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First comprehensive study on the tetrapod fauna of "Byala Krava" Reserve, Central Balkan Mtns., Bulgaria

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Abstract. The "Byala krava" Reserve is located in the easternmost part of the Central Balkan Mountains, within the administrative boundaries of Elena Municipality, Bulgaria. It covers an area of 93.4 hectares and is entirely situated within the EU Natura 2000 network site BG0000211 "Tvardishka Planina." Despite its relatively small size, the reserve is characterized by a mosaic of mountain forest habitats and rocky formations, which contribute to high ecological heterogeneity and potential for species richness. Previous records have indicated the presence of numerous vertebrate species, including those with national and European conservation status. The current study, conducted between May and September 2024, aimed to provide an updated inventory of the vertebrate fauna and assess potential conservation threats. Standardized field methods included transect walks for visual and acoustic detection of amphibians, reptiles, birds, and mammals, along with the use of box traps for small mammals, camera traps for medium and large mammals, and ultrasonic detectors for bats. A total of 55 vertebrate species were documented, comprising 4 amphibians, 1 reptile, 33 bird species, and 17 mammal species, several of which are of conservation concern at national and international levels. In addition to biodiversity data, several anthropogenic pressures were recorded in the surrounding areas, including logging in adjacent areas, poaching, and recreational disturbance. These factors may contribute to habitat degradation and species displacement. The findings emphasize the importance of continuous monitoring and the implementation of targeted management measures to mitigate human impacts and ensure the long-term conservation of the reserve's biological diversity.

Key words: biodiversity, amphibians, reptiles, birds, mammals, vertebrates.

Introduction

The Balkan Peninsula is recognized as a global biodiversity hotspot, with Bulgaria hosting a rich and varied fauna due to its complex topography and diverse ecosystems. Within this context, the Central Balkan Mountains are particularly important for the conservation of forest-dependent vertebrate species. In recent years, biodiversity studies and long-term ecological monitoring have become increasingly important due to the accelerating global decline of species and habitats caused by climate change, habitat fragmentation, pollution, and other anthropogenic pressures. Protected areas are recognized as key instruments for biodiversity conservation; however, their effectiveness depends strongly on continuous scientific assessment and monitoring of species composition and population trends. Recent studies em-

phasize that systematic biodiversity surveys are essential for evaluating conservation status, detecting ecological changes, and supporting evidence-based management decisions in protected areas (Stephenson et al., 2022; Dalton et al., 2024). Furthermore, comprehensive faunal inventories provide baseline data necessary for understanding ecosystem integrity and identifying conservation priorities, particularly in insufficiently studied mountain ecosystems. Despite the establishment of several protected areas in the region, many remain insufficiently studied regarding their vertebrate communities. One such area is the "Byala Krava" Reserve - a strictly protected site within the territory of the Central Balkan Mountains. Until now, only one comprehensive assessment of the tetrapod fauna (amphibians, reptiles, birds, and mammals) has been made (Geographica Ltd., 2014).

The present study represents an integrated field survey of the tetrapod fauna within the "Byala Krava" Reserve. Conducted in May – September 2024 by a multidisciplinary team, the research employed a variety of standard methodologies, including transect walks, live and camera trapping, and acoustic detection. The objective was not only to document the species' presence, but also to assess the ecological integrity of the habitats they occupy and to identify conservation-relevant patterns in species distribution.

By providing the first systematic account of the vertebrate species inhabiting the reserve, this research lays the groundwork for informed management and long-term biodiversity monitoring. Furthermore, the findings offer critical insight into the ecological function of "Byala Krava" as a core habitat for threatened and protected species, contributing to broader conservation efforts across the Central Balkan region.

Materials and methods

Study area

The "Byala Krava" Reserve is situated at the eastern edge of the Central Balkan Mountains, within the administrative boundaries of Kostel village in Elena Municipality, covering 93.4 hectares. The terrain is mountainous and moderately dissected, with an average elevation of 936 meters above sea level. The reserve's highest point reaches 1071 m in the southeastern part, while the lowest is at 699 m in the northwest.

This protected area encompasses the mountainous terrain along the northern slopes of the Elena-Tvarditsa ridge. The reserve derives its name from the distinctive "Byala Krava" ("White Cow") rock formation found at its highest elevation. Its primary purpose is the conservation of ancient beech forests (*Fagus sylvatica* L.), interspersed with sycamore (*Acer pseudoplatanus* L.), ash (*Fraxinus excelsior* L.), Norway maple (*Acer platanoides* L.), and hornbeam (*Carpinus betulus* L.). These beeches form a stable and balanced ecosystem. The soils are characterized as deep, fresh brown forest soils with a clay-sandy texture. Hydrologically, the reserve lacks permanent surface water courses. A significant feature is a karst spring in the northern part. Due to the geological substrate and forest cover, most precipitation infiltrates and contributes to subsurface karst drainage (Bondev, 1991).

The climate is classified as boreal (Dfb) according to the Köppen–Geiger classification, typical for temperate continental regions with mountain influences. It is characterized by cool summers, cold winters, and annual precipitation between 800 and 1100 mm, with stable snow cover for about three months per year. Climatic conditions are heavily moderated by the terrain and dense beech forest cover (Ivanov, 1987).

The entire reserve is included within the Natura 2000 protected area BG0000211 "Tvardishka Planina." Despite comprising only 0.22% of the Natura 2000 zone, it is the sole area designated as a strict nature reserve within this protected region.

Methods

Fieldwork was conducted between May and September 2024. Early access to the area was hindered by barriers and road obstructions, necessitating access via the southern route. One survey effort was significantly impacted by tire damage caused by metal spikes - presumably intended to deter poachers.

The study targeted four main groups of vertebrates - amphibians, reptiles, birds, and mammals, using standard field survey techniques (described below) appropriate to each group.

Amphibians and reptiles were surveyed through visual encounter surveys conducted along predetermined transects that spanned representative habitats within the reserve. Special attention was given to microhabitats such as forest edges, moist leaf litter, and temporary pools or puddles,

which serve as breeding or refuge sites. All individuals were detected visually, including those found during opportunistic searches near water bodies and forest paths.

Birds were documented through a combination of point count stations and transect walks carried out during daylight hours and peak vocal activity periods. Both visual and auditory detections were used for species identification. The method allowed the recording of both resident and migratory species and provided insights into habitat preferences.

Terrestrial mammals were studied using two complementary approaches. Small mammal diversity was assessed through live trapping using Sherman traps (n = 10), strategically placed in suitable habitats such as forest undergrowth and areas with dense ground cover. To detect medium and large mammals, motion-activated infrared camera traps (n = 7) were deployed across the reserve, placed on animal trails. They were set up to take 3 consecutive photos and a 10-second video (5 seconds apart) upon triggering. Additional data on mammal presence was obtained through the identification of tracks, scats, and other field signs encountered during transect walks (Fig. 1).

Bats were surveyed using ultrasonic detectors capable of recording echolocation calls. Recordings were made during evening hours in representative forest habitats, and the resulting sonograms were analyzed to determine species based on call frequency, duration, and structure (Petrov, 2007).

All field observations were geo-referenced using GPS devices and photographed whenever possible for documentation. Species identifications were cross-referenced with taxonomic keys and relevant literature. Each species was assessed in terms of its conservation status based on the provisions of the Bulgarian Biological Diversity Act (BDA, 2002), the Red Data Book of the Republic of Bulgaria (Golemanski, 2015), Annexes II and IV of the EU Habitats Directive 92/43/EEC (EC, 1992), and Appendices II and III of the Bern Convention (Council of Europe, 1979), Hunting And Game Preservation Act - Appendix № 1 (Hunting and Game Preservation Act, 2000), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1973).

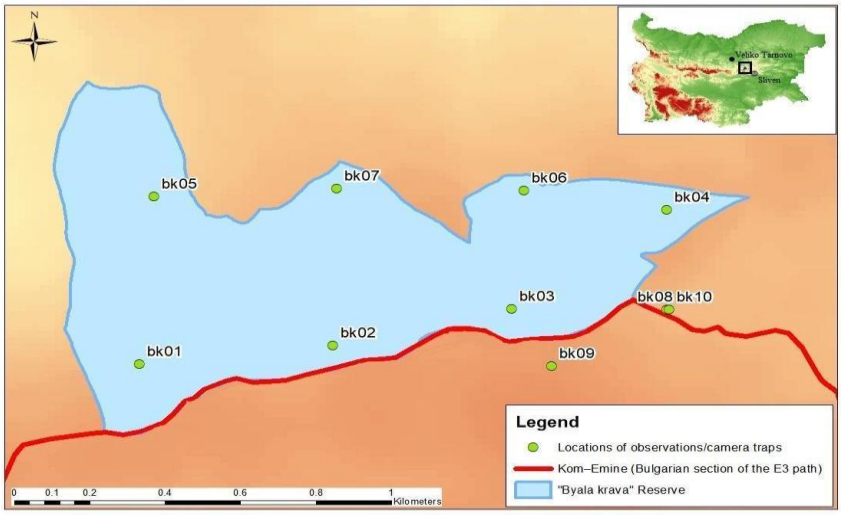

Fig. 1 Map of the study area with camera trap locations and transects.

Results

Five herpetofauna species were confirmed: four amphibians (*Bombina variegata*, *Bufo bufo*, *Rana dalmatina*, *Rana temporaria*) and one reptile (*Podarcis muralis*) (Table 1). Species richness was low, likely due to dense canopy cover and the scarcity of standing water.

The present research identified 33 species of birds from eight orders, presented in Table 2.

A total of 17 species of mammals (13 terrestrial and 4 bats) were documented, including the endangered in Bulgaria wildcat (*Felis silvestris*) and pine marten (*Martes martes*) (Table 3). The most common and widely distributed mammals were the roe deer (*Capreolus capreolus*) and the red deer (*Cervus elaphus*), which were registered on most camera traps and transects.

Discussion

Amphibians and reptiles

The herpetofauna diversity recorded during the present study in the "Byala Krava" Reserve was relatively low, with a total of five species confirmed - four amphibians (*Bombina variegata*, *Bufo bufo*, *Rana dalmatina*, and *Rana temporaria*) and one reptile (*Podarcis muralis*). Several ecological and methodological factors likely contributed to this limited species' richness. One primary limitation was the timing of the fieldwork, which began after the peak of the amphibian breeding season. Most amphibian species in temperate regions, including Bulgaria, are most active and detectable during early spring when they congregate at breeding sites. As field activities commenced in May, some species may have already completed reproduction and dispersed to terrestrial habitats, thereby reducing detection probability. Additionally, the landscape of the "Byala Krava" Reserve is dominated by mature deciduous forest with a dense canopy and limited open or aquatic habitats. The almost complete absence of permanent water bodies within the core zone of the reserve significantly restricts breeding opportunities for many amphibian species, particularly those dependent on standing or slow-flowing water. The amphibian species that were detected were observed either near temporary pools formed in forest roads (e.g., *Bufo bufo*, R*ana dalmatina*) or at the periphery of the reserve, where environmental conditions were more heterogeneous.

The single reptile species recorded, the common wall lizard (*Podarcis muralis*), was found in the buffer zone where rocky and sunlit microhabitats are more prevalent. The reserve's core forested areas are less suitable for heliothermic (sun-basking) reptile species, which typically require open areas with high solar exposure. However, based on habitat suitability and regional distribution, it is our expert opinion that other reptile species, such as *Coronella austriaca* (Smooth snake), and *Vipera berus* (Common European adder), also occur within or near the reserve. These species may have gone undetected due to low survey effort, cryptic behavior, or seasonal timing.

It is worth noting that all five recorded species are listed in either national or international conservation frameworks. Notably, *Bombina variegata* is included in Annex II of the EU Habitats Directive and Annex II of the Bern Convention, indicating its conservation importance and the need for habitat protection measures. The presence of such species underscores the ecological value of the reserve despite its limited herpetofauna diversity.

Similar studies conducted in other Natura 2000 areas in Bulgaria have reported higher amphibian and reptile diversity compared to the present research. For example, Slavchev et al. (2019) documented 22 herpetofauna species in the Natura 2000 site "Pastrina" during a long-term study conducted over five years, which likely contributed to the higher species richness recorded. Future studies should aim to extend the temporal range of fieldwork to include early spring and late summer, when detectability of different amphibian and reptile species is maximized.

Table 1. List of the observed amphibians and reptiles, and legal and conservation status. **BBA** – Bulgarian Biodiversity Act, II, III, IV, V – the number of Appendix in BBA; **RDB** - Red Data Book of the Republic of Bulgaria, - EN – endangered species, VU – vulnerable species, EX - extinct species; **HD** – Habitats Directive 92/43/EEC; **BC** – Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention).

Family/species	Latin name	Legal and conservation status			
		BBA	RDB	HD	BC
Bufonidae					
Common toad	*Bufo bufo*	III			III
Ranidae					
Agile frog	*Rana dalmatina*	II		IV	II
Common frog	*Rana temporaria*	IV		V	III
Bombinatoridae					
Yellow-bellied toad	*Bombina variegata*	II, III		II, IV	II
Lacertidae					
Common wall lizard	*Podarcis muralis*			IV	II

Birds

Most of the identified bird species were common and typical for forest habitats - European robin (*Erithacus rubecula*), Song thrush (*Turdus philomelos*), Eurasian nuthatch (*Sitta europea*), etc. The vast distribution of forests in the researched area provides favorable conditions for woodpeckers' presence, including Black (*Dryocopus martius*), White-backed (*Dendrocopos leucotos*) and Great spotted woodpecker (*Dendrocopos major*), the first two included in the Red Data Book of the Republic of Bulgaria as "Vulnerable" and "Endangered" categories respectively. During the field work, many hollows and other traces of woodpecker activities were observed. Among the rare forest species observed was the Woodcock (*Scolopax rusticola*).

The Cinereous vultures (*Aegipius monachus*) passing through the researched area were mostly birds, released during the long-term reintroduction program and already nesting in the neighboring area of Kotel mountain (Ivanov et al., 2022). The movements of the birds, including entering the reserve's area, were intensively tracked with GPS-GSM transmitters.

Among the other large soaring species, Black stork (*Ciconia nigra*) and Golden eagle (*Aquila chrysaetos*) nesting was not confirmed, so most probable these species visit the area during foraging for food sources. Both species are included in The Red Data Book of the Republic of Bulgaria as "Vulnerable". Most of the observed species in general are under protection from the Biological Diversity Act.

Similar research on bird species richness was conducted in other protected areas in Bulgaria (Dyulgerova & Nikolov, 2014; Shurulinkov et al., 2018). Although some differences could be found in the studies' time range or the methods used, the information gathered in all cases is important for the evaluation of the importance of biodiversity in areas, which could be used for relevant conservation management.

Table 2. List of the observed birds and number of locations in which the species were observed during the study and legal and conservation status. **BDA –** Biological Diversity Act, II, III, IV, V – the number of Appendix in BBA; **HGPA** - I – Hunting And Game Preservation Act; **RDB** - Red Data Book of the Republic of Bulgaria, - EN – endangered species, VU – vulnerable species, EX - extinct species; **BC** – Convention on the Conservation of European Wildlife and Natural Habitats; **CITES –** Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Order/ species	Latin name	No. of locations	Legal and conservation status				
			BDA	HGPA - I	RDB	BC	CITES
Ciconiiformes							
Black stork	*Ciconia nigra*		II, III		VU	II	II
Accipitriformes							
Common buzzard	*Buteo buteo*		III			II	II
Golden eagle	*Aquila chrysaetos*		III		VU	II	
Cinereous vulture	*Aegipius monachus*		II, III		EX	II	II
Charadriiformes							
Woodcock	*Scolopax rusticola*	1	IV		VU	II	
Piciformes							
Great spotted woodpecker	*Dendrocopos major*		III			II	
Black woodpecker	*Dryocopus martius*		II, III		VU	II	
White-backed woodpecker	*Dendrocopos leucotos*	1	II, III		EN	II	
Cuculiformes							
Common cuckoo	*Cuculus canorus*		III			III	
Columbiformes							
Common wood pigeon	*Columba palumbus*	5	IV, VI	+			

Coraciiformes				
European bee-eater	*Merops apiaster*	II		II
Passeriformes				
Grey wagtail	*Motacilla cinerea*	III		II
Robin	*Erithacus rubecula*	II		II
Song thrush	*Turdus philomelos*	III		III
Mistle thrush	*Turdus viscivorus*	III		III
Common blackbird	*Turdus merula*	III		III
Common chiffchaff	*Phylloscopus collybita*	III		II
Wood warbler	*Phylloscopus sibilatrix*	III		II
Goldcrest	*Regulus regulus*	III		II
Firecrest	*Regulus ignicapillus*	III		III
Blackcap	*Sylvia atricapilla*	III		III
Great tit	*Parus major*	III		II
Coal tit	*Periparus ater*	III		II
Sombre tit	*Parus caeruleus*	III		II
Marsh tit	*Poecile palustris*	III		II
Eurasian wren	*Troglodytes troglodytes*	III		II
Common redstart	*Phoenicurus phoenicurus*	III	VU	III
Eurasian Treecreeper	*Certhia familiaris*	III		II
Common chaffinch	*Fringilla coelebs*	III		III
Eurasian nuthatch	*Sitta europaea*	III		II
Corn bunting	*Miliaria calandra*	III		III
Eurasian jay	*Garrulus glandarius*			III
Rook	*Corvus frugilegus*			III

Mammals

The observed mammalian fauna in the "Byala Krava" Reserve, as documented in Table 3, reveals a compelling profile of species richness and conservation priority that extends beyond mere listing. The survey successfully documented several species of wide-ranging carnivores and ungulates, including predators such as the gray wolf (*Canis lupus*) and the red fox (*Vulpes vulpes*). The presence of the European wildcat (*Felis silvestris*), recorded across four locations, is particularly noteworthy given its status as an "Endangered" (EN) species nationally and its specific protection under Annex IV of the Habitats Directive, highlighting the reserve's function as a critical refuge for this elusive felid. Similarly, the pine Marten (*Martes martes*), another "Endangered" (EN) mustelid, warrants focused management efforts.

The high frequency of observation for large herbivores, with roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) being the most detected species (7 and 6 locations, respectively), indicates substantial populations and healthy ecosystem dynamics. While these species are primarily managed under hunting regulations, their abundance is vital for supporting the reserve's predator base. The documentation of multiple bat species, including the Annex II listed Bechstein's bat (*Myotis bechsteinii*), greater mouse-eared bat (*Myotis myotis*), and lesser horseshoe bat (*Rhinolophus hipposideros*), underscores the importance of the reserve's forest structure, potential roost sites (caves/trees), and connectivity within the wider landscape for safeguarding these highly sensitive chiropterans.

The mammalian richness documented in "Byala Krava" (17 species) is significant considering the reserve's small territory of only 93.4 ha, which represents a mere 0.22% of the Natura 2000 site "Tvardishka Planina". In comparison, larger adjacent protected areas like "Bulgarka" Nature Park (MOEW, 2014) have reported a higher number of mammal species (over 60), but those results stem from much larger territories and decadal

monitoring. The presence of apex predators like the gray wolf (*Canis lupus*) and protected felids like the European wildcat (*Felis silvestris*) in such a restricted area suggests that "Byala Krava" acts as a vital core habitat and a quiet refuge within the more fragmented landscape of the eastern Central Balkan. Unlike broader surveys in the Central Balkan National Park (MOEW 2016), our study did not register the brown bear (*Ursus arctos*), which is likely due to the lack of permanent water sources and the relatively short duration of the camera-trapping period.

This diverse representation of the mammalian fauna, from terrestrial predators to arboreal rodents like the red squirrel (*Sciurus vulgaris*) and the edible dormouse (*Myoxus glis*), reinforces the "Byala Krava" Reserve's crucial role in maintaining regional biodiversity, necessitating continued monitoring and strict adherence to established protective legislation.

Table 3. List of the observed mammals, number of locations in which the species were observed and legal and conservation status. **BDA –** Biological Diversity Act, II, III, IV, V – the number of Appendix in BBA; **HGPA** - I – Hunting And Game Preservation Act; **RDB** - Red Data Book of the Republic of Bulgaria, - EN – endangered species, VU – vulnerable species, EX - extinct species; **HD** – Habitats Directive 92/43/EEC; **BC** – Convention on the Conservation of European Wildlife and Natural Habitats. **CITES** – Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Family/ species	Latin name	No. of locations	Legal and conservation status					
			BDA	HGPA - I	RDB	HD	BC	CITES
Canidae								
Red fox	*Vulpes vulpes*	2		+				
Gray wolf	*Canis lupus*	1	II, IV	+	VU	II, IV	II	II
Felidae								
European wildcat	*Felis silvestris*	4	III		EN	IV	II	II
Suidae								
Wild boar	*Sus scrofa*	4		+				
Cervidae								
Red deer	*Cervus elaphus*	6		+			III	
Roe deer	*Capreolus capreolus*	7		+			III	
Leporidae								
European hare	*Lepus europeus*	1		+			III	
Mustelidae								
Stone marten	*Martes foina*	2		+			III	
Pine marten	*Martes martes*	1	III		EN	V	III	
Sciuridae								
Red squirrel	*Sciurus vulgaris*	2		+			III	
Edible dormouse	*Myoxus glis*	1					III	
Erinaceidae								
Northern white-breasted hedgehog	*Erinaceus roumanicus*	1	III					
Muridae								
Wood mouse	*Apodemus sylvaticus*							
Vespertilionidae								
Common pipistrelle	*Pipistrellus pipistrellus*	1	II, III			IV	III	
Greater mouse-eared bat	*Myotis myotis*	2	II, III			II, IV	III	
Bechstein's bat	*Myotis bechsteinii*	1	II, III		VU	II, IV	II	
Rhinolophidae								
Lesser horseshoe bat	*Rhinolophus hipposideros*	1	II, III			II, IV	II	

Conclusions

In conclusion, while species richness of amphibians and reptiles appear modest within "Byala Krava" this may reflect both environmental constraints and methodological limitations rather than true faunal absence. The presence of protected and indicator species highlights the conservation relevance of the area and justifies continued monitoring and habitat-based conservation measures.

A major part of the observed birds during the study is related to forest habitats, including species of conservation significance like the Woodcock (*Scolopax rusticola*) and Black woodpecker (*Dryocopus martius*). In addition, large soaring birds also visit the reserve's territory, including the Cinereous vulture (*Aegipius monachus*), listed as "Extinct" in the Red Data Book of Bulgaria, but reintroduced recently in some adjacent areas of the country. The present study confirms the general importance of the researched area for the ornithofauna and requires additional long-term observations in order to add knowledge to the species richness and the possible conservation threats, which could assist the adequate management of the reserve.

The documentation of 17 mammal species within such a limited area confirms the "Byala Krava" Reserve as a vital refuge and a key biological stepping-stone. These findings emphasize the reserve's role in maintaining ecological connectivity within the "Tvardishka Planina" Natura 2000 site and its importance as a core habitat for species of high conservation value in the eastern Central Balkan.

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