavi Province). This study aimed to determine the food composition and dietary overlaps in these raptors based on pellets and provide data on this critical zoogeographic area (Misonne, 1959).

Material and methods

Study area

The study area (Binalud protected area) has a total area of 61,936 hectares. It is located at 58°53'to 59°25' E and 36°6' to 36°28' N, between the cities of Torqabeh-Shandiz, Neyshabur and Chenaran (Fig. 1).

Considerable variation exists in the area's vegetation, including various trees and shrubs (genera *Astragalus, Artemisia, Juniperus, Salix* and *Berberis*) (Moghaddam & Koocheki, 2003). The hydrological conditions and the rivers in the study area (e.g., Dowlat Abad, Zoshk, Kang, and Jaghargh rivers) have provided suitable habitats for various species wolves, foxes, cats, pikas, buzzards, owls, and kestrels.

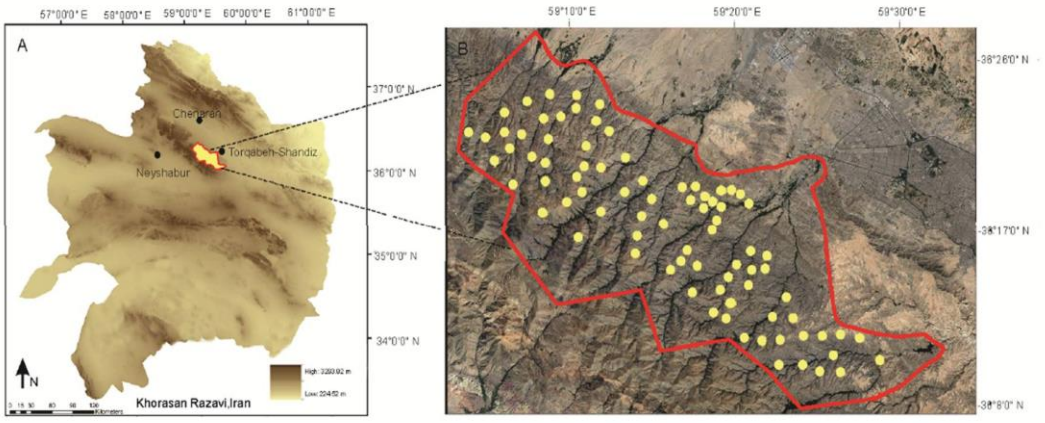

Figure 1. Map showing the geographical location of the study area. Khorasan Razavi Province, Iran (A), and Binalud protected area (B).

Data collection, pellet analysis, and prey identification

A total of 358 pellets, belonging to common buzzard (*Buteo buteo*), long-legged buzzard (*Buteo rufinus*), little owl (*Athene noctua*), common kestrel (*Falco tinnunculus*), golden eagle (*Aquila chrysaetos*), and Eurasian sparrowhawk (*Accipiter nisus*) were collected during the autumn and winter of 2017 and spring and summer of 2018. Although pellets are more likely to be regurgitated at roosting sites and are often found around abandoned buildings, at the base of trees and mud walls, holes in cliffs, and around utility poles, all other locations showing signs of raptor presence were also explored for collection of pellets. Pellets were collected in separate bags and were transferred to the laboratory of the Faculty of Natural Resources and Environment, Ferdowsi University of Mashhad (FUM). Subsequently, the external features and structure (shape, color, weight, length, and diameter) of the collected pellets were measured and recorded (Fig. 2).

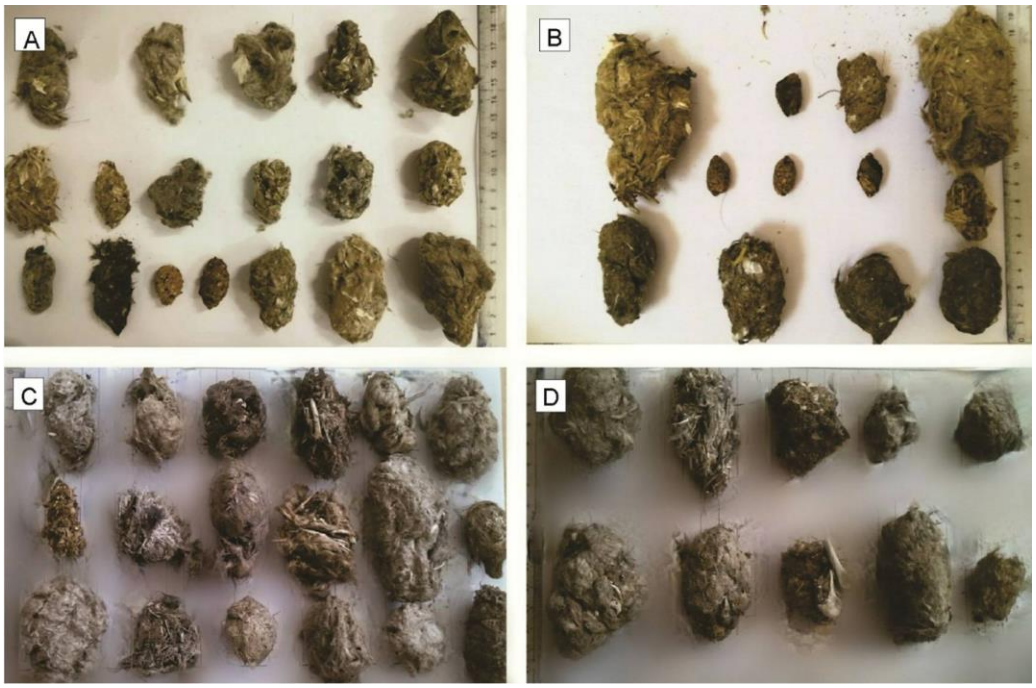

Figure 2. Pellets collected during different seasons: spring (A), summer (B), autumn (C) and winter (D), photographed by authors.

The characteristics of the collected pellets and prey remains were checked with the literature (Brown et al., 1999; Darvish et al., 2006).

Data on the weight, length, and diameter of pellets were statistically analyzed. The pellets were soaked, and prey remains in the pellets were teased apart for further identification following the protocol used by Carevic et al. (2013). All the remains were identified to the lowest possible taxonomic level. Prey items were clustered into eight groups based on taxonomic similarities, including rodents (Muridae), birds (passerine), birds (poultry), reptiles, hedgehogs and shrews, ground squirrel, insects, and hares and pikas (Lagomorpha).

Rodents' remains in the pellets were identified based upon skull, jawbone, and dental formula using an identification key (Darvish et al., 2006). Some pellets lacked enough skeletal and cranial remains, so it was only possible to detect an anonymous rodent. Since insects were not our specialty and given the conservation and management concerns of this study, we did not attemptto identify insects precisely.

Table 1. Dimensions of pellets from six raptor species in NE Iran.

Raptor species	Season	N	Length (mm)			Diameter (mm)			Weight (g)		
			Mean±SD	Min	Max	Mean ±SD	Min	Max	Mean ±SD	Min	Max
Common buzzard (*Buteo buteo*)	**Spring**	42	38.16±9.05	22	57.8	23.87±4.7	12	37	2.56±1.36	0.6	7.8
	Summer	118	47.25±12.4	21	89	31.37±7.67	15	54	5.06±3.24	1	18
	Autumn	41	40.09±12.53	19	75	24.41±7.38	13	40	3.76±4.96	0.9	17
	Winter	82	31.05±6.49	14.5	47	47.91±11.37	24	82	4.24±1.99	1	10
	Total	292	38.54±11.87	22	82	35.46±13.64	11.3	89	4.24±3.12	0.6	33
Little owl (*Athene noctua*)	**Spring**	7	42±8.5	32	56	16.7±5.3	12	25	1.87±0.34	1.4	2.4
	Summer	1	36	36	36	15	15	15	1.7	1.7	1.7
	Autumn	3	40.66±7.02			17.1±2.47			2.8±1.61		
	Winter	11	39.18±10.87	15	56	18.57±7.17	12	36	2.11±0.88	1.4	4.6
	Total	22	40.20±7.82	27.66	49.33	17.5±2.3	13	25.3	2.4±1.2	1.5	2.9
Common kestrel (*Falco tinnunculus*)	**Spring**	4	33.57±5.15	31	41.3	15.22±1.15	13.5	15.8	1.35±0.1	1.2	1.4
	Summer	1	24	24	24	14	14	14	1.4	1.4	1.4
	Autumn	3	29.66±2.31			17.53±3			1.4±0.02		
	Winter	2	35.65±17.46	23.3	48	37.5±3.35	35	40	2.6±0.14	2.5	2.7
	Total	10	31.23±7.51	14	41.3	20.88±10.19	13.5	48	1.62±0.52	1.2	2.7
Long-legged buzzard (*Buteo rufinus*)	**Spring**	9	41.78±8.6	28	56	25.78±4.66	21	35	3.42±1.12	2.2	6.1
	Summer										
	Autumn										
	Winter										
	Total	9	41.78±8.6	28	56	25.78±4.66	21	35	3.42±1.12	2.2	6.1
Golden eagle (*Aquila chrysaetos*)	**Spring**	9	77.7±8.69	65	89	46.17±3.16	42	52	21.47±8.83	11.3	39
	Summer	2	34±4.29	31	37	71±11.31	63	79	9.9±0.14	9.9	10
	Autumn	11	50.68±11.03	42	79	69.75±19.35	31	89	19.36±9.19	9.8	39
	Winter										
	Total	22	55.2±8.51	46	68.33		45.33	73.33		10.33	29.33
Eurasian sparrowhawk (*Accipiter nisus*)	**Spring**	2	19±2.83	17	21	13±1.414	12	14	0.6±0.00	0.6	0.6
	Summer	1	20	20	20	12	12	12	0.62	0.62	0.62
	Autumn										
	Winter										
	Total	3	19.5±2.7	18.5	20.5	12.5±1.4	12	13	0.61	0.61	0.61

Statistical analyses

All the obtained data, including length, weight, diameter, color, and texture of the pellets and the detected items for each specimen, were entered into Microsoft Excel 2019 and analyzed in SPSS version 16.

In order to study the diet of raptors and investigate their food niche overlap, the common method for examining pellets of raptors (Obuch & Khaleghizadeh, 2011; Carevic et al., 2013), i.e., determination of the proportion of prey items, was used. The relationship between species and the physical characteristics of pellets was analyzed using SPSS ver. 16. Since the data for weight, length, and diameter had normal distributions, one-way analysis of variance (ANOVA) was usedto test differences in these variables among the raptors. We used Duncan's multiple range test to test pairwise differences in pellet characteristics between raptors (DMRT). Additionally, we investigated seasonal variation in food items' richness and how prey items are utilized in different seasons by a common buzzard, common kestrel, and little owl. The association between the contents pellets and season were tested using a chi-square test in SPSS ver. 16. The pellets of Eurasian sparrow hawk were excluded because of limited sample size. Finally, we evaluated food niche overlap for five raptor species (excluding Eurasian sparrowhawk) based on several indexes. Pianka's niche overlap index (Pianka, 1974) was calculated from the presence-absence matrix, and Horn's overlap index (Horn, 1966) was calculated based on the proportion of the resources utilized by each species. Lastly, simplified Morisita's original index of overlap (Morisita, 1959) was applied to the numbers of prey species in Software for Ecological Methodology ver.7.2 (Krebs, 2001).

Results

The collected pellets belonged to the common buzzard, long-legged buzzard, little owl, kestrel, golden eagle, and sparrow hawk. One-way ANOVA shows significant differences among raptorsin the weight, length, and pellets' diameter (Table2).

Table 2. The results of ANOVA' test on the dimensions of the raptors' pellets, length (mm), diameter (mm), and weigth (g); (Sig=0, α=0.05)

Sig.	F	Mean Square	df	Sum of Squares			
0	22.324	3012.438	4	18074.63	(Combined)	Between Groups	Length*Species
		134.939	356	45339.447		Within Groups	
			352	63414.077		Total	
0	24.845	1350.263	4	8101.576	(Combined)	Between Groups	Diameter*Species
		54.347	356	18260.533		Within Groups	
			352	26362.109		Total	
0	42.919	471.101	4	2826.608	(Combined)	Between Groups	Weight*Species
		10.976	356	3688.094		Within Groups	
			352	6514.702		Total	

The results of DMRT demonstrate homogenous subsets which are significantly different from each other. In all measured characteristics, the common buzzard and long-legged buzzard were placed in the same homogenous subset. The maximum pellet length, weight and diameter belonged to golden eagles, and the minimum belonged to little owls (Table 1). The pellets of golden eagles were significantly ($P < 0.05$) heavier than those of other raptors (for more details about dimensions of pellets, see Table 1).

The results of DMRT indicate that pellet diameter is significantly different among the raptors. Based on the results of DMRT for pellet diameter, the golden eagle did not cluster with any other species.

A total of 850 individual prey remains were identified. The proportion of prey items was significantly different among the raptors. However, remains of murids were most common in general, followed by birds (passerine). The least common prey items were ground squirrels and birds (poultry). Overall, the results indicated that during the four seasons, the diets of the studied raptors contained 48.8 % rodents (Muridae), 17.8% birds (passerine), 4.7% birds (poultry), 5.6% lagomorphs (1.5% tolai hare (*Lepus tolai*) and 4.1% Afghan pika (*Ochotona rufescens*)), 8.9% insects (spiders, beetles, grasshoppers, and ants), 10.5% reptiles (snakes and lizards, especially Gekkonidae spp), 4.9% hedgehogs and shrews (4.4% shrews, and 0.5% long-eared hedgehogs (*Hemiechinus auratus*), and 3.1% yellow ground squirrel (*Spermophilus fulvus*) (Table 3). Among the rodents, genus *Meriones* (mostly *M. persicus* and less than 10% *M. libycus*), 38% relative frequency, and genus *Microtus* (mostly *M. socialis* and *M. arvalis*), with 36% relative frequency, had the highest percentages in pellets. Indian crested porcupine (*Hystrix indica*), house mouse (*Mus musculus*), and short-tailed nesokia (*Nesokia indica*) with 2, 4.1, and 5%, respectively, had the lowest frequency among rodent remains in the studied pellets.

Table 3. The frequency of different prey items in the contents of the raptors' pellets.

Pray item	*Golden eagle* (*Aquila chrysaetos*)	Little owl (*Athene noctua*)	Common kestrel (*Falco tinnunculus*)	Common buzzard (*Buteo rufinus*)	Long-legged buzzard (*Buteo rufinus*)	Eurasian sparrowhawk (*Accipiter nisus*)
Rodents (Muridae)	58	61	38	40	46	47
Birds(passerine)	18	6	15	16	15	33
Ground squirrel	4	5	3	10	2	0
Insects [1]	1	7	13	2	4	4
Reptiles [2]	4	11	11	11	22	10
Hedgehogs and shrews	3	5	2	4	2	0
Birds (poultry)	4	1	7	8	3	3
Lagomorpha	5	1	8	6	3	3

[1] **Spiders. Beetles, Grasshoppers, ants, and unidentified**
[2] **Lizards. Snake and Unidentified**
[3] **Pika, and Hare**

The results of the chi-square test showed that prey items were significantly different among the raptors ($P < 0.05$), without significant differences between seasons. Although statistically insignificant, notable patterns were observed in different seasons. In spring, the pellets (especially little owl pellets) contained considerable percentages of insects. In summer, pellets contained a substantial richness of rodent species, and rodents had the highest frequency. In spring, birds (passerine) showed similar frequency in raptors' pellets, except for the little owl. Seasonal comparison for common buzzard, common kestrel, and little owl showed that richness in prey items was highest in summer, followed by autumn.

Pianka's overlap index (ranging from 0–1) shows that the largest food overlap exists between a long-legged buzzard and common buzzard (0.97), and golden eagle with a common buzzard (0.87); the smallest food overlap exists between the little owl and golden eagle (0.22). Morisita's index revealed similar results since the largest overlap was found between the little owl and common buzzard (0.884), and the golden eagle with common buzzard (0.87); the smallest food overlap was found between the little owl and golden eagle (0.21). Based upon Horn's index,

maximum niche overlaps were based upon Horn's index, maximum niche overlaps were between a long-legged buzzard and common buzzard (0.89), and a common buzzard with a common kestrel. A minimum food overlap (0.18) was observed between a little owl with a golden eagle (similar to other food overlap indexes). All food overlap indexes showed a small overlap between the golden eagle with the little owl (Table 4).

Table 4. Food overlap indexes for all the raptors.

Pairwise comparisons	Pianka	Morisita	Horn
Long-legged buzzard -Common buzzard	0.97	0.676	0.89
Long-legged buzzard -Little owl	0.585	0.23	0.38
Long-legged buzzard -Common kestrel	0.414	0.403	0.626
Long-legged buzzard -Golden eagle	0.771	0.768	0.818
Long-legged buzzard -Eurasian sparrowhawk	0.23	0.22	0.22
Common buzzard-Little owl	0.85	0.884	0.71
Common buzzard-Common kestrel	0.78	0.86	0.79
Common buzzard-Golden eagle	0.87	0.87	0.862
Common buzzard-Eurasian sparrowhawk	0.25	0.24	0.22
Little owl-Common kestrel	0.64	0.74	0.782
Little owl-Golden eagle	0.22	0.21	0.18
Little owl-Eurasian sparrowhawk	0.37	0.279	0.345
Common kestrel-Golden eagle	0.62	0.618	0.657
Common kestrel-Eurasian sparrowhawk	0.433	0.344	0.408
Golden eagle-Eurasian sparrowhawk	0.433	0.22	0.21

Discussion

Various studies have been conducted in Iran and throughout the world on raptors' diets based on pellet analysis. Most of these studies have been carried out on a particular species (e.g., Bakaloudis et al., 2012). Rarely have such studies dealt with dietary niche' overlap and comparison of food habits for sympatric raptors, as recently done by Romanowski and Lesiński (2020). This study examined a total of 358 pellets belonging to six raptors. The results demonstrated that the raptors mainly feed on rodents throughout the year. This study's results are consistent with those of Obuch and Kristin (2004), who showed that prey remains in pellets mostly belonged to invertebrates, mammals, and birds. Since the highest frequency of prey items was found for rodents, our findings are also in concordance with the results of Davis (1975), Ghiasyi (1996), Shao and Lio (2008), and Zhao (2011).

However, our observed prey item frequencies were not in agreement with the results of Hounsome et al. (2004) and Souttou et al. (2006), who found insects to have the highest percentage. These differences could be attributed to various reasons. For instance, Obuch and Kristin (2004) observed that the prey composition of one species (little owl) could be different between different localities in arid climates (Egypt, Syria, and Iran). Another reason might be the small sample size; researchers such as Souttou et al. (2006) and Pocora et al. (2012) have studied only 35 and 103 pellets, respectively. Although we had a small sample size for the long-legged buzzard, we observed similar results to Bakaloudis et al. (2012), showing reptile remains were more frequent than avian remains.

Despite the similarity between our findings and those of Romanowski and Lesiński (2020) in terms of species dietary niches and richness of prey items, the results of this study demonstrated that there was a significant difference between the foods eaten by the studied raptors. Murids made up the majority of the diets, and passerines were the most common prey during summer. The

frequency of prey items (especially in owls) is similar to what has been observed by Shao et al. (2007) in northwestern China. Seasonal patterns for common buzzard, common kestrel, and little owl in this study agree with Hussain Khan et al. (2016), who demonstrated that the richness of prey items is highest in summer, followed by autumn.

Conclusion

The study of niche overlaps revealed food competition among most raptors in the study area. However, we believe that sympatric species (even those in the same guild) undergo niche partitioning, at least in prey size (Romanowski & Lesiński, 2020). Although human settlements provide various habitats for the raptors, land-use change and habitat fragmentation during the last decade have caused the local extinction of these species. To protect raptors in the Binalud protected area, we recommend that landscape fragmentation be controlled and managed first. Secondly, the birds' food sources in the region, including small mammal species, need to be managed. Moreover, given the role of raptors in the biological control of rodents as pests of agricultural areas in the Binalud region, more effective management of prey-predator relationships and protection of raptors in this region should be pursued. Based on the results of our work and similar studies, Iran's Department of Environment can plan for the conservation of Iran's avian fauna.

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