ACTA ZOOLOGICA BULGARICA

ACTA ZOOLOGICA BULGARICA

Acta zool. bulg., 74 (3), 2022: 385-402
Published online 9 June 2022
http://www.acta-zoologica-bulgarica.eu/2022/002606

Terrestrial Ecology and Behaviour
Research Article

Habitat Preferences of Three Species of Diurnal Birds of Prey in Relation to their Potential Foraging Resources in the Balkan Mountains Range, Bulgaria

Nadejda Djorgova[1]*, Dimitar Ragyov[1], Georgi Popgeorgiev[1], Valko Biserkov[1], Yordan Biserkov, Diana Zlatanova[2] & Boris P. Nikolov[1]

[1] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Street, 1113 Sofia, Bulgaria
[2] Department of Zoology and Anthropology, Faculty of Biology, Soia University "St. Kliment Ohridski", 1164 Sofia, Bulgaria

Abstract: We assessed the prerequisites for foraging resources availability in connection with breeding habitat choice for the golden eagle (*Aquila chrysaetos*), long-legged buzzard (*Buteo rufinus*) and peregrine falcon (*Falco peregrinus*) along the Balkan Mountains, by applying spatial distribution models of their main prey species. In the study area, the most probable foraging resources for the golden eagle were the rock partridge, the common quail and the European ground squirrel, for the long-legged buzzard – the common vole, and the peregrine falcon – the mistle thrush and the common wood pigeon. In most territories of the three birds of prey species, there were prerequisites for the presence of at least several prey species. Reptiles did not make a significant contribution as a food source for the golden eagle and long-legged buzzard. Spatial distribution models for assessing the preconditions for foraging resources availability in the breeding territories of birds of prey can be applied as indirect methods in a reliable alternative approach. Additionally, this allows the identification of possible contribution of certain prey species in the birds of prey food spectrum in a given area.

Key words: Golden Eagle *Aquila chrysaetos*, Long-legged Buzzard *Buteo rufinus*, Peregrine Falcon *Falco peregrinus*, raptors, spatial distribution models

Introduction

The identification of the habitat quality is a key goal in the conservation of endangered species, allowing for their better protection and management (Pedrini & Sergio 2002). The foraging resources are one of the most important components of the habitat. Birds of prey, as other predators, to minimise their energy expenses choose the habitats that are the most suitable for hunting (Krebs et al. 1983). The availability of appropriate prey is a major factor influencing the choice of nesting area for birds of prey and largely determines the long-term occupation of the territories, successful reproduction and the establishment of a stable population in the area.

The main purpose of modelling the preferences of different species for habitat is to identify the relationship between habitat characteristics and species distribution. Often, field research on birds of prey is costly and time-consuming because the birds are low in number and live in remote mountainous areas (Watson 1997). Therefore, identify-

*Corresponding author: djorgova@gmail.com

ing the important areas for these species using spatial models that utilise the ready-made habitat data is an extremely good opportunity (McLeod et al. 2002). Spatial models are widely applied in modern research (McLeod et al. 2002, Lopez-Lopez et al. 2007). In recent years, habitat modelling has played an increasingly important role in studying the distribution of organisms (Guisan & Thuiller 2005). Predictive models were used in conservation biology for a variety of purposes, including monitoring rare species, assessing probabilities of changes in habitat, identifying suitable sites for reintroduction (Yanez & Floater 2000), design of protected areas (Li et al. 1999, Larson et al. 2004) and supporting their management (Bradbury et al. 2000), and even assessment of global impact processes such as climate change (Berry et al. 2002, Thuiller 2003, Skov & Svenning 2004). Modelling of prey species availability is an important pre-requisite for every good habitat model for predator species.

The golden eagle *Aquila chrysaetos* (Linnaeus, 1758) and the peregrine falcon *Falco peregrinus* Tunstall, 1771 were numerous in Bulgaria until the beginning of the 20th century but later their populations began to decline. The current number of the golden eagle is 150 pairs (Petrov et al. 2015) and the peregrine falcon is present with about 200 pairs (Stoyanov et al. 2015). The long-legged buzzard *Buteo rufinus* (Cretzschmar, 1827) settled in Bulgaria as a nesting species in the middle of the 20th century (Boev 1962); in our days, it has a breeding population of about 800-1000 pairs (Vatev et al. 2015). The main part of the European population of the long-legged buzzard occurs on the Balkan Peninsula.

All three species are of high conservation concern in Bulgaria therefore they are protected by the Biodiversity Act, Annexes II and III. They are also listed in the Red Data Book: the golden eagle and the long-legged buzzard are in the category Vulnerable (VU) (Petrov et al. 2015, Vatev et al. 2015), and the peregrine falcon is in the category Endangered (EN) (Stoyanov et al. 2015).

During the breeding season the golden eagle is found at rocky cliffs, gorges and areas with high rocky walls, and in rock formations, near open spaces. It nests on cliffs – on platforms under canopy or in small caves (Simeonov et al. 1990); tree nests are less common (Simeonov et al. 1990, Miltschew & Georgiewa 1992, Petrov et al. 2007). It feeds mainly on medium-sized mammals and birds as well as on reptiles and amphibians. In winter, it also feeds on carrion. Some pairs on the Balkan Peninsula were observed to specialise in feeding on tortoises (Arabadzhiev 1962, Boev 1980, Simeonov et al. 1990, Watson 1992, Georgiev 2009).

The long-legged buzzard inhabits open hilly terrains in the foothills near river gorges, deforested mountain slopes, separate rock formations, stone quarries with open spaces around them (arable land, pastures), where it goes for hunting (Simeonov et al. 1990, Vatev et al. 2015). It positions its nests in niches or on edges of vertical or hard to reach cliffs (Boev 1962, Michev et al. 1984, Vatev 1987, Simeonov et al. 1990), as well as in quarries and trees, often near shrubby areas and high voltage electric poles (Milchev 2009, Demerdzhiev et al. 2014). The diet of the long-legged buzzard includes small and medium-sized mammals and birds, reptiles, amphibians, and large insects (Cramp & Simmons 1980, Michev et al. 1984, Vatev 1987, Simeonov et al. 1990, Snow & Perrins 1998, Milchev 2009, Orta et al. 2020). Varied prey is hunted with small rodents being an important part of its diet (Petrov 1964). The European ground squirrel appears to be a preferred prey, where available (Petrov 1964, Michev et al. 1984, Dudas & Sandor 1993). In the area of the Besaparski hills, a transition to alternative prey (domestic pigeons) has been observed, as a feeding adaptation due to the reduction of the ground squirrel colonies (Demerdzhiev et al. 2014).

The peregrine falcon inhabits rocky terrains near open spaces with groups of trees and small groves. It is very rare in the alpine areas of the mountains above the tree line and in settlements (Simeonov et al. 1990, Stoynov et al. 2007, Stoyanov et al. 2015). It feeds mainly on birds, and sometimes on small mammals (Arabadzhiev 1962, Simeonov et al. 1990, Stoyanov 2003, Ragyov et al. 2008, White et al. 2020).

The golden eagle, the long-legged buzzard and the peregrine falcon are one of the most common diurnal birds of prey in the Balkan Mountains Region with overlapping distribution. To assess the prerequisites for foraging resources availability in connection with these three species breeding habitat choices we applied spatial distribution modelling for prey species in the study area and conducted analyses according to three research questions: (1) According to the suitable habitats in the study area, what were the key prey species in the breeding territories of the three target birds of prey species? (2) In the study area what was the degree of the breeding territories heterogeneity in terms of main prey species diversity? (3) What are the differences between the different parts of the Balkan Mountains in terms of main prey species suitable habitats for the respective bird of prey?

Materials and Methods

Study area

The Balkan Mountains are a well pronounced mountain range in Bulgaria with an area of 11,596 km^2. It is about 530 km long and between 15 and 45 km wide. It is divided into three parts – Western, Central and Eastern Balkan. Its average altitude is 722 m, and its highest altitude is 2376 m (Botev Peak). In the Balkan Mountains, a mountainous variety of the temperate continental climate predominates, and the seasonal distribution of precipitation characterises it as an area with a temperate continental retention regime.

Deciduous forests predominate, composed of European beech (*Fagus sylvatica*), common hornbeam (*Carpinus betulus*), durmast oak (*Quercus petraea*), with patches of Moesian beech (*Fagus sylvatica moesiaca*), sweet chestnut (*Castanea sativa*), Turkey oak (*Quercus cerris*) and Balkan pine (*Quercus frainetto*). The coniferous forests do not form a continuous vegetation belt. Forests of Norway spruce (*Picea abies*), less woods of Scots pine (*Pinus sylvestris*) and remnant woods of Balkan pine (*Pinus peuce*) predominate. Alpine grass vegetation is widespread in the highest parts of the mountain (Kopralev 2002).

The fauna of the Balkan Mountains is characterised by significant species diversity. Forest fauna species predominate, and alpine species are also found in the high mountain belt (Gruev & Kuzmanov 1994). The study area covers about 46% of the territory of the Balkan Mountains and parts of the sub-Balkan fields (Fig. 1).

Fieldwork

The data on the nest locations of the golden eagle, the long-legged buzzard and the peregrine falcon on the territory of the Balkan Mountains were collected in 2006-2010 during the breeding season (March to July). Prior to the study, potential nesting sites such as cliff formations and solitary cliffs were identified based on reports of previous cases of nesting, also, a survey of topographic maps and maps of Google Earth™ was performed.

Potential locations were explored from an optimal distance, depending on the field conditions. The terrain was scanned using Leica 8 x 42 HD-B binoculars with a laser rangefinder and a 20-60x Swarovski spotting scope. The centres of the breeding territories were mapped through triangulation based on data from a GPS device (Garmin MAP 60CSx), laser rangefinder of the binoculars, and compass. When a position with direct visibility to the active nest was not available and its location could not be determined with the adopted accuracy, the centre of the breeding territory was set to the place most vigorously defended from other raptors,

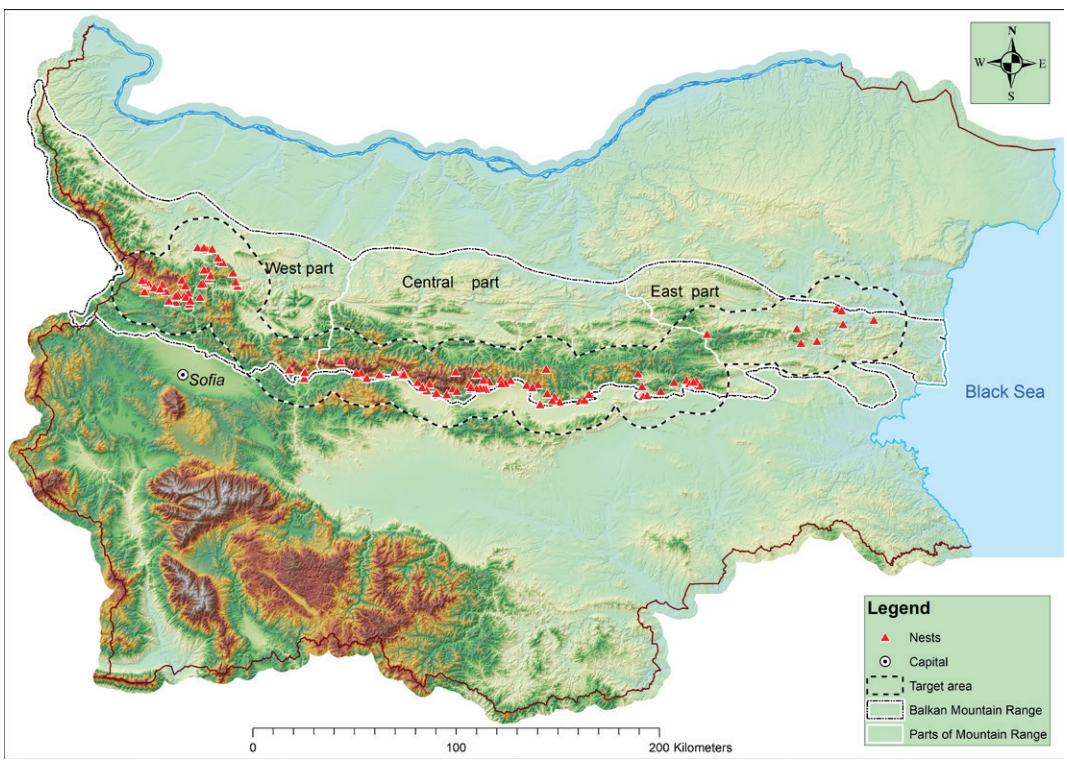


Fig. 1. Map of study area with the breeding territories of the golden eagle, the long-legged buzzard and the peregrine falcon.

Table 1. Potential prey species covered by the analyses for the golden eagle, the long-legged buzzard and the peregrine falcon

Nº	Potential prey species	*Aquila chrysaetos*	*Buteo rufinus*	*Falco peregrinus*
1	*Rupicapra rupicapra*	x		
2	*Lepus europaeus*	x	x	
3	*Spermophilus citellus*	x	x	
4	*Microtus arvalis*		x	
5	*Anthus spinoletta*			x
6	*Alauda arvensis*			x
7	*Alectoris graeca*	x	x	x
8	*Columba palumbus*			x
9	*Coturnix coturnix*	x	x	x
10	*Perdix perdix*	x	x	x
11	*Turdus viscivorus*			x
12	*Testudo graeca*	x		
13	*Testudo hermanni*	x		
14	*Coronella austriaca*		x	
15	*Dolichophis caspius*		x	
16	*Lacerta viridis*		x	

or to an inactive nest near indications of being used in previous years. As a total, 38 territories of the golden eagle, 54 territories of the long-legged buzzard and 20 territories of the peregrine falcon were identified (Fig. 1).

Of all prey species found in the survey area, in the present study we considered the following: eight prey species of the golden eagle, nine species from the food spectrum of the long-legged buzzard and seven species from the food spectrum of the peregrine falcon (Table 1). The selection of the species from the food spectrum of the three species of birds of prey for the present study was based on: (1) Literature data on the food spectrum of the three species of birds of prey within their habitats. (2) The scarce literature data on the food spectrum of the three species of birds of prey in the study area. (3) Expert assessment of the presence, abundance and degree of overlap of the habitat preferences of the species from the food spectrum with the open spaces, which are preferred hunting areas for all three species of birds of prey.

GIS analyses

The analyses and maps were created using ArcGIS 10.6 (ESRI, Redlands, CA, USA). The following input layers used in the analyses: (1) Centres of breeding territories (point layers), created by GPS coordinates. (2) Nesting territories (polygon layers) obtained by conditionally buffering the centers of the breeding territories with a radius of 6000 m for *A. chrysaetos* (McGrady et al. 2002) and 4000 m for *B. rufinus* (Alivizatos & Gounter 1997) and *F. peregrinus*. (3) Spatial distribution models of 16 species from the food spectrum of the golden eagle, the long-legged buzzard and the peregrine falcon.

All models were built on actual data on the presence of the prey species both in the target area and outside it, using MaxEnt program (Phillips et al. 2006, Phillips & Dudik 2008, Phillips et al. 2017). Three models have been developed earlier – common vole model (at 30 m resolution, Popov 2015), the European ground squirrel and the chamois models (at 20 m resolution, prepared by V. Popov under the project "Mapping and determination of the conservation status of natural habitats and species Stage I" under the operational program "Environment 2007-2013" of the MOEW). The models of the rest of the 13 prey species and were developed at 40 m resolution especially for the current study. The models were built with the following number of locations for each prey species: *Lepus europaeus* – 560, *Anthus spinoletta* – 350, *Alauda arvensis* – 1690, *Alectoris graeca* – 45, *Columba palumbus* – 980, *Coturnix coturnix* – 380, *Perdix perdix* – 850, *Turdus viscivorus* - 1830, *Testudo graeca* – 1458, *Testudo hermanni* – 2865, *Coronella austriaca* – 680, *Dolichophis caspius* – 129, *Lacerta viridis* – 12,380. The data on the locations of the birds were provided by BSPB, and the rest were from the personal archive of the authors.

The modelling procedure was based on 23 variables: 19 bioclimatic variables from WorldClim v. 2, averaged for the period 1970-2000, with original pixel size approx. 1 km^2 (Fick & Hijmans 2017); topographic variables – altitude (m), exposure (°) and slope (°), calculated using Spatial Analyst in ArcGIS from a digital elevation model (DEM) with a resolution of 20 m; CORINE Land Cover – CLC 2006.

The scale of the original raster (excluding DEM-based ones) was reduced to a pixel size of 40 m, using "cubic convulsion" resampling in ArcGIS. Metric projection coordinate system WGS 84, UTM zone 35N was used in all analyses. For the final version of the model, 100 replicates with the "Bootstrap" option and 25 % of the points selected randomly for verification of each replication were set. 100 000 background points and a logistic standard for the source data were used to facilitate their interpretation (Fig. 2, AP).

Parameters analysed included: 1. Cumulative area (m^2) of habitats with probability of prey spe-

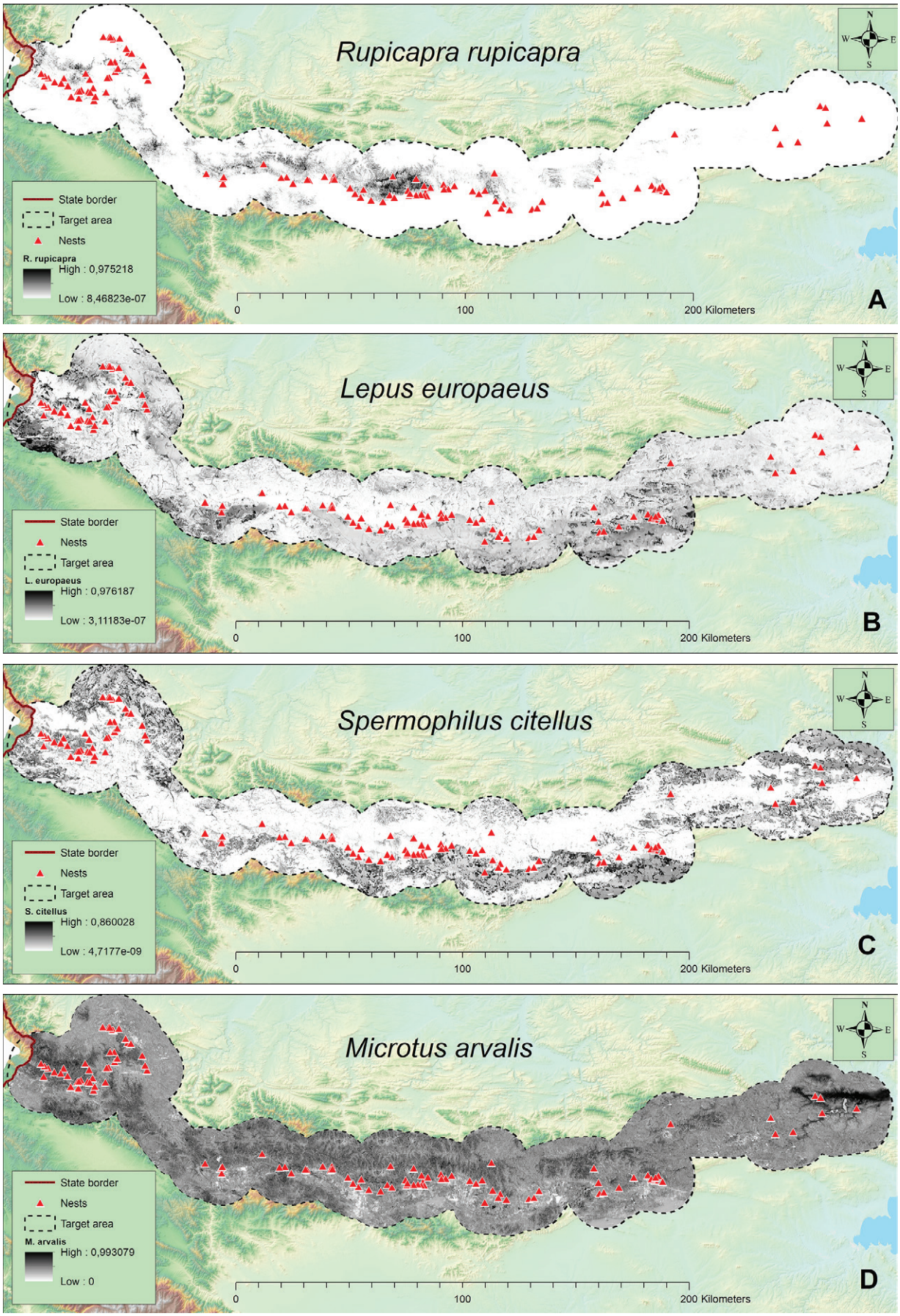
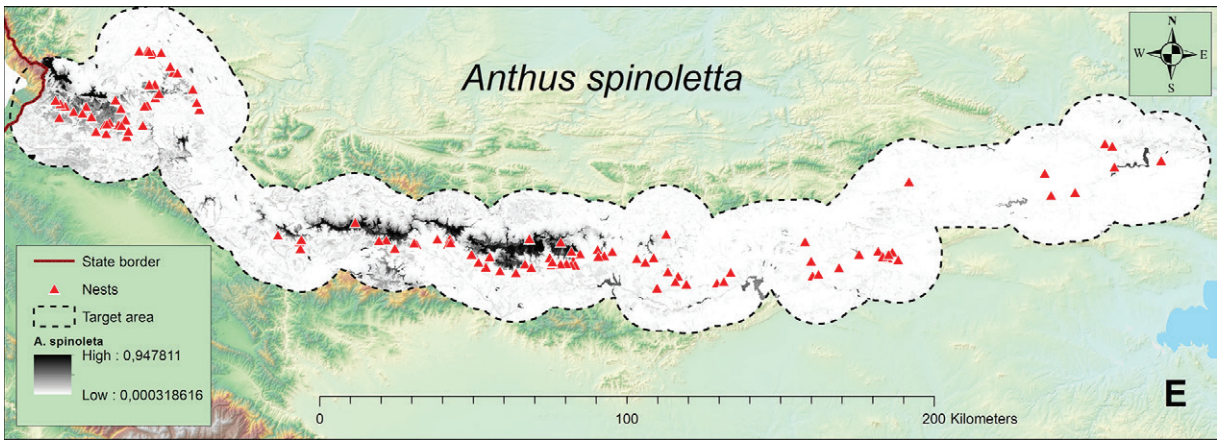
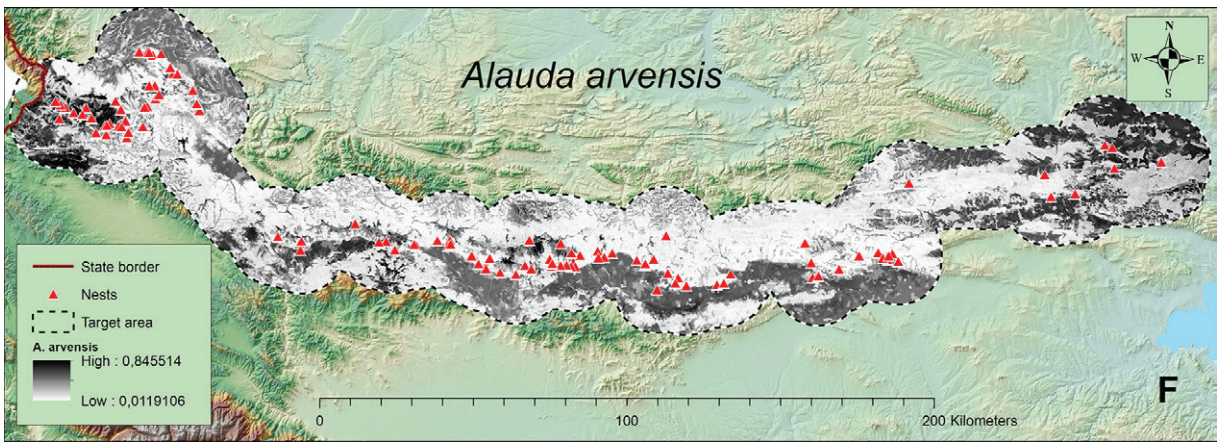
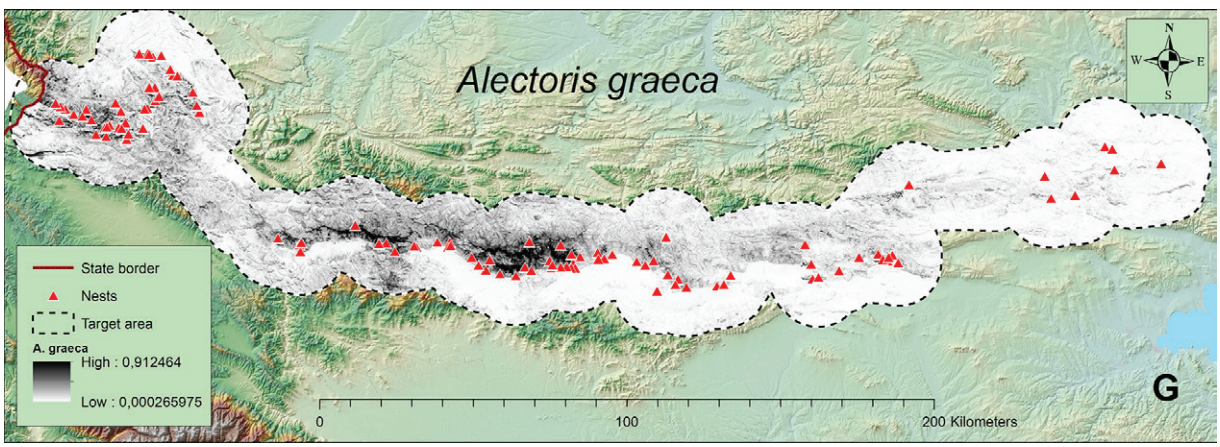


Fig. 2. Spatial models of 16 species from the food spectrums of the golden eagle, the long-legged buzzard and the peregrine falcon.







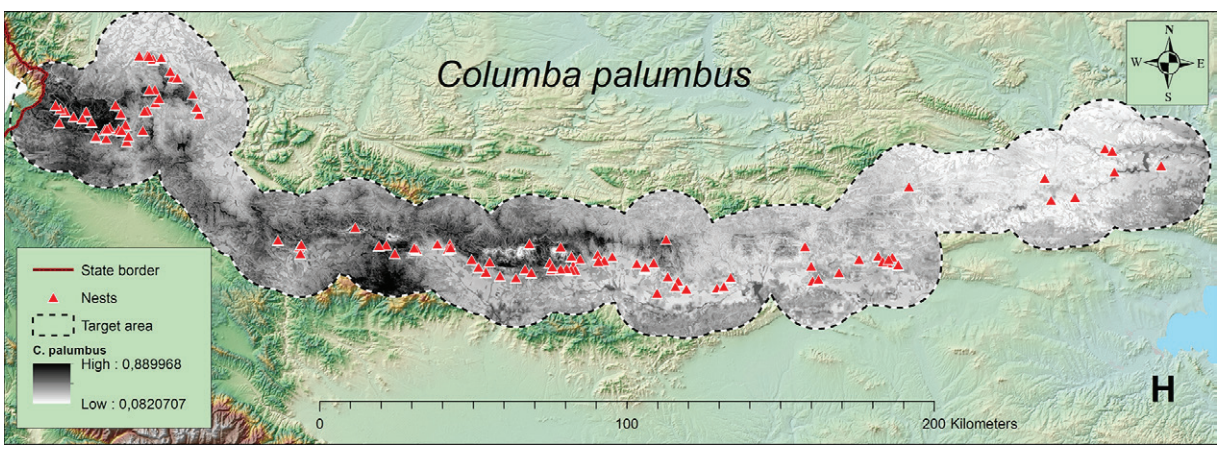


Fig. 2. Continuation.

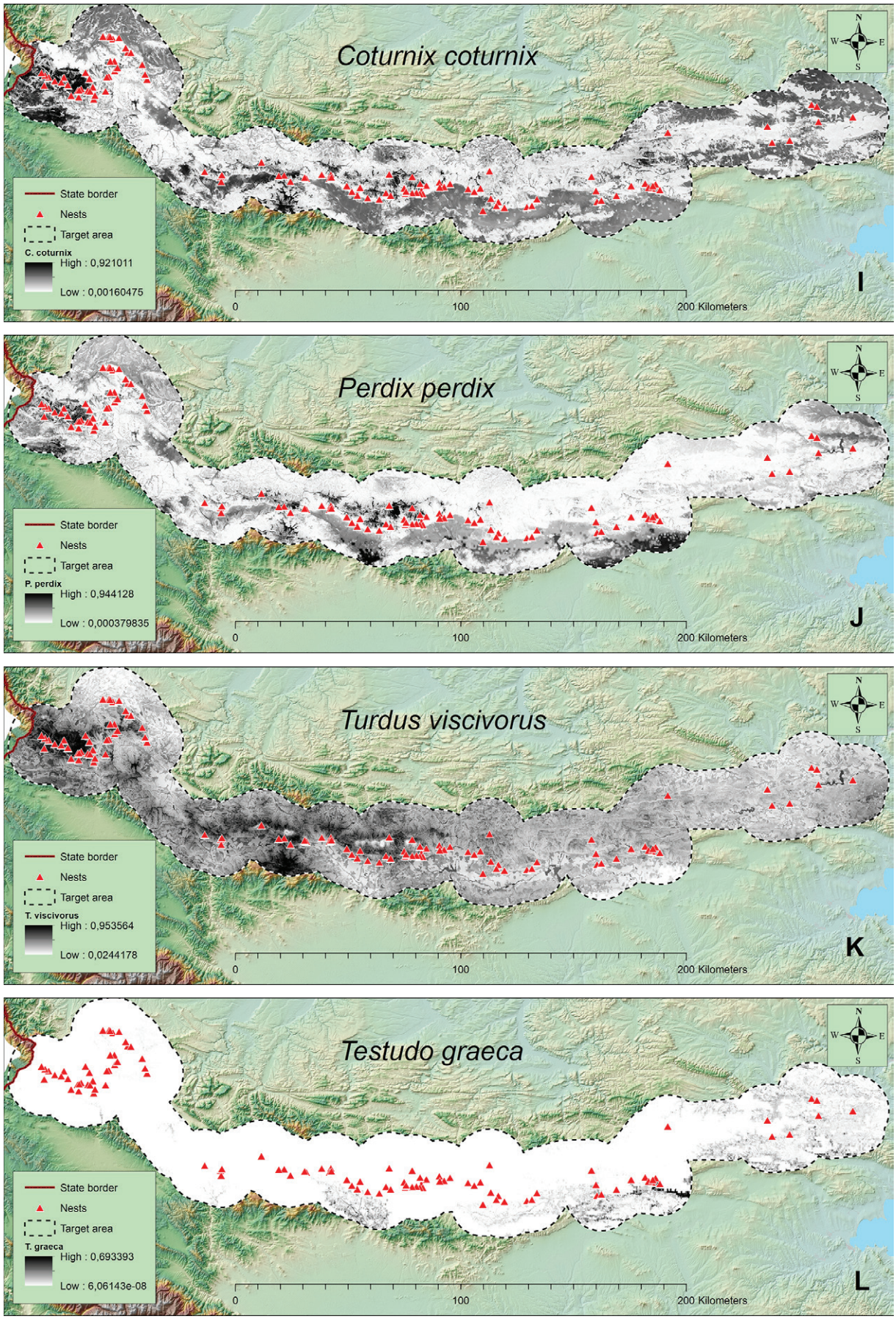


Fig. 2. Continuation.

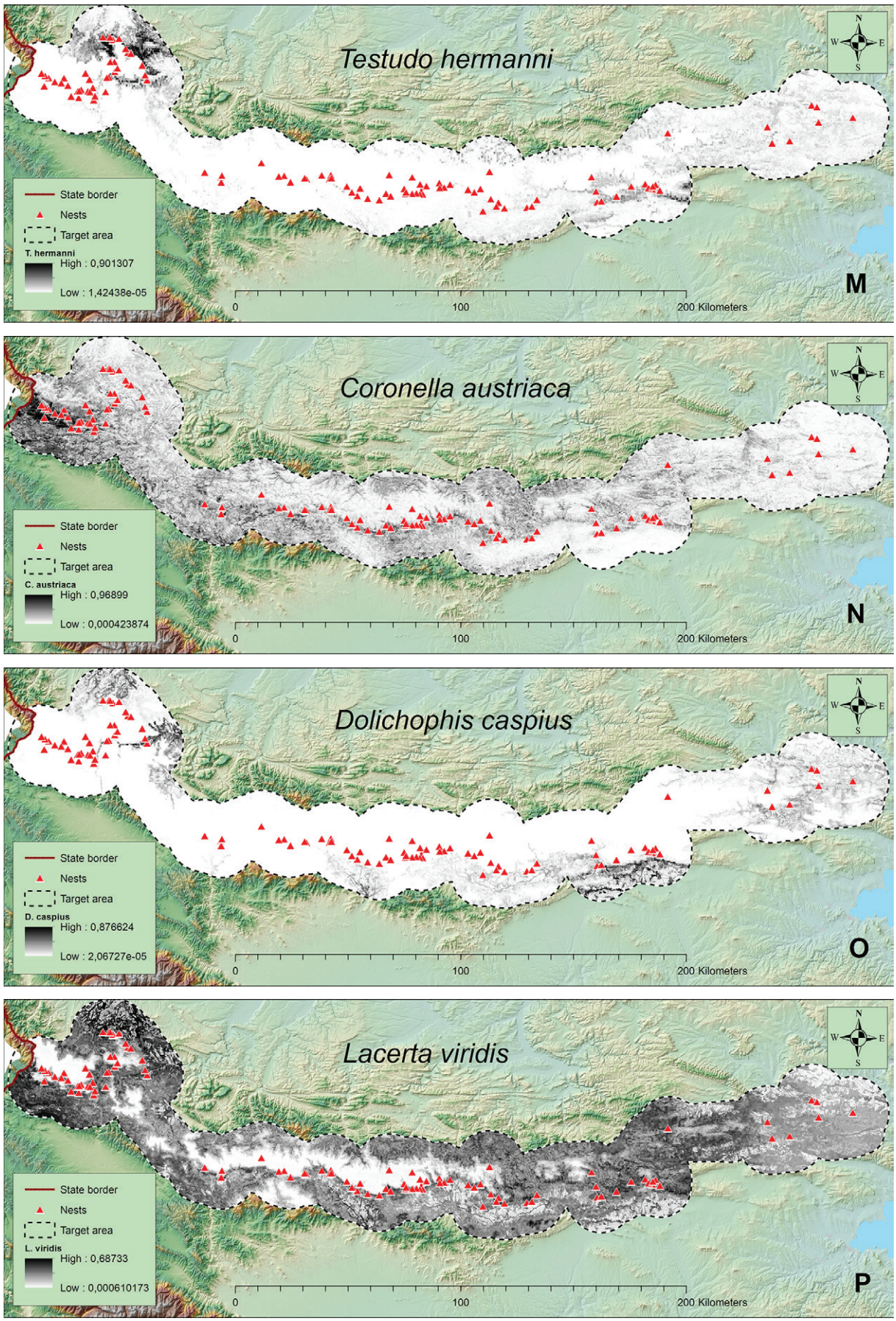


Fig. 2. Continuation.

cies presence over 50 %. It is calculated as a sum of raster cells for the habitat areas of each prey species, calculated for each breeding territory of the target birds of prey species. 2. Areas (m^2) of habitats in which the probability of each prey species presence was over 50 %. Those were registered individually for each of the prey species in each breeding territory of the target birds of prey species. The analyses included each of the eight species for the golden eagle, nine species for the long-legged buzzard, and seven species for the peregrine falcon (Table 1). 3. Pairs' shared areas (m^2) of the habitats with foraging resources – areas of the habitats with foraging resources in which each pair of the target birds of prey species used independently or shared either with birds of the same species and other species, registered for each breeding territory of the target birds of prey species.

Statistical analyses

Statistical data analyses were performed using STATISTICA, v. 12 (Data Analysis Software System, StatSoft Inc. 2014) and PAST software (Hammer et al. 2001). Descriptive statistics were used to calculate the following parameters: (1) Percentage of the prey species habitats cumulative areas from the areas of the target birds of prey breeding territories; (2) Percentage of habitat areas for the eight golden eagle prey species, nine long-legged buzzard prey species and seven peregrine falcon prey species. The habitat areas were calculated for each prey species with the cumulative areas in the breeding territory of each target species of birds of prey; (3) Percentage of the breeding territories of the three species of birds of prey according to the prey species diversity; (4) Percentage of the cumulative habitat areas of the prey species from the area of the breeding territories of the three species of birds of prey in Western, Central and Eastern parts of the Balkan Mountains; (5) Percentage of the habitat areas of each of the eight prey species for the golden eagle, of the nine prey species for the long-legged buzzard, and of the seven prey species for the peregrine falcon in Western, Central and Eastern Balkan, from the cumulative areas of the breeding territories of target species; (6) Percentage of the areas of the habitats with foraging resources employed independently and of the areas of the habitats with foraging resources, shared with birds of prey of the same species and the other target species, from the cumulative habitats of the prey species in the territories of the golden eagle, the long-legged buzzard and the peregrine falcon.

Prey species diversity in the nesting territories of the golden eagle, the long-legged buzzard and the peregrine falcon was defined by the Shannon diversity index (H) calculated in PAST software (Hammer et al. 2001). The comparison of the three species according to different parameters, as well as the comparison of the prerequisites for the availability of foraging resources in the three parts of the Balkan Mountains for each of the target species was performed using non-parametric one-way ANOVA.

Results

The highest percentage of cumulative areas was found for the peregrine falcon – 65.51 % (SD = 60.49; n = 20), followed by long-legged buzzard with a very similar value – 63.07 % (SD = 53.97; n = 54), and by the golden eagle – 31.13 % (SD = 26.78; n = 38) (Fig. 3). Statistically significant differences were found between the golden eagle and the long-legged buzzard for the cumulative areas (Kruskal-Wallis test: $H_{2, 112} = 11.866$, P = 0.0027).

In the breeding territories of the golden eagle, the highest average area percentage of the suitable habitats was for *A. graeca* – 29.13 % (SD=21.89; n=38), followed by *C. coturnix* – 27.31 % (SD = 20.97; n = 38) and *S. citellus* – 25.03 % (SD = 31.49; n = 38). Lower percentages were found for *P. perdix* – 4.88 % (SD = 5.19; n = 38), *L. europaeus* – 4.74 % (SD = 10.28; n = 38), *T. hermanni* – 4.51 % (SD = 14.36; n = 38) and *R. rupicapra* – 4.34 % (SD = 5.60; n = 38). Almost no habitats suitable for *T. graeca* were found – 0.06 % (SD = 0.37; n = 38) (Fig. 4A).

In the territories of the long-legged buzzard, cogently the highest average area percentage of the suitable habitats was for *M. arvalis* – 42.55 % (SD = 17.65; n = 54), followed by *S. citellus* – 14.11 % (SD = 17.99; n = 54), *A. graeca* – 14.05 % (SD = 13.46; n = 54) and *C. coturnix* – 12.99% (SD=14.32; n = 54). The percentage was lower for the suitable habitats of *C. austriaca* – 7.48 % (SD = 7.29; n = 54), *L. viridis* – 4.00 % (SD = 11.62; n = 54), *L. europaeus* – 2.57 % (SD = 5.75; n = 54) and *P. perdix* – 1.99 % (SD = 2.57; n = 54). The percentage of the suitable habitats for *D. caspius* was negligibly low – 0.25 % (SD = 1.16; n = 54) (Fig. 4B).

In the territories of the peregrine falcon, the highest average area percentage of the suitable habitats was for *T. viscivorus* – 35.96 % (SD = 10.70; n = 20), followed by *C. palumbus* – 27.13 % (SD = 13.29; n = 20), *A. graeca* – 19.03 % (SD = 13.30; n = 20) and *C. coturnix* – 10.91 % (SD = 15.70; n =20). The percentage was the lowest for the habitats suitable for *A. spinoletta* – 3.41 % (SD = 5.42;

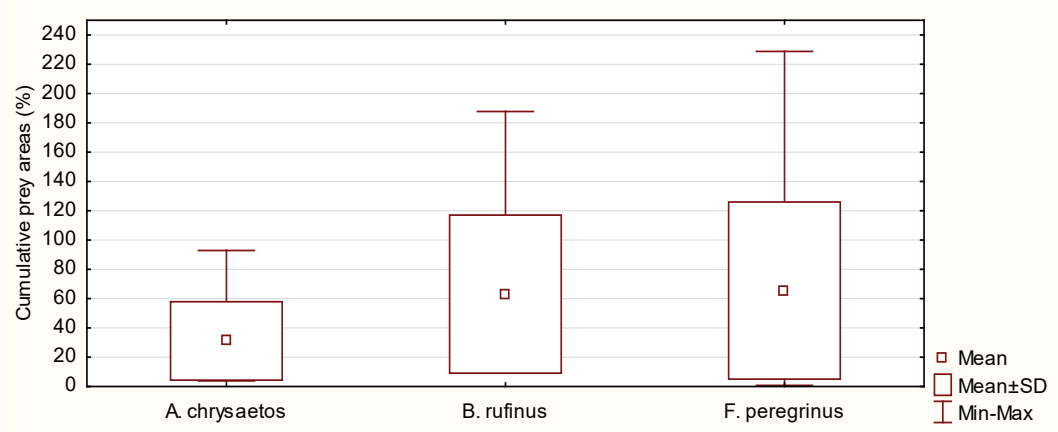


Fig. 3. Percentage of cumulative habitat areas of the prey species from the areas of the breeding territories of the golden eagle, the long-legged buzzard and the peregrine falcon.

Table 2. Percentage distribution of the breeding territories of the golden eagle, the long-legged buzzard and the peregrine falcon according to the prey species diversity

Prey species diversity in breeding territories	Distribution of breeding territories [%]		
	Aquila chrysaetos **(n=38)**	***Buteo rufinus*** **(n=54)**	***Falco peregrinus*** **(n=20)**
1 prey species	2.63	0	0
2 prey species	7.89	0	0
3 prey species	5.26	0	10
4 prey species	0	9.26	10
5 prey species	15.79	1.85	10
6 prey species	60.53	12.96	10
7 prey species	7.89	24.07	60
8 prey species	0	48.15	
9 prey species		3.7	

n = 20), *A. arvensis* – 2.77 % (SD = 2.24; n = 20) and *P. perdix* – 0.80 % (SD = 1.13; n = 20) (Fig. 4C).

The average Shannon (H) index value for the nesting territories of the golden eagle was found to be 1.03 (SD = 0.34; range 0 – 1.66; n = 38). It was 1.25 (SD = 0.24; range 0.54 – 1.53; n = 54) for the long-legged buzzard, and 1.30 (SD = 0.27; range 0.74 – 1.74; n = 20) – for the peregrine falcon. The percentage distribution of the breeding territories of the golden eagle, the long-legged buzzard and the peregrine falcon according to the prey species diversity is presented in Table 2.

The results showing the presence of suitable habitats for 16 potential prey species in the territories of the golden eagle, long-legged buzzard and peregrine falcon in the three parts of the Balkan Mountains are presented in Fig. 5 (A-C). For results of the descriptive statistics, see Table 3.

When comparing the prerequisites for the availability of foraging resources in the territories of the golden eagle, located in the three parts of the mountain (Fig. 5A), statistically significant differences were found between the Western and Eastern and the Central and Eastern parts of the mountain for *A. graeca* (Kruskal-Wallis test: $H_{2, 38}$ = 15.539, P = 0.0004), *S. citellus* (Kruskal-Wallis test: $H_{2, 38}$ = 13.161, P = 0.0014), *P. perdix* (Kruskal-Wallis test: $H_{2, 38}$ = 12.620, P = 0.0018) and *R. rupicapra* (Kruskal-Wallis test: $H_{2, 38}$ = 15.789, P = 0.0004). Statistically significant differences in the cumulative areas between Western and Eastern Balkan (Kruskal-Wallis test: $H_{2, 38}$ = 7.089, P = 0.0289). The differences between Central and Eastern Balkan were very close to the reliable ones.

When comparing the percentage of the habitats of potential prey from the territories of long-legged buzzard in Western, Central and Eastern Balkan (Fig. 5B), statistically significant differences for *S. citellus* between the western and central parts of the mountain were established (Kruskal-Wallis test: $H_{2, 54}$ = 14.605, P = 0.0007). The differences for *C. austriaca* were statistically significant between the Western and Central and between the Western and Eastern parts (Kruskal-Wallis test: $H_{2, 54}$ = 13.462, P = 0.0012). Statistically significant differences for *L. europaeus* were found between the Western and the Central and between the Central and Eastern parts (Kruskal-Wallis test: $H_{2, 54}$ = 19.014, P = 0.0001). The differences between the Western and Eastern Balkan were statistically significant for *M. arvalis* (Kruskal-Wallis test: $H_{2, 54}$ = 6.923, P = 0.0314) and *P. perdix* (Kruskal-Wallis test: $H_{2, 54}$ = 7.893, P = 0.0193). Statistically significant differences were also established between the Western and Central

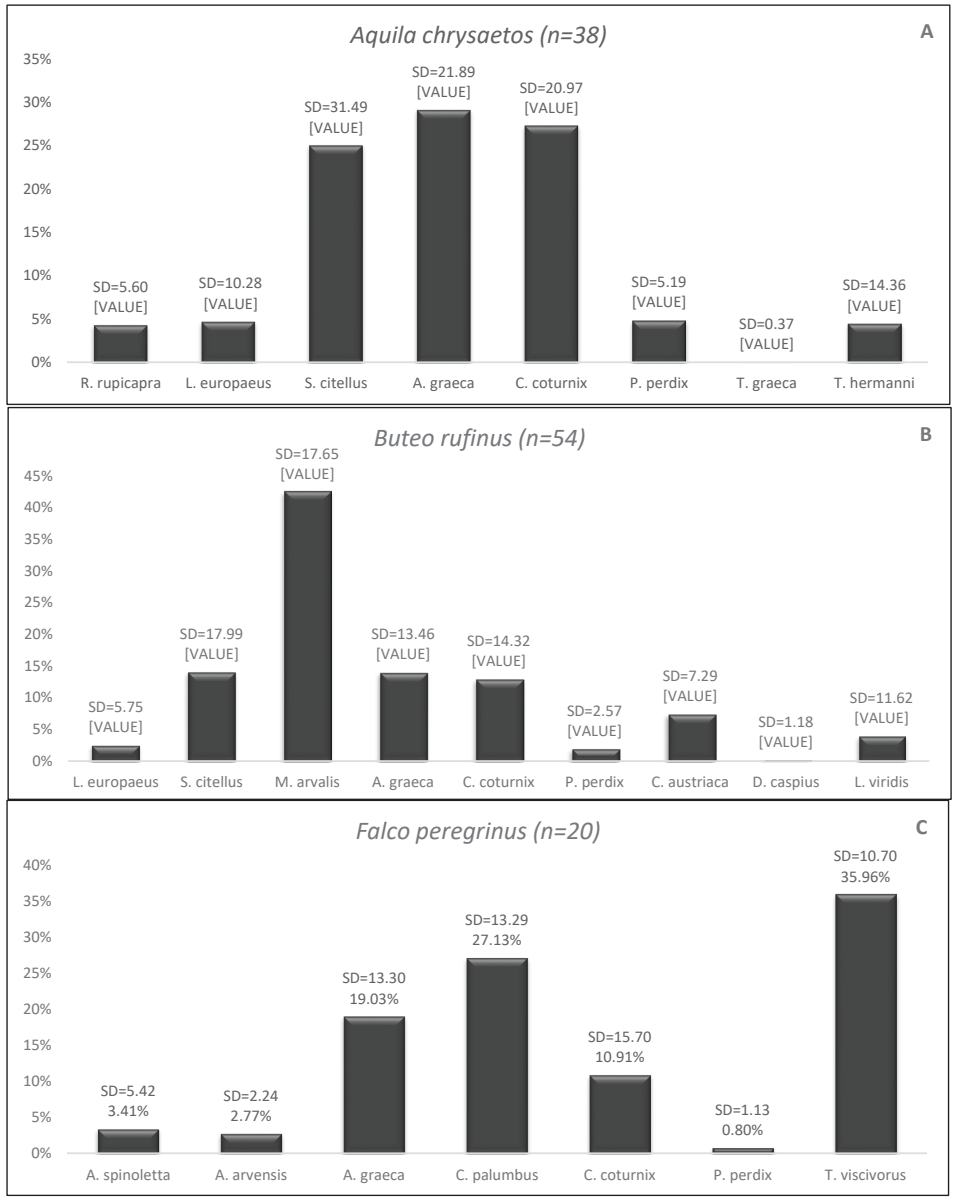


Figure 4 (A-C). Area percentage of the habitats of eight prey species in the territories of the golden eagle (A), nine prey species in the territories of the long-legged buzzard (B) and seven prey species in the territories of the peregrine falcon (C)

Fig. 4. Area percentage of the habitats of eight prey species in the territories of the golden eagle (A), nine prey species in the territories of the long-legged buzzard (B) and seven prey species in the territories of the peregrine falcon (C).

Balkan in the cumulative areas (Kruskal-Wallis test: $H_{2, 54} = 14.402$, $P = 0.0007$).

Comparing the prerequisites for the presence of foraging resources in the territories of the peregrine falcon located in the three parts of the Balkan Mountains (Fig. 5C) revealed statistically significant differences only for two of the prey species covered by the analyses: for *C. palumbus* between Western and Central Balkan and between Western and Eastern Balkan (Kruskal-Wallis test: $H_{2, 20} = 10.929$, $P = 0.0042$), and *T. viscivorus* between Western and Central Balkan (Kruskal-Wallis test: $H_{2, 20} = 8.643$, $P = 0.0133$). No significant differences were found in terms of cumulative areas with present prey among the three parts of the Balkan Mountains.

When comparing the cumulative areas with present prey in the Western, Central and Eastern Balkan, statistically significant differences in the western and eastern parts of the mountain were found among the three species of birds of prey. In the Western Balkan, the differences were significant between the golden eagle and the long-legged buzzard (Kruskal-Wallis

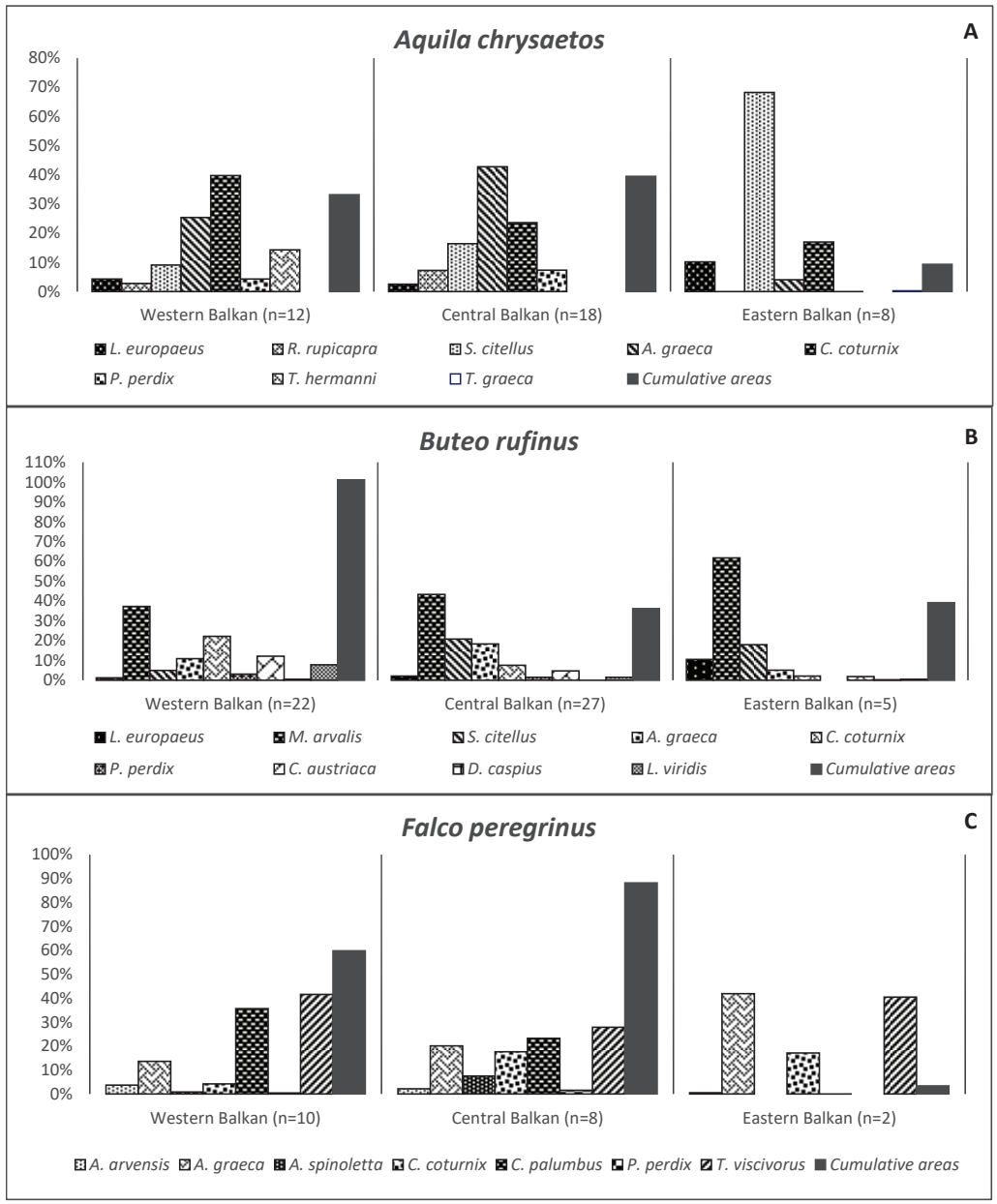


Fig. 5. Percentage of the cumulative and individual (for each prey species) areas of the suitable habitats of eight species of potential prey in the territories of the golden eagle (A), nine species of potential prey in the territories of the long-legged buzzard (B) and seven species of potential prey in the territories of the peregrine falcon (C) in Western, Central and Eastern Balkan.

test: $H_{2, 44} = 7.209$, P = 0.0272). In Central Balkan, no differences were registered among the three species by this parameter. In Eastern Balkan, differences were proven statistically between the golden eagle and the long-legged buzzard and between the long-legged buzzard and the peregrine falcon (Kruskal-Wallis test: $H_{2, 15} = 10.906$, P = 0.0043).

The golden eagle used alone in its territories on average 58.84 % (SD = 22.23; n = 38) of the areas with prey, and on average 41.16 % (SD = 22.23; n = 38) of the prey areas were shared 16.60 % (SD = 13.96; n = 38) with birds of the same species, and 24.56 % (SD = 19.12; n = 38) with birds of the other two species. In the territories of the long-legged buzzard, the areas used by the species alone were on average 53.39 % (SD = 21.58; n = 54), and these, which share were on average 46.61 % (SD = 21, 58; n = 54) – 10.49 % (SD = 9.48; n = 54) - with birds of the same species, and 36.12 % (SD = 23.27; n = 54) with birds of the other species. The peregrine falcon used alone in its territories on average 77.17 % (SD = 12.27; n = 20) of its prey areas; on average

Table 3. Results of the descriptive statistics for the areas of the suitable habitats of eight species of potential prey in the territories of the golden eagle (A), nine species of potential prey in the territories of the long-legged buzzard (B) and seven species of potential prey in the territories of the peregrine falcon (C) in Western, Central and Eastern Balkan

	West Balkan					Central Balkan					East Balkan				
A	***Aquila chrysaetos***														
Prey	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD
R. rupicapra	12	4.54	0.02	15.86	5.13	18	7.26	0.02	16.81	6.45	8	0.05	0.00	0.24	0.10
L. europaeus	12	3.98	0.00	10.30	3.87	18	2.56	0.00	31.96	7.45	8	10.21	0.00	46.55	18.90
S. citellus	12	9.86	0.16	39.78	13.10	18	16.44	0.00	83.64	25.30	8	68.24	21.48	100.00	25.59
A. graeca	12	27.63	5.18	54.44	14.52	18	42.76	7.59	74.16	20.73	8	4.07	0.00	19.37	7.72
C. coturnix	12	33.15	0.00	73.32	28.15	18	23.61	1.29	60.23	14.27	8	16.99	0.00	39.48	11.70
P. perdix	12	6.56	0.00	19.80	6.16	18	7.37	0.00	19.80	5.17	8	0.15	0.00	1.17	0.41
T. graeca	12	0.00	0.00	0.00	0.00	18	0.00	0.00	0.00	0.00	8	0.28	0.00	2.27	0.80
T. hermanni	12	14.28	0.00	65.37	23.27	18	0.00	0.00	0.00	0.00	8	0.00	0.00	0.00	0.00
Cumulative prey areas	12	40.16	8.19	92.87	29.06	18	39.46	3.90	90.18	29.46	8	9.32	4.20	14.70	3.39
B	***Buteo rufinus***														
Prey	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD
L. europaeus	22	1.23	0.02	3.38	0.91	27	2.18	0.00	23.72	6.41	5	10.58	0.00	21.14	8.66
S. citellus	22	5.00	0.03	33.45	8.85	27	20.82	0.16	62.62	21.03	5	17.98	0.34	38.94	15.01
M. arvalis	22	37.26	9.35	81.58	15.18	27	43.32	16.10	72.94	16.80	5	61.73	42.61	87.43	21.58
A. graeca	22	10.85	2.74	22.41	5.71	27	18.32	0.00	48.54	17.20	5	5.04	0.00	10.31	4.98
C. coturnix	22	22.12	0.00	54.61	17.44	27	7.56	0.00	28.77	6.88	5	2.17	0.08	6.81	3.04
P. perdix	22	3.09	0.00	8.81	3.13	27	1.46	0.00	4.78	1.87	5	0.00	0.00	0.00	0.00
C. austriaca	22	12.13	0.13	25.20	9.04	27	4.75	0.00	11.64	3.16	5	1.82	0.02	3.80	1.35
D. caspius	22	0.48	0.00	8.38	1.82	27	0.08	0.00	1.18	0.25	5	0.22	0.00	0.56	0.24
L. viridis	22	7.84	0.01	51.30	17.38	27	1.53	0.00	10.80	3.14	5	0.47	0.00	1.34	0.56
Cumulative prey areas	22	101.31	20.84	187.74	64.69	27	36.33	11.80	97.69	19.02	5	39.25	18.21	85.36	26.36
C	***Falco peregrinus***														
Prey	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD
A. spinoletta	10	0.83	0.00	3.16	1.23	8	7.49	0.00	21.02	6.79	2	0.00	0.00	0.00	0.00
A. arvensis	10	3.71	0.00	7.45	2.31	8	2.14	0.00	5.94	1.91	2	0.58	0.00	1.16	0.82
A. graeca	10	13.64	3.66	33.29	8.06	8	20.05	10.42	30.70	8.13	2	41.87	19.83	63.92	31.18
C. palumbus	10	35.62	22.06	48.30	7.75	8	23.29	6.18	32.39	8.53	2	0.03	0.00	0.07	0.05
C. coturnix	10	4.26	0.00	16.48	5.58	8	17.68	1.90	63.71	20.62	2	17.09	0.61	33.57	23.31
P. perdix	10	0.39	0.00	2.52	0.77	8	1.51	0.00	4.22	1.31	2	0.00	0.00	0.00	0.00
T. viscivorus	10	41.56	27.61	59.83	8.75	8	27.84	12.07	40.01	8.69	2	40.42	34.24	46.60	8.74
Cumulative prey areas	10	59.82	7.90	153.30	46.46	8	88.14	0.84	228.80	73.65	2	3.43	2.20	4.66	1.74

22.83 % (SD = 12.27; n = 20) were shared - 16.67 % (SD = 13.38; n = 20) with birds of the same species, and 6.17 % (SD = 10.78; n = 20) with birds of the other species (Fig. 6).

Statistically significant differences were found between the golden eagle and the peregrine falcon, as well as between the long-legged buzzard and the peregrine falcon in the prey areas used alone and to the shared prey areas (Kruskal-Wallis test: $H_{2, 112} = 19.010$, $P = 0.0001$). There were differences regarding the prey areas, shared with birds of the other species (Kruskal-Wallis test: $H_{2, 112} = 28.881$, $P < 0.0001$) but not for those shared with birds of the same species.

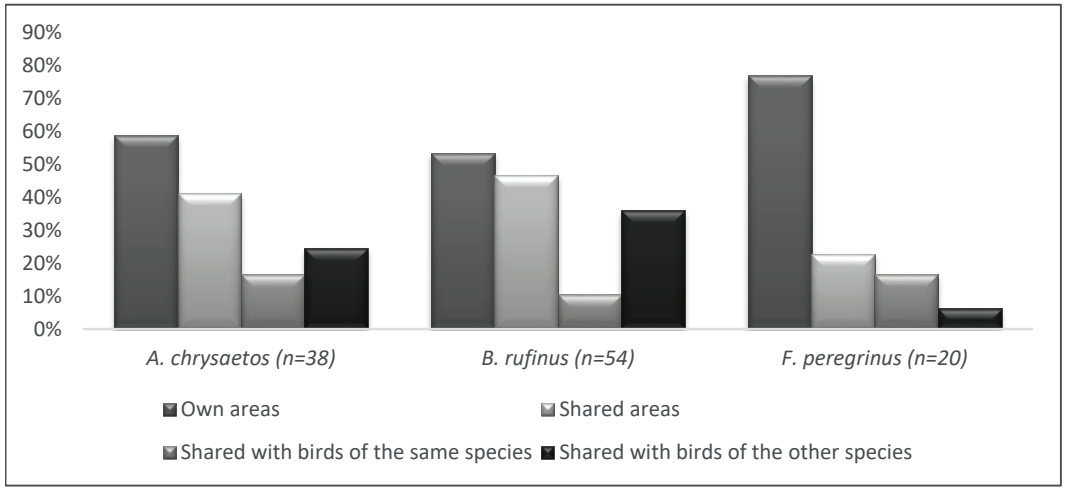


Fig. 6. Percentage of the areas of the habitats with foraging resources which were used independently and of the areas of the habitats, shared with birds of the same species and the other species in the territories of the golden eagle, the long-legged buzzard and the peregrine falcon.

Discussion

Species distribution models although valuable per se, are prone to bias, limitations and lack of credibility due to issues with sampling design, accuracy and resolution of input maps, biotic interactions and lack of model evaluation (post hoc validation and verification) (Guisan & Zimmermann 2000). In the current study, we did not perform a post hoc model evaluation, as our aim was a theoretical study on the potential presence of prey species through the availability of suitable habitat. Although the inherited limitations of such an approach, this is a good starting point for future studies on the prey actual distribution by defining the potentials for their presence.

The golden eagle has a wide food spectrum, it can use alternative foraging resources, when its preferred prey is lower in number (Moss 2011, Katzner et al. 2020), and can adapt its food in response to anthropogenic changes in the environment (Watson et al. 1993). It possesses numerous adaptive hunting skills (Sulkava et al. 1998). In the present study, the outcome of the analyses of the areas with habitats assessed as suitable for golden eagle's prey species indicated that the possible main foraging resources for the golden eagle in the Balkan Mountains must be the rock partridge, the quail and the ground squirrel. The data from the modeled probability of presence of these prey species in the three parts of the Balkan Mountains, implied that the quail and the rock partridge played the leading role as a foraging resource for the golden eagle in the Western and Central Balkan. The key prey species for this bird of prey in the Eastern Balkan was (convincingly so) the ground squirrel - with the highest degree of probability as the most accessible foraging resource. The presence of the ground squirrel in the central part of the mountain was much lower, and in the western very limited. Tortoises, listed as the main species in the food spectrum of the golden eagle on the Balkan Peninsula, Bulgaria inclusive (Arabadzhiev 1962, Boev 1980, Grubač 1986, Simeonov et al. 1990, Watson 1992, Georgiev 2009), in the study area were extremely sparse in the territories of the golden eagle. A low percentage of habitats suitable for Hermann's tortoise was registered in the territories of the golden eagle only in the Western Balkan, and there was a single habitat suitable for Hermann's tortoise in the territory of only one pair of golden eagles in the Eastern Balkan. That gave us reason to assume that in the study area, tortoises did not make a significant contribution as a food source for the golden eagle.

The long-legged buzzard is a species also with broad food preferences. Its diet includes representatives of almost all groups of vertebrates (Cramp & Simmons 1980, Snow & Perrins 1998, Orta et al. 2020). It is able to adapt to local prey abundance (Mrlik & Landsfeld 2002) and switch to alternative food sources (Demerdzhiev et al. 2014). The common vole, with the highest percentage of suitable habitats in the territories of the long-legged buzzard in the study area, stood out as a possible leading foraging resource. The highest average values for habitats suitable for the common vole were found in the Eastern part of the mountain (over 60 %), and the probability of this species presence was also relatively high in the other two parts (about 40 %). The ground squirrel, which has been pointed out as a key species in the food spectrum of the long-

legged buzzard (Michev et al. 1984, Alivizatos & Gounter 1997, Milchev 2009, Redinov 2010), had a more tangible presence in Central and Eastern Balkan, and additionally, it was sparsely distributed in the Western Balkan. In the Western Balkan, the quail in the territories of the long-legged buzzard seemed to hold the second place after the common vole by the presence of suitable habitats, respectively as a possible foraging resource. In many studies in other parts of the range of the long-legged buzzard, reptiles were often found to be present in its food spectrum (Alivizatos & Gounter 1997, Grubač 1999, Hosseini-Zavarei et al. 2008, Yi-Qun et al. 2008, Friedemann et al. 2016). Due to the mountainous nature of the study area, the habitats suitable for reptiles were more limited. Habitats that suggest the presence of the smooth snake and green lizard, often mentioned as a species in the food spectrum of the long-legged buzzard (Michev et al. 1984, Vatev 1987, Simeonov et al. 1990, Milchev 2009), were found mainly in the Western Balkans and with a low percentage, which suggested that the reptiles could not be considered a reliable food source for the long-legged buzzard population in the Balkan Mountains.

A characteristic feature of the peregrine falcon is that its diet is dominated by birds, which are the most abundant in the area (Karyakin & Nikolenko 2009). In the territories of the species in the study area, the mistle thrush had the highest percentage of suitable habitats, followed by the wood pigeon and to a lesser extent of the rock partridge and the quail. When comparing the territories of the peregrine falcon in the three parts of the Balkan Mountains, based on the percentage share of suitable habitats, the mistle thrush could play a leading role as a foraging resource. In the eastern part of the mountain, the percentage of the available habitats suitable for the rock partridge was present in coverage very close to this of the mistle thrush, but a relatively low distribution and abundance of the rock partridge in that part of the mountain was reported (Nikolov et al. 2007, Boev & Nikolov 2015). Therefore, this species probably could not contribute significantly as a source of food for the peregrine falcon in the Eastern Balkan. The presence of the wood pigeon in the territories of the peregrine falcon according to the developed model was most likely concentrated in the Western and Central Balkan.

The peregrine falcon often feeds on feral pigeons (*Columba livia f. domestica*) (Mearns 1983, Stoyanov 2003, Ragyov et al. 2008) and although not included in the analyses in the present study, this species could be a possible food source in the territories located near settlements. The distribution of the quail in the western part of the mountain was extremely scarce. This species could play a role as a foraging resource in the other two parts of the mountain, where the probability of its presence in the territories of the peregrine falcon was about 17 %. Although there was evidence of a relatively high percentage of mammals in the food spectrum of some pairs of the peregrine falcon (about 33% of its prey biomass) (Bradley & Oliphant 1991), due to a lack of information on the presence of mammals in the food spectrum of the peregrine falcon in the study area, species of this class were not included as potential prey in the analyses in this study. The presence of mammals in the diet of this species could be the subject of further studies in the future.

As a result of the performed analyses, it was established that the cumulative areas of the habitats suitable for the potential presence of prey obtained by species distribution models were an important parameter for assessing the preconditions for the presence of foraging resources. The more important analysis in this case was not so much what portion of the bird of prey territory included habitats of potential prey, but how many species (diversity) of potential prey were in that territory.

According to the prey species diversity, the breeding territories of the golden eagle in the study area varied from extremely homogeneous, in which there was only one food species (2.63 % of the territories) to territories in which there were prerequisites for the presence of seven out of the eight potential food species, covered by the analyses (7.89 % of the territories). The majority of the territories (60.53 %) were likely to have around six species of prey.

The prey species diversity in the nesting territories of the long-legged buzzard varied from possible presence of four (9.26 %) up to all nine prey species (3.70 % of the territories). In almost half of the breeding territories (48.15 %), there were prerequisites for the presence of eight species from its food spectrum.

The species diversity of the foraging resource in the territories of the peregrine falcon varied from three species (in 10 % of the territories) to seven species (in 60 % of the territories), i.e. in the predominant part of the territories, there were prerequisites for the presence of all the food species covered by the analyses.

Considering the fact that in the Balkan Mountain Region, in addition to the main prey species included in the analyses, there are others potential prey species inhabiting the open spaces, it can be said that the breeding territories of target species in the study area have good trophic potential. In some

territories, the cumulative areas reached values above 200 percent (Fig. 3), due to the fact that all trophic species included in the analyses have similar habitat requirements – related to open spaces where target species prefer to hunt.

The values of Shannon (H) were the highest for the peregrine falcon, which suggests that its territories had the highest degree of heterogeneity in terms of the diversity of habitats suitable for different species of prey, while those for the golden eagle were characterised by the lowest degree of heterogeneity. The average value of Shannon (H) in the territories of the long-legged buzzard was closer to that found for the peregrine falcon.

When comparing the cumulative areas of the habitats suitable for the presence of prey, the golden eagle was found to have better prerequisites for the presence of foraging resources in the Western and Central Balkan. The territories of the species in the Eastern Balkan were the poorest in terms of foraging resources, which might be an explanation for the lower number of nesting areas established in that part of the study area.

When comparing the nesting territories of the long-legged buzzard, those located in the western part of the mountain possessed the greatest potential for the availability of foraging resources. In the Eastern Balkan, the territories of the long-legged buzzard were characterised by much better preconditions for the availability of foraging resources, compared to those of the other two species.

There is a lack of differences among the three parts of the Balkan Mountains for the peregrine falcon in sense of potential for the availability of foraging resources, but this was expected, in the light of the small number of territories occupied by the species in the Eastern Balkan. This might be due to the fact that the potential for prey species presence is there, but it was not fully realised in actual presence, due to biotic interactions or/and anthropogenic factors. However, the Central Balkan appeared to be the richest in foraging resources, followed by the Western Balkan.

No dependence was established between the cumulative areas of the habitats suitable for the availability of foraging resources and the number of nesting areas in the three parts of the Balkan Mountains. That confirmed the opinion that the occupation of nesting areas depends not only on the availability of foraging resources but also on many other factors (Djorgova et al. 2021a,b).

Based on the significant differences found in the cumulative areas between the golden eagle and the long-legged buzzard, we could assert that in the study area the long-legged buzzard chose nesting territories that were significantly richer in habitats suitable for prey than the territories of the golden eagle.

The sharing of foraging resources is an essential aspect of the intraspecific and interspecific competitive relationships among all species, including birds of prey. It can influence the choice of nesting area and thus it had been a subject of research and evaluation in several studies (Martinez et al. 2008, Evans et al. 2010). In the case of the golden eagle, no clear boundaries were found between their hunting areas - they overlapped significantly, sometimes two or three pairs of eagles hunting on the same hill at different times (Watson 1957). Overlapping territories have also been reported for the peregrine falcons, with clear spatial and temporal separation as birds from different pairs tending not to hunt in the same area at the same time (Jenkins & Benn 1998). Comparing the three studied species, the golden eagle and the long-legged buzzard had a similar percentage of shared (over 40%) and non-shared (over 50 %) areas in their territories with the habitats with foraging resources. The difference lay between the percentage of areas shared with birds of the same species (higher average values were reported for the golden eagle) and with birds of the other species, where the percentage was higher (but not statistically significant) for the long-legged buzzard. The peregrine falcon had the highest percentage of "own" areas (77.17 %), respectively the percentage of shared areas was the lowest (22.83 %), of which 16.67 % were shared with birds of the same species and only 6.17 % - with birds of the other two species. Those results obtained for the peregrine falcon could be explained by the differences in the food spectrum between it and the other two species.

Conclusion

The use of spatial models as an indirect method for assessing the availability of foraging resources for animals and birds of prey in particular is a valuable, low-cost tool that can predict the distribution of species and to some extent even the density of their populations. It allows identifying the possible contribution of certain species in the food spectrum of the birds of prey in a given area and this might serve as a basis for more targeted research. This approach would be particularly applicable for areas where there is still a lack of specific data on the number and distribution of some prey species. The method is especially useful in cases where the target birds of prey species have wide food spectrum, large nesting territories or when the study covers a large area with rugged terrain while very limited field resources are available. Undoubt-

edly, the subsequent verification with field data on the food spectrum of the studied species would only contribute to increasing credibility of modelling results and the reliability of the approach.

Acknowledgements: We are grateful to the Bulgarian Society for the Protection of Birds for providing initial data on the presence in the study area of seven species of birds from the food spectrum of the golden eagle, the long-legged buzzard and the peregrine falcon, which were used in the development of spatial models for the study. We would also like to thank Anton Donchev, Georgi Gerdzhikov, Ivaylo Dimchev and Emma Gateva for providing information on additional locations of the brown hare in the Balkan Mountains, which served in the preparation of the spatial model of the species.

References

Alivizatos H. & Goutner V. 1997. Feeding habits of the Long-legged Buzzard *(Buteo rufinus)* during breeding in North-eastern Greece. Israel Journal of Zoology 43: 257–266.

Arabadzhiev I. 1962. Birds of Prey in Bulgaria. Science and Art, Sofia, pp. 176 (in Bulgarian).

Berry P.M., Dawson T.P., Harrison P.A. & Pearson R.G. 2002. Modelling potential impacts of climate change on the bioclimatic envelope of species in Britain and Ireland. Global Ecology and Biogeography 11: 453–462.

Boev N. 1962. Données sur L'Etendue de l'aire d'habitat estivale de certaines espèces d'oiseaux en Bulgarie. Bulletin de l'Institut de Zoologie et Musée 11: 31-46 (In Bulgarian, summary in French).

Boev N. 1980. What does the Golden Eagle feed on? Hunting and Fishing 12: 24–25.

Boev Z. & Nikolov S. 2015. Rock Partridge (Alectoris graeca Meisner, 1804). In: Red Book of the Republic of Bulgaria. Vol 2. Animals. BAS & MOEW, Sofia (in Bulgarian).

Bradbury R.B., Kyrkos A., Morris A.J., Clark S.C., Perkins A.J. & Wilson J.D. 2000. Habitat selection and breeding success of yellowhammers on lowland farmland. Journal of Applied Ecology 37: 789–805.

Bradley D.M. & Oliphant L.W. 1991. The diet of the Peregrine Falcons at Rankin Inlet, Northwest Territories: an unusually high proportion of mammalian prey. Condor 93: 193–197.

Cramps S. & Simmons K.E.L. 1980. The birds of the Western Palearctic: Vol. II. Oxford University Press, Oxford.

Demerdzhiev D., Dobrev V. & Popgeorgiev G. 2014. Effects of Habitat Change on Territory Occupancy, Breeding Density and Breeding Success of Long-legged Buzzard (*Buteo* rufinus Cretzschmar, 1927) in Besaparski Ridove Spatial Protestion Area (Natura 2000), Southern Bulgaria. Acta zoologica bulgarica, Suppl. 5: 191–200.

Djorgova N., Ragyov D., Biserkov V., Biserkov J. & Nikolov B.P. 2021a. Habitat preferences of diurnal raptors in relation to human access to their breeding territories in the Balkan Mountain Range, Bulgaria. Avian Research 12: 29.

Djorgova N., Ragyov D., Biserkov V., Naumov B. & Nikolov B.P. 2021b. Breeding habitat characteristics of Golden Eagle *Aquila chrysaetos* (Linnaeus, 1771), Long-legged Buzzard *Buteo rufinus* (Cretzschmar, 1829) and Peregrine Falcon *Falco peregrinus* Tunstall, 1771 in the Balkan Mountain Range, Bulgaria. Acta Zoologica Bulgarica 73(3): 357–370.

Dudas M. & Sandor I. 1993. Nesting of the Long-legged Buzzard (*Buteo rufinus)* in the Hortobagy. Aquila 100: 296–298.

Evans R., Pearce-Higgins J., Whitfield P.D., Grant J., MacLennan A. & Reid R. 2010. Comparative nest habitat characteristics of sympatric White-tailed *Haliaeetus albicilla* and Golden Eagles *Aquila chrysaetos* in western Scotland. Bird Study 57: 473–482.

Fick S.E. & Hijmans R.J. 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37(12): 4302–4315. DOI:10.1002/joc.5086.

Friedemann G., Leshem Y., Kerem L., Schacham B., Bar-Massada A., Mcclain K.M., Bohrer G. & Izhaki I. 2016. Multidimensional differentiation in foraging resource use during breeding of two sympatric top predators. Scientific Reports 6. DOI: 10.1038/srep35031.

Georgiev D. 2009. Diet of the Golden Eagle (*Aquila chrysaetos*) (Aves: Accipitridae) in Sarnena Sredna Gora mountains (Bulgaria). Ecologia Balcanica 1: 95–98.

Grubač B. *1986.* The Golden Eagle *Aquila chrysaetos chrysaetos* in South-eastern Yugoslavia. Larus 38/39: 95–135.

Grubač B.R. 1999. Distribution and ecology of the Long-legged Buzzard (*Buteo rufinus* Cretzschmar, 1827) in Central Balkans. Contributions to the Zoogeography and Ecology of the Eastern Mediterranean Region 1: 125–130.

Gruev B. & Kuzmanov B. 1994. General Biogeography. University Press „St. Kliment Ohridski", Sofia, 498 p. (in Bulgarian).

Guisan A., & Zimmermann N. E. 2000. Predictive habitat distribution models in ecology. Ecological modelling 135(2-3): 147–186.

Guisan A. & Thuiller W. 2005. Predicting species distribution: Offering more than simple habitat models. Ecology Letters 8: 993-1009.

Hammer S., Harper D.A.T. & Ryan P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9 pp.

Hosseini-Zavarei F., Farhadinia M.S. & Absalan H. 2008. Habitat Use of Long-Legged Bazzard *Buteo rufinus* in Miandasht Wildlife Refuge, Northeastern Iran. Podoces 3(1/2): 67-72.

Jenkins A. & Benn G. 1998. Home range size and habitat requirements of Peregrine Falcons on the Cape Peninsula south Africa. Journal of Raptor Research 32(2): 90–97.

Karyakin I.V. & Nikolenko E.G. 2009. Peregrine Falcon in Altai-Sayan Region, Russia. Raptor Conservation 16: 96–128.

Katzner T.E., Kochert M.N., Steenhof K., McIntyre C.L., Craig E.H. & Miller T.A. 2020. Golden Eagle (*Aquila chrysaetos*), version 2.0. In: Birds of the World (Rodewald P.G. & Keeney B. K., Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.goleag.02

Kopralev I. *(ed.) 2002.* Geography of Bulgaria. Publisher ForCom, pp. 760 (in Bulgarian).

Krebs J.R., Stephens D.W. & Sutherland W.J. *1983.* Perspectives in optimal foraging. In: Brush A.H. & Clark G.A. (eds.). Perspectives in ornithology. Cambridge University Press, New York: 165–215.

Larson M.A., Thompson F.R., Millspaugh J.J., Dijak W.D. & Shifley S.R. 2004. Linking population viability, habitat suitability, and landscape simulation models for conservation planning. Ecological Modelling 180: 103–118.

Li W.J., Wang Z.J., Ma Z.J. & Tang H.X. 1999. Designing the core zone in a biosphere reserve based on suitable habitats: Yanchang biosphere reserve and the red-crowned crane (*Grus japonensis*). Biological Conservation 90: 167–173.

López-López P., Garcia-Ripollés C., Soutullo Á., Cadahia L. & Urios V. 2007. Identifying potentially suitable nesting habitat for golden eagles applied to 'important bird areas' design. Animal Conservation 10: 208–218.

Martinez J.E., Martinez J.A., Zuberogoitia I., Zabala J., Redpath S.M. & Calvo J.F. 2008. The effect of intra- and interspecific interactions on large scale distribution of cliff nesting raptors. Ornis Fennica 85: 13–21.

McGrady M.J., Grant J.R., Bainbridge I.P. & McLeod D.R.A. 2002. A model of Golden Eagle (*Aquila chrysaetos*) ranging behavior. Journal of Raptor Research 36: 62–69.

McLeod D., Whitfield P.D., Fielding A., Haworth P. & McGrady M. (2002). Predicting home range use by golden eagles *Aquila chrysaetos* in western Scotland. Avian Science 2: 183–198.

Mearns R. 1983. The diet of the peregrine *Falco peregrinus* in south Scotland during the breeding season. Bird Study 30: 81–90.

Michev T., Vatev I., Simeonov P. & Profirov, L. 1984. Distribution and Nesting of the Long-Legged Buzzard *Buteo rufinus* (Cretzchmar, 1827) in Bulgaria. Ecology 13: 74–81 (in Bulgarian).

Milchev B. 2009. Breeding biology of Long-Legged Buzzard *Buteo rufinus* in SE Bulgaria, nesting also in quarries. Avosetta 33: 1–8.

Moss E. 2011. Golden eagle (*Aquila chrysaetos*) ecology and forestry. Introductory Research Essay № 10, Swedish University of Agricultural Sciences.

Mrlik V. & Landsfeld B. 2002. The occurrence of Long-legged Buzzard (*Buteo rufinus*) in parts of Central Europe during 1980-1998 and possible factors for its recent expansion. Egretta 45: 104–114.

Nikolov S., Boev Z. & Delov V. 2007. Rock Partridge (*Alectoris graeca*). In: Atlas of the breeding birds in Bulgaria. Conservation series/book 10: 188–189, BSPB, Sofia (in Bulgarian).

Orta J., Boesman P.F.D., Kirwan G.M. & Marks J.S. 2020. Long-legged Buzzard (*Buteo rufinus*), version 1.0. In: Birds of the World (del Hoyo J., Elliott A., Sargatal J., Christie D.A. & de Juana E., Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.lolbuz1.01

Pedrini P. & Sergio F. 2002. Regional conservation strategies for a large predator: Golden Eagles (*Aquila chrysaetos*) in the Alpine range. Biological Conservation 103: 163–172.

Petrov A. 1964. On feeding habits of Buteo rufinus Cretzchm. On the lower Cuma. Zool. Schurm. 43: 1412–1414. (in Russian).

Petrov Ts., Spiridonov J., Domuschiev D. & Kurtev, M. 2015. Golden Eagle (*Aquila chrysaetos*, Linnaeus 1758). In: Red Book of the Republic of Bulgaria. Vol 2. Animals. BAS & MOEW, Sofia (in Bulgarian).

Phillips J., Anderson R.P. & Schapire R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190: 231–259.

Phillips S.J. & Dudik M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31: 161–175.

Phillips S.J., Dudík M. & Schapire R.E. 2017. Maxent software for modeling species niches and distributions (Version 3.4.1). Available from http://biodiversityinformatics.amnh.org/open_source/maxent/ (accessed on 2/08/2017).

Popov V.V. 2015. Presence-only Habitat Suitability Modelling Using Unclassified Landsat ETM+ Imagery: Fine-resolution Maps for Common Small Mammal Species in Bulgaria. Acta Zoologica Bulgarica 67(1): 51–66.

Ragyov D., Demerdziev D. & Angelov I. 2008. Peregrine in Bulgaria – general overview. In: Sielicki J., Mizera T. (editors). Peregrine Falcon populations – status and perspectives in the 21st century. Turul, Warsaw 2008: European Peregrine Falcon Working Group, Society for the Protection of Wild Animals "Falcon", p. 345–360.

Redinov K.O. 2010. Ecology of the Long-legged Buzzard in Mykolayiv region (South Ukraine). Berkut 19(1-2): 116–132 (in Russian).

Simeonov S., Michev T. & Nankinov D. 1990. Fauna of Bulgaria. Vol. 20 Aves, Part I. pp. 148. Publisher of BAS (in Bulgarian).

Skov F. & Svenning J.C. 2004. Potential impact of climatic change on the distribution of forest herbs in Europe. Ecography 27: 366–380.

Snow D.W. & Perrins C.M. (eds.). 1998. The birds of the western palearctic. Vol. I. Concise edition. Oxford University Press, Oxford, 1008 pp.

Stoyanov G. 2003. Peregrine Falcon *Falco peregrinus*. Acrocephalus 24(116): 41–42.

Stoyanov G.P., Borisov B., Antonov A., Domuschiev D. & Petrov Ts. 2015. Peregrine Falcon (*Falco peregrinus,* Tunstall, 1771). In: Red Book of the Republic of Bulgaria. Vol 2. Animals. BAS & MOEW, Sofia (in Bulgarian).

Stoynov E., Petrov Ts., Tonchev B., Ruskov K., Hristov H. & Profirov L. 2007. Peregrine Falcon (*Falco peregrinus*). In: Atlas of the breeding birds in Bulgaria. Conservation series/book 10: 188–189, BSPB, Sofia (in Bulgarian).

Sulkava S., Huhtala K., Rajala P. & Tornberg R. 1998. Changes in the diet of the Golden Eagle *Aquilla chrysaetos* and small game populations in Finland in 1957-96. Ornis Fennica 76: 1–16.

Thuiller W. 2003. BIOMOD – optimizing predictions of species distributions and projecting potential future shifts under global change. Global Change Biology 9: 1353–1362.

Vatev I. 1987. Notes on the breeding biology of the Long-legged Buzzard (*Buteo rufinus*) in Bulgaria. The Journal of Raptor Research 21(1): 8–13.

Vatev I., Angelov I., Domuschiev D. & Profirov L. 2015. Long-legged Buzzard (*Buteo rufinus*, Cretzschmar 1827). In: Red Book of the Republic of Bulgaria. Vol 2. Animals. BAS & MOEW, Sofia (in Bulgarian).

Watson A. 1957. The breeding success of Golden Eagles in the north-east highlands. The Scottish Naturalist 69(3): 153–169.

Watson J. 1992. Status of the Golden Eagle *Aquila chrysaetos* in Europe. Bird Conservation International 2: 175-183.

Watson J. 1997. The Golden Eagle. T & A.D. Poyser, London.

Watson J., Leitch A.F. & Rae S.R. 1993. The diet of the Golden Eagle *Aquila chrysaetos* in Scotland. Ibis 135: 387–393.

White C.M., Clum N.J., Cade T.J. & Hunt W.G. 2020. Peregrine Falcon (*Falco peregrinus*), version 1.0. In: Birds of the World (Billerman S.M., Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.perfal.01

Yanez M. & Floater G. 2000. Spatial distribution and habitat preferences of the endangered tarantula *Brachypelma klaasi* (Araneae: Theraphosidae) in Mexico. Biodiversity and Conservation 9: 795–810.

Yi-Qun W., Ming M., Feng X., Ragyov D., Shergalin J., Nai-Fa L. & Dixon A. 2008. Breeding biology and diet of the Long-legged Buzzard (*Buteo rufinus*) in the Eastern Junggar basin if Northwestern China. The Journal of Raptor Research 42(4): 45–52.

Received: 19.01.2022
Accepted: 27.05.2022