Journal of Archaeological Science: Reports 72 (2026) 105784

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

The Koznik fortress menu: archaeozoological insights into the diet during the late medieval and early modern periods

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ARTICLE INFO

Keywords:
Archaeozoology
Animal remains
Diet
Koznik
Late medieval period
Early modern period

ABSTRACT

The Koznik fortress, located on the western slopes of Mount Kopaonik, 9 km west of Aleksandrovac in southern Serbia, occupies a dominant position at 922 m, overlooking the Rasina River. Built on the foundations of an ancient predecessor, the fortress flourished during the latter half of the 14th century and during the 15th century. The Upper Town has an almost triangular base adjusted to the terrain configuration and was fortified with eight towers, while the Suburb developed south of the fortress. From its earliest mention in 1381, Koznik remained under Serbian rule until 1425–1427, after which it passed under Ottoman control while retaining its strategic importance until its abandonment in the late 17th century, with a brief interruption between 1451 and 1453, when it was once again under Serbian administration. Archaeological investigations have been carried out at Koznik on several occasions, with the most recent campaigns in 2019 and 2022 focusing on the Upper Town and the Suburb. The analysed faunal assemblage derives from these excavations and constitutes the first archaeozoological dataset from both late medieval and early modern period layers of the fortress. The results reveal significant differences in the exploitation of domestic and wild animals across the settlement zones and through time. These patterns provide insights into dietary dynamics, access to more valuable meat portions, and practices related to the use of secondary animal products. Beyond illuminating aspects of everyday life at Koznik, these findings help to fill the gap in archaeozoological evidence for the late medieval and particularly the early modern period in Serbia, establishing an essential foundation for future studies on animal husbandry, diet, and economic practices in this still underexplored context.

1. Introduction

The issue of human diet in the past is highly significant for reconstructing and understanding various aspects of the everyday life of human communities throughout different periods of human history. Patterns of nutrition, that is, the dietary practices of the population in the late medieval and early modern periods, based on data obtained through the analysis of archaeozoological material from the territory of present-day Serbia, remain generally insufficiently understood. In order to expand our knowledge of dietary practices during both of the aforementioned periods, animal remains from the Koznik fortress were analyzed. Since no archaeozoological analyses have been performed previously, the results of this paper represent pioneering efforts in understanding human–animal relations at the site. The significance of this assemblage lies in the fact that it allows changes in animal exploitation practices to be traced at the same archaeological site over time. By comparing the late medieval and early modern phases within a single landscape and settlement context, it becomes possible to identify potential shifts in subsistence strategies and economic organization. This is particularly informative given the broader historical framework: during the late medieval period Koznik was under Serbian rule, while in the following centuries it housed an Ottoman garrison owing to its strategic position. The material therefore offers valuable insight into how political and administrative transformations may have influenced patterns of animal use and provisioning at the site.

2. Historical and archaeological background

The Koznik fortress is located approximately 8 km northwest of Brus and about 9 km west of Aleksandrovac, positioned above the Rasina

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https://doi.org/10.1016/j.jasrep.2026.105784
Received 19 February 2026; Received in revised form 1 April 2026; Accepted 20 April 2026
Available online 28 April 2026

River on the eastern slopes of Mount Kopaonik. At an elevation of 922 m a.s.l., it belongs to the group of high-altitude fortifications (Fig. 1). The fortress exercised firm control over the routes leading from the Toplica Valley, across the Rasina River toward the West and Great Morava rivers and the approaches to the capital of Kruševac. At the same time, it controlled the eastern access to Mount Kopaonik and the Ibar Valley via the Jošanica River (Fig. 2).

From its first mention in 1381, in the charter of Prince Lazar to the Great Lavra of St. Athanasius on Mount Athos (Ćirković, 1983: 82–83; Mladenović, 2003: 171–175), until 1425–1427, Koznik remained under Serbian rule. Thereafter, it came under Ottoman control, with the exception of a brief interval between 1451 and 1453 (Blagojević, 1995; Petrović, 2010: 136–137). In the centuries following, Koznik housed an Ottoman garrison and, owing to its strategic position, became the seat of the Koznik nahiye within the Kruševac sanjak. After the Great Vienna War in 1689, when Serbian insurgents captured the fortress, it was abandoned and left to decay (Amedoski and Petrović, 2011; Amedoski et al., 2011; Zirojević, 1974: 126–127).

Early researchers of Koznik, publicists, travel writers, and ethnologists (Milan Đ. Milićević (Milićević, 1876: 712–713), Felix Kanitz (Kanitz, 2007: 80–81), and Sima Trojanović (Trojanović, 1889: 249)), provided only summary descriptions of the fortress ruins and recorded folk legends related to the construction of the fortification. Of particular note is the brief and intuitive observation by Gjuro Szabo (Szabo, 1927: 337), published in a folk encyclopedia, suggesting an ancient origin of the fortress, which later proved to be anticipatory.

The presently visible fortification remains of Koznik consist of the Upper Town and the Suburb. The Upper Town has an approximately triangular ground plan with a quadrangular extension in its southwestern corner, measuring a maximum of 58 × 44 m, and was surrounded by eight towers, one of which is today almost unrecognizable (Fig. 3). In the southeastern part of the fortification, a circular cistern with four wells dating to the Ottoman period was identified. To the south, at a lower elevation, there was another, smaller cistern, likely dating to the medieval period (Well 5). The remains of Moravian-style stone architectural sculpture and fragments of wall paintings suggest that a court church once stood within the fortress complex.

Koznik was perceived in a similar manner by prominent researchers of medieval fortifications, architects Aleksandar Deroko and Ivan Zdravković (Fig. 4). In the published ground plans of the Upper Town, the dimensions of the fortification were recorded, featuring eight robust square towers, as well as a palace and a rectangular structure positioned along the western wall within the ramparts. Both researchers also identified remains of a tower in the Suburb (Deroko, 1950: 119–120, 154, figs. 105–107; Zdravković, 1956; Zdravković, 1970: 48–51).

Research and conservation works at Koznik, organized by the Institute for the Protection of Cultural Monuments in Kraljevo, were carried out with frequent interruptions between 1971 and 1988. As part of these efforts, archaeological investigations were carried out in support of conservation objectives. The results of these investigations have never been published, and the available reports are often lacking drawings of profiles and plans of the investigated areas (Đorđević, 1980: 335–336; Stanić, 1975: 321–322; Vukadin and Minić, 1980: 307; Vukadin, 1984: 46–47; Vukadin, 1988: 286).

At the time, Koznik was considered regarded as part of the group of Moravian fortresses, that is, to the group of newly built strongholds of the 14th century, based on the identification of architectural features characteristic of the military architecture of Moravian Serbia. Accordingly, Koznik was regarded as an example of a small hilltop fortress with an irregular ground plan adapted to the terrain (Popović, 1989).

Archaeological investigations at the fortress were resumed in 2009 and 2011 by the Regional Museum of Župa, under the direction of Associate Professor Dr. Đorđe Janković of the Faculty of Philosophy, University of Belgrade. These investigations resulted in a significant advancement in the understanding of Koznik. The discovery of ramparts in the Suburbs (14th–15th century) demonstrated that Koznik occupied a much larger area than previously assumed, while the recovered pottery shifted the date of the fortress's foundation to Late Antiquity and the Early Byzantine period (4th–6th century). In addition, evidence from the portable archaeological material indicates that Koznik was already in use during the twelfth century during the territorial expansion of the Serbian state under Grand Prince (Veliki Župan) Stefan Nemanja, including into the Rasina region, when Koznik may have functioned as a county (župa)[1] administrative center (Janković, 2014).

Following another hiatus, archaeological investigations were resumed in 2019, organized by the Regional Museum of Župa and the Institute of History in Belgrade, in the area of the Suburb. Through surface tracking of the fortification lines, approximately 400 m of the western and southern ramparts and the outer defensive wall were defined (Fig. 5). The earthen embankment observed in front of the western and part of the southern rampart was identified as a wall of a covered way, extending over a length of 107 m. Built of rubble stone and mortar, with a thickness of 1.7 m, it was positioned 3.8 m in front of the western rampart. The debris remains indicate that these walls were of modest height, approximately 1.5 m, most likely corresponding to the height of the defenders. The outer defensive wall represents one of the innovations of the Moravian Serbia period and, in this case, protected only the most exposed part of the fortification on the approach side. During the same survey, the southwestern tower of the Suburb was partially investigated, in front of which a dry moat was recorded.

Finally, in 2022, archaeological investigations were conducted by Dr Dejan Bulić (Institute of History in Belgrade) to define the eastern rampart of the fortress, to explore Well No. 5, and to examine several structures within the acropolis. On this occasion, modern remote-sensing methods were employed, including LiDAR scanning, geophysical surveys, and radiocarbon (^{14}C) dating.

Using LiDAR data, the eastern rampart was identified, and its outer face was traced across almost its entire length through surface survey (Fig. 6). In the southern section of the rampart, the assumption regarding the existence of an additional southeastern tower in the Suburb was confirmed.

Regarding chronology, in addition to material dating to the Ottoman period and the Late Middle Ages, two ancient coins were discovered during the 2022 trial excavation of the palace. At present, the only evidence of an ancient layer derives from beneath Structure 2 in the Upper Town. Radiocarbon (^{14}C) dating confirmed that samples of animal bones from Structure 1 and Structure 2 date to the very end of the 13th century. It appears that the earliest medieval fortification was limited solely to the area of the Upper Town, and that earlier Late Antique ramparts were partially reused; thus, the remains of the older fortification are represented by the foundations of the former northern rampart.

To the south of the Upper Town lay the Suburb, with several structures still visible on the surface. The most recent investigations in 2019 and 2022 have defined the entire area of the Suburb (Fig. 5). According to current knowledge, the Suburb was fortified during the period of the Despotate, both to protect the surrounding population from the Ottomans and to secure access to water.

Outside the fortified Suburb, traces of habitation and at least two necropolises have been identified. On the right and left sides of the road leading from the village of Grad to the Koznik fortress, the *Veliko* and *Malo groblјište* (Large and Small Cemeteries) are situated opposite one another (Fig. 7). The location of the medieval marketplace was at *Trgovišti*, also known as *Pazarišti*, a saddle-shaped pass outside the fortified Suburb, on the left bank of an unnamed stream (Milošević, 1997: 84). Following a relatively gentle slope adapted to the terrain, *Pazarište* opens toward the north and the *Torovi* area, a narrow, elongated terrace on the northern and northeastern sides of the Koznik slope, with visible remains of former structures. This area is recorded in the cadastral

[1] A župa is a term for a smaller administrative area on the territories of medieval Serbian lands (Vujanić et al. 2011: 359)

Fig. 1. Koznik fortress (photo: D. Bulić).

records as Suburb (*Podgrađe*), which logically suggests its identification with one of the two Suburbs mentioned in the Ottoman defters.

Like other fortified towns from the period of the Nemanjić dynasty, Koznik represents a fortification constructed in a difficult-to-access yet strategically advantageous location, with a primarily defensive function. Since the ramparts of the Suburb have only recently been identified, the term 'Koznik town' previously referred solely to the Upper Town, which led to its interpretation as a newly built, small hilltop fortification of Moravian Serbia dating to the second half of the 14th century. Recent archaeological investigations have clarified why Koznik was established in such a hard-to-reach location, in contrast to most Moravian Serbia towns that developed in fertile lowland areas (e.g. Kruševac, Stalać, Smederevo). Koznik was not a newly founded Moravian Serbia town, but rather an older county fortification, and therefore new principles of urban and fortification planning could not be fully applied. The visible persistence of architectural traditions from earlier periods is directly linked to the existence of an earlier fortification, which was renovated and adapted to the changing requirements of the time. Following recent archaeological research, Koznik has emerged from being regarded as a small hilltop fortification to becoming, in terms of area, one of the largest towns of Moravian Serbia.

3. Materials and methods

During the archaeological campaigns in 2019 and 2022, a total number of 3810 fragmented animal remains were collected manually. Specimens originating from contexts of uncertain date, such as surface and upper layers where mixing with recent material may have occurred, were not included in this study. Chronology was established based on stratigraphic data and associated portable archaeological material, allowing the assemblages to be assigned to the following periods: the late medieval period (14th–first third of the 15th centuries) and the early modern period (second half of the 15th–17th centuries). Within dated layers, 2065 specimens were discovered in the Upper Town (palace, structures 1/22 and 2/22, pit 1/22, Well 5, tower near the northern entrance, area in front of the northern gate, and the eastern rampart) and the Suburb (inner side of the rampart and interior of the tower). However, information on some specimens (1486) originating from layers broadly dated to the 14th–17th centuries is provided in Table 1; these specimens are not discussed in detail in the text, but brief remarks are given on several particularly interesting specimens.

Taxonomic identification, as well as the determination of skeletal elements and their laterality, was carried out using relevant literature (Schmid, 1972; Eisenmann, 1986; Hillson, 1986; Prummel and Frisch, 1986; Peters, 1988; Boyd et al., 1994; Cohen and Serjeantson, 1996; Tomek and Bocheński, 2000; Radu, 2003; Johnstone, 2004; Zeder and Lapham, 2010; Zeder and Pilaar, 2010; Volynskyi et al., 2025) and by comparison with specimens from the comparative collection of the Bioarchaeology Laboratory at the Faculty of Philosophy, University of Belgrade. Due to pronounced fragmentation, species-level identification was not always possible, and some specimens were assigned to higher taxonomic categories. Morphological similarity between sheep and goat bones, as well as equids (horse, donkey, mule), further complicated identification. Specimens that could not be precisely determined at the species level were classified as sheep/goat (*Ovis/Capra*) or equids (*Equus* sp.). To distinguish species within the genus *Equus*, both tooth morphology and postcranial skeletal elements were examined. Species identification based on tooth morphology was carried out following the literature (Eisenmann, 1986; Johnstone, 2004, with references therein). Diagnostic postcranial elements used for species determination include

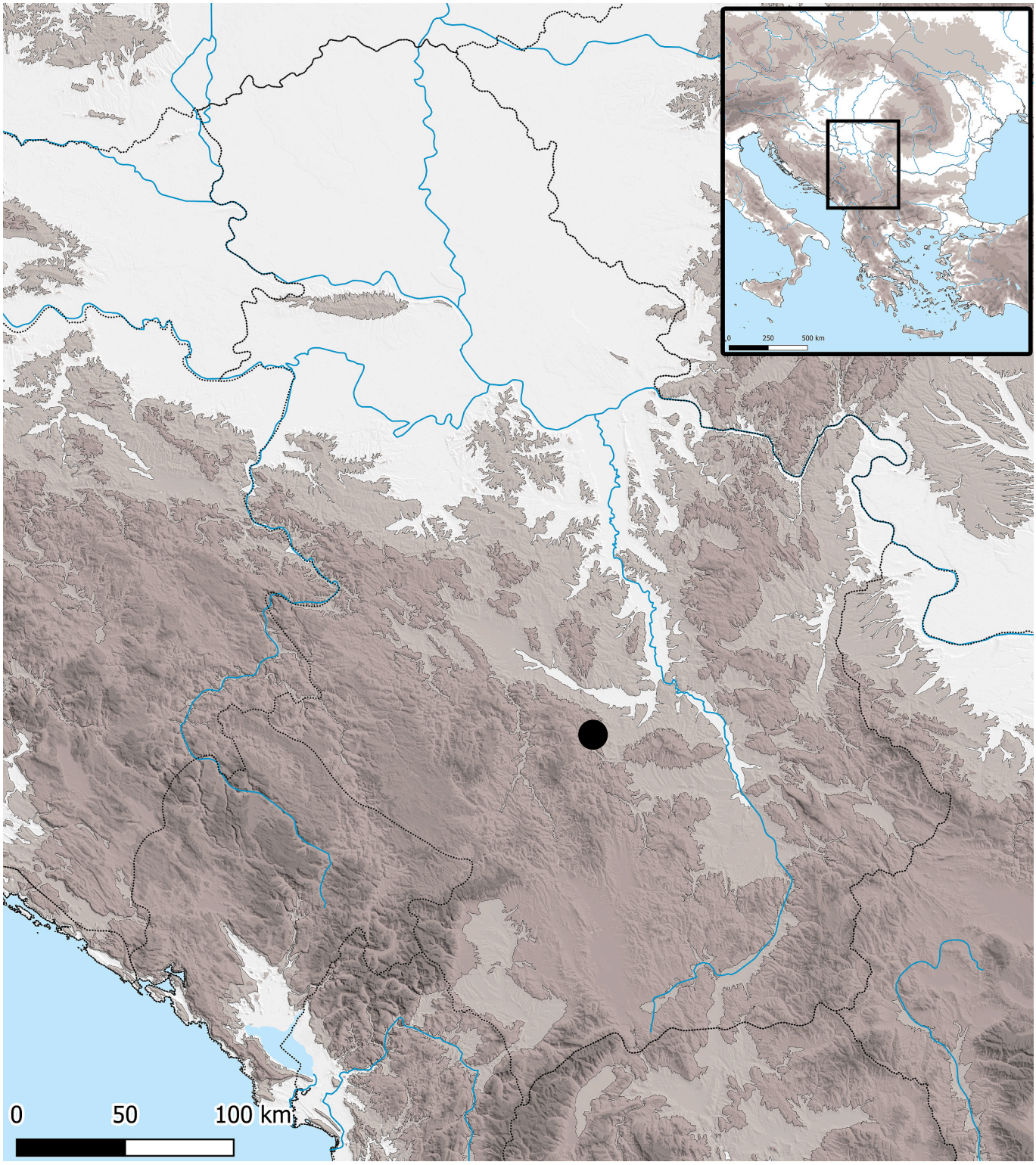

Fig. 2. Geographical position of the Koznik fortress (made by J. Pendić, edited).

the scapula, humerus, radius, metacarpus, femur, tibia, astragalus, and first phalanx (Peters, 1988). Quantification of the archaeofaunal material was performed using three parameters: number of identified specimens (NISP), number of diagnostic zones (DZ (Watson, 1972), and minimum number of individuals (MNI). Age-at-death was determined based on tooth eruption (Silver, 1969; Habermehl, 1975, 1985; Tomé and Vigne, 2003), crown height (Levine, 1982), degree of wear (Grant, 1982), and epiphyseal fusion (Silver, 1969; Habermehl, 1975; Heinrich, 1991; Cochard, 2004; Zeder et al., 2015). For birds, age estimation was based on epiphyseal ossification and long bone porosity (Serjeantson, 2009). Sex determination was largely limited due to the fragmentary nature of the assemblage; in the Koznik sample, sex could only be established based on canine morphology and associated alveoli in domestic and wild pigs (Schmid, 1972), and on the presence of medullary bone in birds (Davis, 1987; Sadler, 1991; Serjeantson, 2009). Taphonomic traces such as decomposition, gnawing, burning, and butchery

Fig. 3. Koznik fortress, aerial view (photo: D. Bulić).

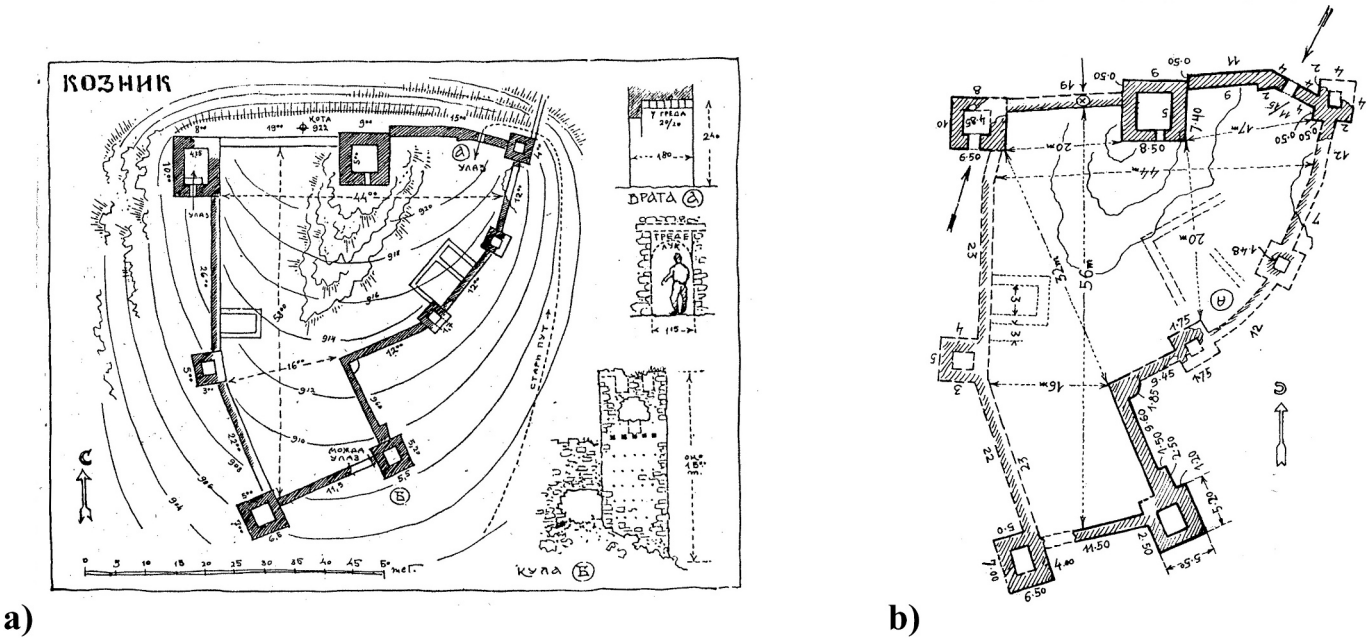

Fig. 4. a) Ground plan of the fortress according to A. Deroko (Deroko, 1950: 119); b) Ground plan of the fortress according to I. Zdravković (Zdravković, 1970: 49).

marks were also recorded. Skeletal elements were grouped into three categories based on meat yield: high-meat elements (trunk and upper limbs), medium-meat elements (lower limbs), and low-meat elements (skull, metapodials, and phalanges). Biometric data were collected following the standardized A. F. D. Drisch system (Driesch, 1976). Animal size was estimated using withers height coefficients proposed by L. Kiesewalter for horses (Kiesewalter, 1880), M. Teichert for sheep (Teichert, 1975), Z. Schram for goats (Schramm, 1967), and J. Matolcsi for cattle (Matolcsi, 1970). According to the Živaljević et al. (2021) total length of beluga sturgeon was also estimated. Biometric analysis was additionally performed using the log-ratio method, also known as the logarithmic size index (LSI) (Meadow, 1999), applied to all postcranial measurements, including lengths, breadths, and depths of long bones. This method involves calculating the logarithmic ratio between archaeological measurements and selected standard reference values. The reference standards were derived from well-documented specimens: for cattle, an adult female of the *Rätisches Grauvieh* breed (withers height 126 cm; body weight 508 kg) (Inv. no. 2435); for sheep, a male

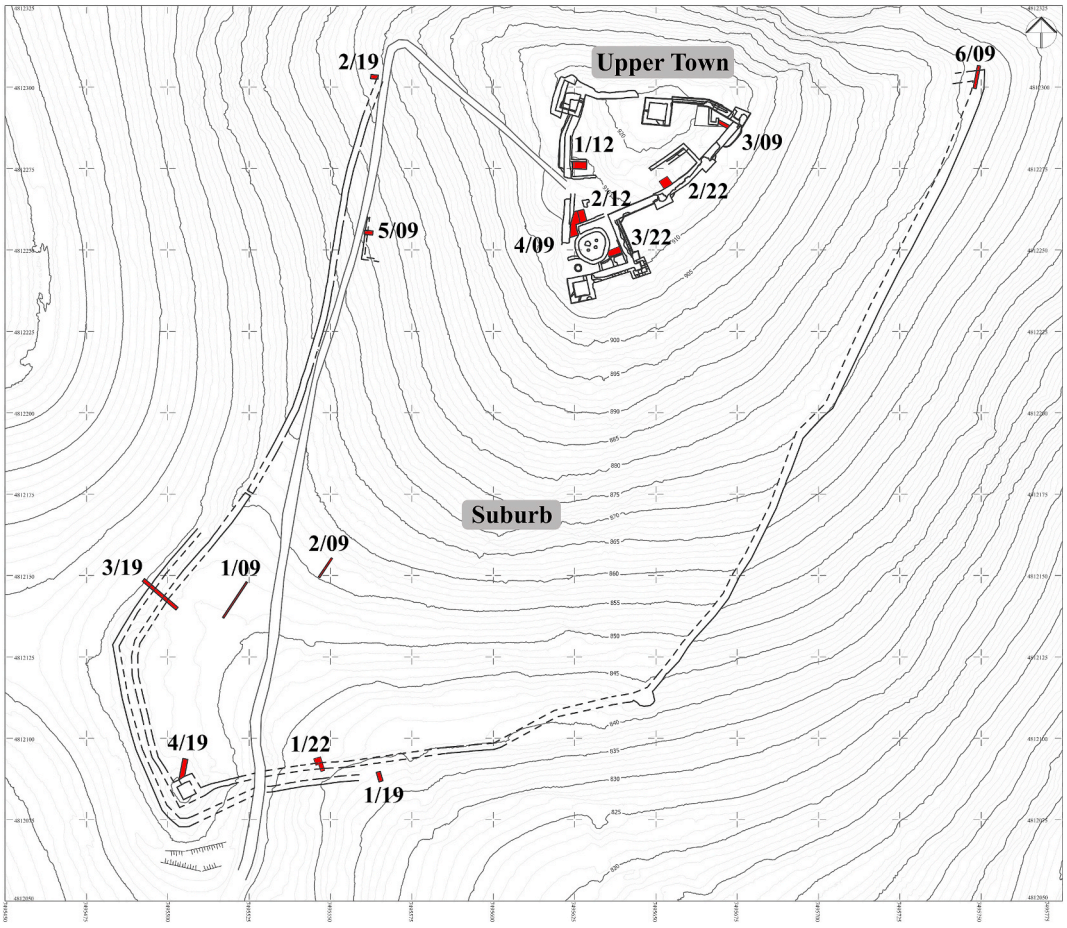

Fig. 5. Ground plan of the Koznik fortress (2022), with archaeological excavation units from 2009, 2012, 2019, and 2022 marked in red.

Fig. 6. LiDAR-derived image of Koznik fortress.

individual of the *Soay* breed (withers height 65 cm, four years old, approximately 30 kg) (Inv. no. 2448); for goats, an adult male (Inv. no. 1597); and for pigs, a male wild boar aged two to three years (approximately 120 kg) (Inv. no. 1446). All reference data were obtained from the IPNA comparative collection at the University of Basel (IPNA, 2026). All pathological changes were recorded, noting their location and providing detailed descriptions with suggested differential diagnoses (Williams et al., 2017; Bartosiewicz, 2013; Rassadnikov, 2022; Rassadnikov, 2024). Chi-square tests were applied to examine significant differences in the representation of economically important domestic mammals and butchery marks on bones. The strength of association for tables larger than 2×2 was expressed using Cramer's V (Cohen, 1988; Shennan, 1988). All statistical analyses were performed in IBM SPSS Statistics 25.0.

4. Results

As already mentioned, during the archaeological campaigns of the Koznik fortress in 2019 and 2022, a total of 2065 animal remains were collected, which can be chronologically assigned to the 14th– first third of the 15th or second half of the 15th–17th centuries (Table 1).

Due to the high degree of fragmentation, 829 specimens (approximately 37%) could be identified to the species or genus level. Among the domestic mammal remains, sheep (*Ovis aries* Linnaeus, 1758), goat (*Capra hircus* Linnaeus, 1758), pig (*Sus domesticus* Erxleben, 1777), cattle (*Bos taurus* Linnaeus, 1758), horse (*Equus caballus* Linnaeus, 1758), donkey (*Equus asinus* Linnaeus, 1758), mule (*Equus caballus* Linnaeus, 1758 x *Equus asinus* Linnaeus, 1758), dog (*Canis familiaris* Linnaeus, 1758), and cat (*Felis domesticus* Erxleben 1777) were identified. Among wild mammals, the presence of wild boar (*Sus scrofa* Linnaeus, 1758), red deer (*Cervus elaphus* Linnaeus, 1758), roe deer

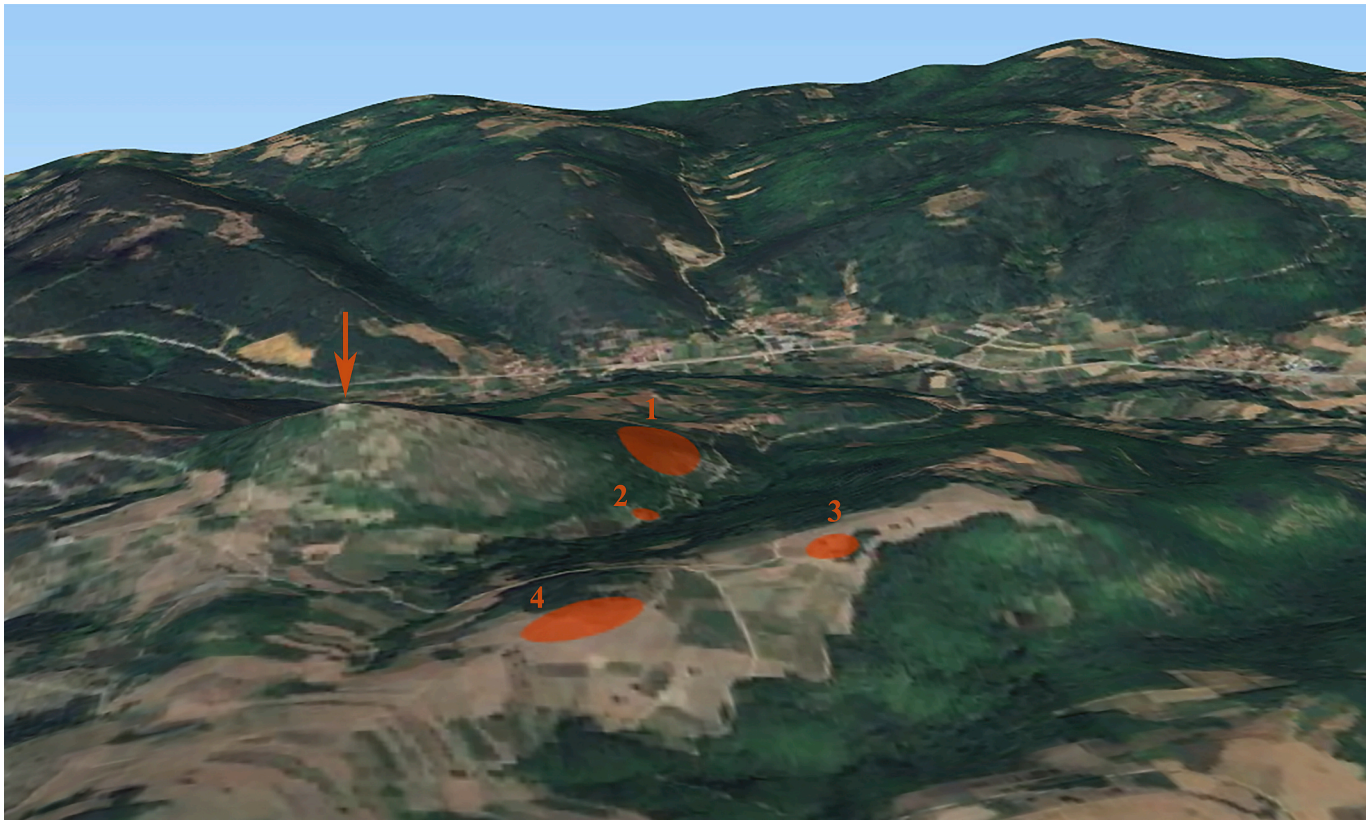

Fig. 7. Koznik fortress and its surroundings: red arrow – Koznik fortress; 1 – Torovi (Suburb 2); 2 – Trgovište; 3 – Veliko grobljište; 4 – Malo grobljište (made by I. Kajtez).

(*Capreolus capreolus* Linnaeus, 1758), and European hare (*Lepus europaeus* Pallas, 1778) was recorded. Bird remains included domestic chicken (*Gallus gallus domesticus* Linnaeus, 1758), goose (*Anser anser domesticus* Linnaeus, 1758), duck (*Anas platyrhynchos domesticus* Linnaeus, 1758), and magpie (*Pica pica* Linnaeus, 1758). Among fish remains, beluga sturgeon (*Huso huso* Linnaeus, 1758) was identified, while molluscs were represented solely by shells of the Burgundy snail (*Helix pomatia* Linnaeus, 1758).

4.1. Animal remains from the late medieval period

The material recovered from medieval contexts comprises a total of 1298 specimens. Of these, 1054 originate from the Upper Town, while 244 were found in the Suburb (Table 1).

4.1.1. Upper Town

According to all parameters (NISP, DZ, MNI), the Upper Town assemblage is dominated by domestic mammal remains – primarily sheep and goats, followed by pigs, while cattle occur in slightly lower numbers (Table 1). In addition to these domestic species, remains of wild animals were identified, specifically wild boar and hare. Bird remains include chicken, goose, and duck, while Beluga sturgeon is the only fish species identified. Fragmentation of the archaeofaunal material is pronounced, with complete or nearly complete specimens accounting for only about 7% of the sample. Most remains are isolated teeth, carpals, tarsals, and phalanges of mammals, as well as some bird bones. Taphonomic traces were observed on specimens from the Upper Town, including 10.7% gnawed most probably by dogs, approximately 21.2% burned, and 1.2% showing signs of surface decomposition (Supplementary 1).

4.1.1.1. Domestic mammals. The representation of mammals based on NISP, DZ, and MNI is shown in Table 1 and Fig. 8a. Across all parameters, the most frequent remains are those of sheep and goats, followed by pigs and then cattle, although MNI indicates similar numbers of caprines and pigs. Sheep outnumber goats in all parameters, with ratios approximately 3:1.

Age-at-death, estimated from tooth eruption and wear, could be determined for caprines and pigs. Among caprines, out of nine lower jaws, four belonged to a juvenile individual (3–18 months), while five belonged to adults older than 2.5 years. For pigs, most jaws belonged to individuals older than two years (NISP = 8), followed by juveniles aged 6–18 months (NISP = 5), and finally individuals aged 19–24 months (NISP = 4) (Supplementary 1). Age data based on epiphyseal fusion indicate that the Upper Town assemblage primarily includes young individuals of sheep, goats, cattle, and pigs (Fig. 9; Supplementary 1). Sex determination was possible for four domestic pig specimens; based on size and morphology of canines and their alveoli, all are inferred to be males (Schmid, 1972).

In the archaeofaunal assemblage from the Upper Town, almost all skeletal elements of the economically most important domestic species were recorded. Based on meat yield (Fig. 10), cattle remains are most frequently represented by elements with large and medium amounts of meat, while elements with minimal meat are the least common (approximately 21% NISP). For caprines, All three categories are represented in roughly equal proportions, with a slightly higher proportion of elements carrying high meat yields. In the case of pigs, elements with minimal and high meat yields are the most numerous (40% and 38% of NISP, respectively), whereas those with a medium meat yield are the least common (26% of NISP). Butchery marks were observed on 15% of the specimens, primarily reflecting skeletal disarticulation (75%), while evidence of filleting and skinning occurs less frequently. Among the economically most important domestic species, these marks are most often observed on sheep (Fig. 11c) and goat bones (approximately 68%),

Table 1
Distribution of different animal taxa (based on NISP, DZ, MNI).

Period	14th–first third of 15th centuries						sec. half of 15th–17th centuries						mixed (14–17th c.)	
Location	Upper Town			Suburb			Upper Town			Suburb			Upper Town	Suburb
Taxon	NISP	DZ	MNI	NISP	DZ	MNI	NISP	DZ	MNI	NISP	DZ	MNI	NISP	NISP
Sheep (*Ovis aries*)	51	38.5	8	16	15	5	32	33	4	8	8.5	2	74	11
Goat (*Capra hircus*)	15	14	3	4	3	3	10	10	2	14	12	2	35	3
Caprines (*Ovis/Capra*)	131	59.5		15	3.5		50	46		75	19		198	26
Pig (*Sus domesticus*)	111	55.5	9	7	5	2	19	14	3	14	4.5	2	108	12
Cattle (*Bos taurus*)	31	16.5	3	22	16.5	3	31	16.5	2	51	27.5	6	51	11
Horse (*Equus caballus*)				9	7	1				1	0	1		1
Donkey (*Equus asinus*)				1	0	1				1	1	1		2
Mule (*Equus caballus* x *Equus asinus*)										1	1	1		
Equids (Equidae)				1	1					6	2			3
Dog (*Canis familiaris*)				3	0.4	1	15	27	4					
Cat (*Felis domesticus*)							15	27	2					
Wild boar (*Sus scrofa*)	5	3.5	1				2	1.5	1				17	2
Red deer (*Cervus elaphus*)							3	2	2					
Roe deer (*Capreolus capreolus*)							1	1	1					
Hare (*Lepus europaeus*)	5	3.4	1	1	0	1	2	2	1				8	1
Mammals identified to the species/genus level:	**349**	**190.9**	**25**	**79**	**51.4**	**17**	**180**	**180**	**22**	**171**	**75.5**	**15**	**491**	**72**
Large-sized mammals	240			65			86			122			192	64
Medium-sized mammals	440			95			3			169			490	126
Small-sized mammals	1													
Mammals, total:	**1030**			**239**			**269**			**462**			**1173**	**262**
Chicken (*Gallus domesticus*)	12			3			19			3			22	3
Goose (*Anser domesticus*)	3												4	2
Duck (*Anas domesticus*)	2						1							
Magpie (*Pica pica*)										1				
Sparrowhawk/goshawk (*Accipiter* sp.)													1	
Phasianids (Phasianidae)	5			2			4			1			9	1
Anatids (Anatidae)	1													
Birds (Aves)							2						4	2
Birds, total:	**23**			**5**			**26**			**5**			**40**	**8**
Beluga sturgeon (*Huso huso*)	1												1	
Common barbel (*Barbus barbus*)													1	
Fish, total:	**1**												**2**	
Freshwater shell from *Unio* genus (*Unio* sp.)													1	
Burgundy snail (*Helix pomatia*)							5							
Molluscs, total:							**5**						**1**	
TOTAL:	**1054**			**244**			**300**			**467**			**1216**	**270**

followed by pigs, and are least frequent on cattle bones. Processing of animal carcasses involved the use of metal tools such as cleavers, saws, and knives.

Pathological changes were observed on five specimens. On two upper jaws of sheep/goat (one specimen above a premolar, the other above the first and second molars) and one lower jaw of a sheep (below the first molar), bone tissue had receded on the buccal side, most likely due to infection. This condition often leads to tooth loss in animals and arises when a localized bacterial infection becomes chronic (Bartosiewicz, 2013: 176–182). Arthrothic grooving was recorded on the trochlea of a sheep humerus, and this is a symptom that might be a consequence of reduced mobility in animals (Bartosiewicz, 2013: 117–118). A supratrochlear foramen was recorded on one humerus of a sheep or goat. This phenomenon, still insufficiently studied, may represent a rare genetic and developmental variation that occurs more frequently in isolated populations derived from a small number of ancestors. Although most often interpreted as hereditary, a mechanical cause cannot be excluded, nor can the possible influence of local ecological factors on husbandry conditions and livestock management (Williams et al., 2017: 265–266).

Despite the pronounced fragmentation of the material, biometric data could be recorded for some elements from the Upper Town (Supplementary 1). Withers height could only be estimated for a sheep, based on two calcanei and one metatarsal bone, yielding values from 51.4 cm to 66.6 cm (Teichert, 1975: 51–69).

4.1.1.2. Wild mammals. Wild boar and hare are the only hunted mammal species present in the Upper Town during the late medieval period. Based on all quantification parameters, both species are equally represented (Table 1, Fig. 8a). Three wild boar specimens belonged to individuals that were older than 8 months, 1.5 years, and 2 years at the time of death, while one fibula belonged to an individual younger than 4 years (Zeder et al., 2015: 139–140). In the case of hare, one mandible with fully erupted permanent teeth points to an age of more than 5 weeks (Habermehl, 1985), while the fused proximal epiphysis of one ulna indicates an age of more than 4 months. The other specimens likely belonged to adult individuals (Cochard, 2004). Canine size and morphology indicate that at least one male wild boar was present in the sample. Butchering traces are present on hare bones. They were created during disarticulation of the skeleton and were most likely made with a knife.

4.1.1.3. Birds and fish. In addition to mammal remains, bird and fish remains were also recorded (Table 1). Among birds, domestic chicken, goose, and duck are present, with chickens being the most frequent. Remains of this species consist of postcranial skeleton bones, particularly those with higher meat yield, with the most numerous elements being the coracoid, humerus, scapula and tibiotarsus. Most chicken bones (75% NISP) belonged to adults. More precise age estimation was possible for two specimens based on skeletal fusion: one juvenile under 19 weeks, identified by an unfused tarsometatarsus, and one individual older than 14 weeks, determined from the fused carpometacarpus (Serjeantson, 2009: 39–40). Three goose bones (sternum, humerus and carpometacarpus) and two duck bones (ulna and coracoid) likely

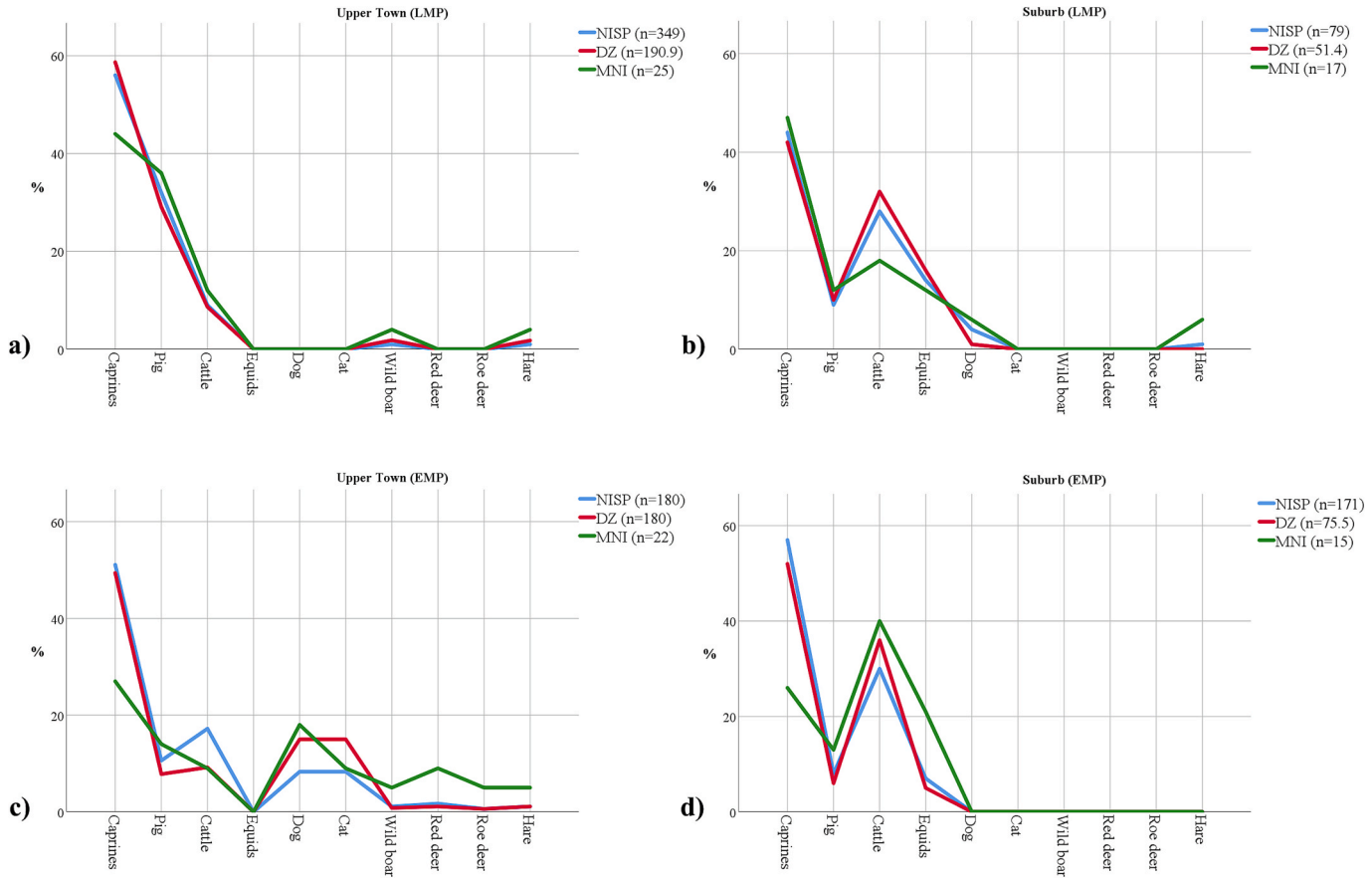

Fig. 8. Relative distribution of mammals in the Upper Town and the Suburb during the late medieval (LMP) (a–b) and early modern periods (EMP) (c–d) (based on NISP, DZ, MNI).

belonged to adult individuals. The presence of medullary bone in the humeri indicates that at least one female chicken and one female goose were included in the sample (Serjeantson, 2009: 49–53). Butchery marks were observed on the goose humerus and two chicken tibiotarsi, consisting of knife cuts made during skeletal disarticulation and meat removal.

Regarding fish remains, only a left palatopterygoid of beluga sturgeon was recovered (Fig. 11f), with an estimated total length of 226.2 cm for the individual (Živaljević et al., 2021: 423).

4.1.2. *Suburb*

In the Suburb area, according to all parameters (NISP, DZ, MNI), the most numerous remains are those of domestic mammals – primarily sheep, goats, and cattle – while pigs appear in somewhat lower numbers (Table 1). In addition to these species, remains of equids (horses and donkeys), dogs, and hares were also found, while among birds only the domestic chicken was reliably identified. In the Suburb, fragmentation of material is also very pronounced. Whole and nearly whole specimens make up 9% of the finds, mostly consisting of isolated teeth, tarsal bones, and phalanges. Regarding traces of taphonomic processes, 11.1% of specimens show gnawing marks made by dogs, 23% traces of burning, and 0.8% traces of surface weathering (Supplementary 1).

4.1.2.1. Domestic mammals. According to all quantification parameters it can be said that in this sample the most common remains are those of sheep and goats, followed by cattle and pigs, while equid remains are the rarest (Table 1, Fig. 8b). Sheep remains are more numerous compared to goats by all parameters, with their ratio ranging between 4–5:1 by the number of identified specimens and diagnostic zones, and 1.7:1 by the minimum number of individuals.

Data on the age of animals at the time of death from the Suburb area are limited, which is a consequence of the small sample size. Of the twelve caprine mandibles identified, seven derived from subadult individuals aged 18 to 30 months, while five derived from adults over two and a half years of age (Supplementary 1). Epiphyseal fusion data indicate a greater presence of adult caprines in the material, while in the case of pigs, young individuals dominate (Fig. 9a–b; Supplementary 1). In cattle, individuals with fused epiphyses in the middle stage were somewhat more common than in pigs (Fig. 9c; Supplementary 1). Although no specimens with late-stage epiphyseal fusion were recorded, those in early and middle stages could potentially have belonged to adult individuals.

In the Suburb area, almost all skeletal elements of the economically most significant species are present, but in terms of the amount of meat they carry, the situation differs compared to the Upper Town (Fig. 10). In sheep and goats, skeletal elements with negligible meat yield are the most common (60% NISP). These are followed by remains with a small yield (around 26% NISP), while those with high meat yield are the rarest. A similar pattern was observed in cattle – elements with negligible meat yield dominate, followed by those with a small yield, while the smallest proportion consists of meat-rich remains. On the other hand, in pigs, the majority of remains are from elements with a small meat yield (57% NISP), followed by those with a large yield (43% NISP), while elements with negligible meat yield were not recorded in the Suburb. Butchery marks were observed on about 7% of specimens, recorded on four sheep and goat bones and one cattle metacarpal. These are mostly disarticulation marks (81.3%), while cut marks from filleting and skinning appear sporadically. All traces were produced using cleavers and knives.

Only one specimen showed traces of pathological changes. On a

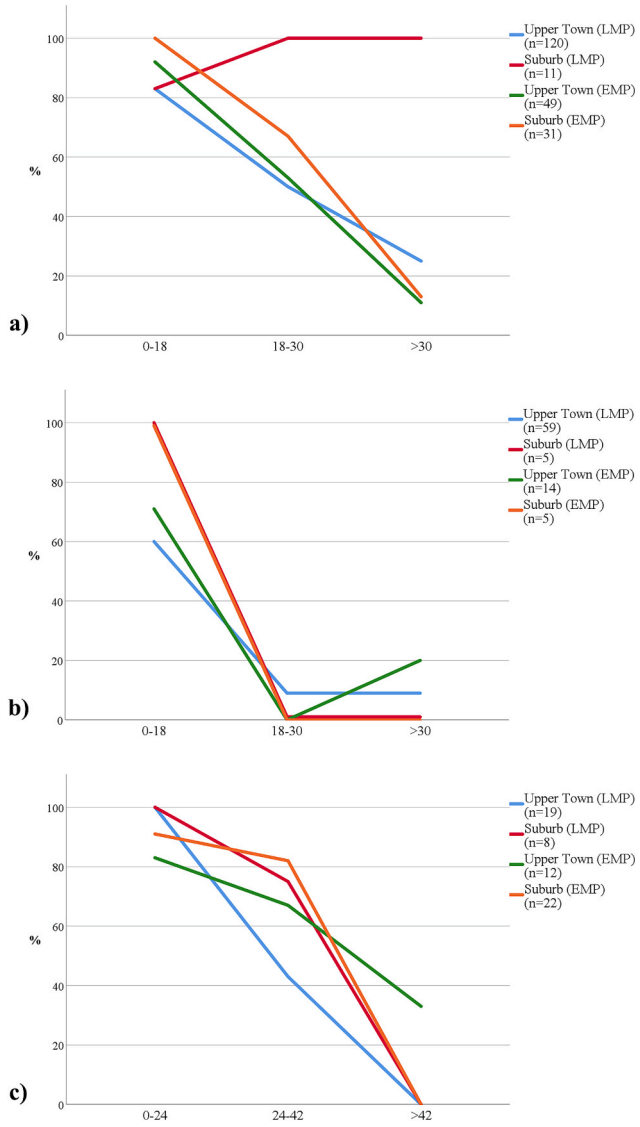

Fig. 9. Survivorship curves of caprines (a), pigs (b), and cattle (c), based on the degree of epiphyseal fusion (in months); LMP – late medieval period; EMP – early modern period.

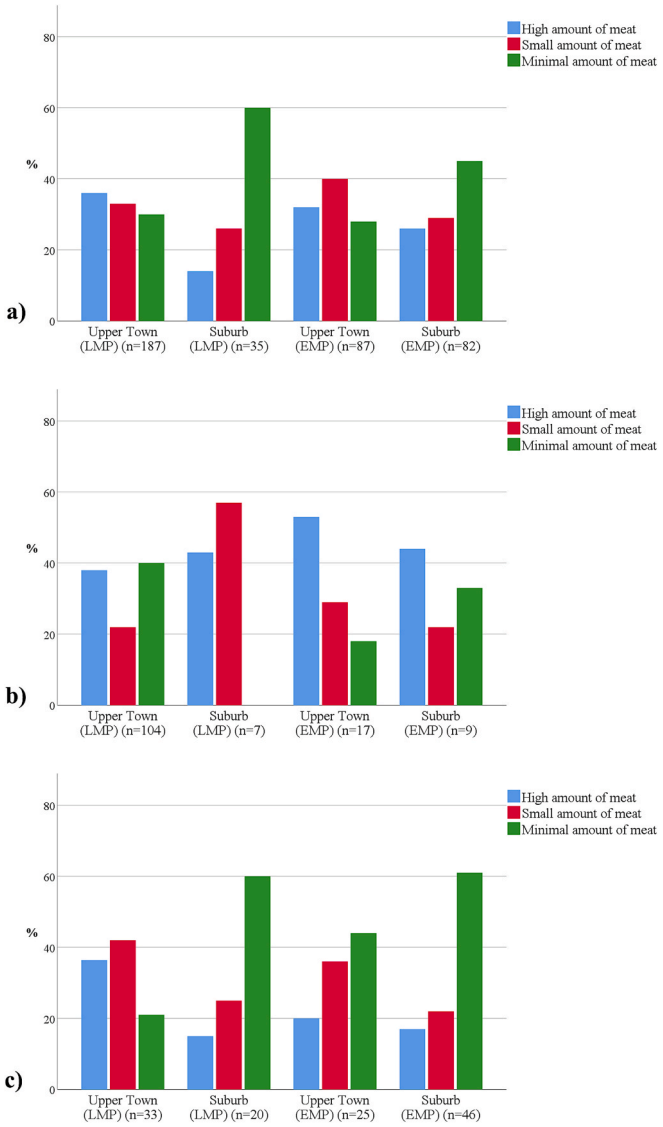

Fig. 10. Relative distribution of caprine (a), pig (b), and cattle (c) skeletal elements according to the amount of meat they bear (by %NISP; isolated teeth are not included in the total number of specimens); LMP – late medieval period; EMP – early modern period.

sheep mandible, a dental pathology was observed in the form of tooth loss during the animal's lifetime, i.e., the alveolus for the second premolar was closed. Such a change is most often the result of trauma or periodontal disease (Bartosiewicz, 2013: 176–182).

Although fragmentation of material was also significant in the Suburb, it was possible to record biometric data for certain skeletal elements (Supplementary 1). The withers height of cattle could be estimated from two metacarpal bones, yielding values of 96.2 cm and 98.3 cm (Matolcsi, 1970). For sheep, withers height was determined from one metatarsal bone and amounted to 60.7 cm (Teichert, 1975). For a horse, this value was estimated from one metatarsal (134.9 cm) and one radius (139.5 cm) (Kiesewalter, 1880).

In addition to the economically most important species, remains of equids are also present in the sample, with both horse and donkey confirmed (Table 1, Fig. 8b). Horse remains mainly include bones of the lower legs (radius, tibia, metatarsal bone, and phalanges) as well as isolated teeth, while one upper permanent premolar or molar belonged to a donkey. Only one specimen (an axis vertebra) was identified to genus level, and almost all equid remains most likely derived from adult individuals (Silver, 1969; Levine, 1982). Additionally, three bone fragments of dog (a humerus and two third metacarpal bones) were recorded. All elements represent adult individuals.

4.1.2.2. Wild mammals. A hare mandible is the only bone of wild mammals (Table 1, Fig. 8b), belonging to an individual that was over 5 weeks old at the time of death (Habermehl, 1985).

4.1.2.3. Birds. Bird remains were also recorded in the Suburb, with the domestic chicken being the only reliably identified species (Table 1). Two tarsometatarsi and one ulna were found, belonging to adult individuals, at least two of which were older than 19–27 weeks (Serjeantson, 2009). The presence of a spur on one of the tarsometatarsi indicates that at least one male was represented in the sample (Fig. 11e) (Sadler, 1991).

4.2. Animal remains from the early modern period

Animal remains from the early modern period are less numerous than those from the late medieval sample, with a total of 767 specimens recovered. Of this number, 300 derive from the Upper Town, while 467 specimens were found in the Suburb (Table 1).

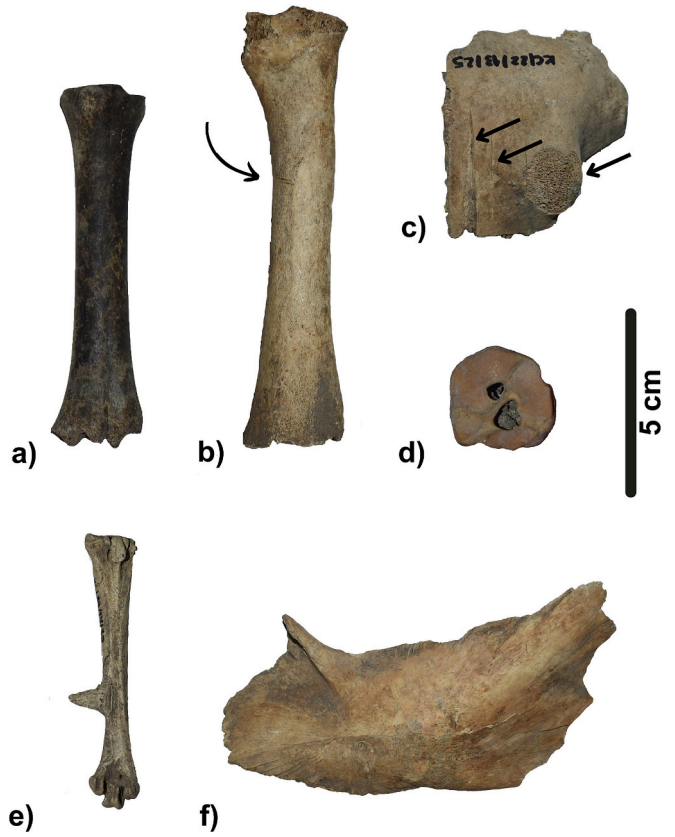

Fig. 11. a) Caprine metacarpus with burning marks (Upper Town, sec. half of the 15th–17th c.); b) Sheep right radius with butchery marks (Upper Town, sec. half of the 15th–17th c.); c) Sheep cranium with butchery marks (Upper Town, 14th–first third of the 15th c.); d) Goat metatarsus with pathological changes (Upper Town, 14th–first third of the 15th c.); e) Rooster right tarsometatarsus (Suburb, 14th–first third of the 15th c.); f) Beluga sturgeon left palatopterygoideum (Upper Town, 14th–first third of the 15th c.) (photo by T. Mladenović).

4.2.1. Upper Town

In the Upper Town sample, according to all three parameters (NISP, DZ, MNI), domestic mammals are the most numerous, primarily sheep and goats, while pigs and cattle occur in somewhat smaller numbers (Table 1). Dog and cat remains are also present, as well as wild mammal species – wild boar, red deer, roe deer, and hare. Among birds, chicken and duck are represented, while the only mollusc recorded is the vineyard snail. Fragmentation of the material is highly pronounced. Whole and nearly whole specimens make up 7.5% of the sample, mostly the isolated teeth, tarsal bones, and phalanges of food animals, but also skeletal elements of dogs, cats, and birds. Traces of taphonomic processes, in the form of surface weathering, burning, and gnawing, were also observed in the Upper Town specimens from the early modern period. Dog gnawing was observed on 15% of the specimens, burning on approximately 33% (Fig. 11a), and surface weathering on 0.3% (Supplementary 1). Almost all burned specimens came from Well no. 5 and Structure 2/22, mostly carbonized or partially carbonized, while bones with scorched ends appeared sporadically.

4.2.1.1. Domestic mammals. Table 1 and Fig. 8c show the representation of mammals according to NISP, DZ, and MNI. By all three parameters, sheep and goats dominate. Pigs and cattle are somewhat less frequent, while dog and cat remains are the least represented. When NISP and diagnostic zones are considered, the pattern is similar, with cattle being more numerous than pigs; however, according to MNI, pigs outnumber cattle. Sheep are much more frequent than goats according to all parameters: the sheep-to-goat ratio is about 3:1 by NISP and DZ, and 2:1 by MNI.

Based on tooth eruption and wear data, one sheep mandible belongs to an adult individual. For cattle, one mandible belongs to an individual aged between two and three years, and two to adults (older than 4 years), while one pig mandible belongs to an individual aged between 6 and 12 months (Supplementary 1). Epiphyseal fusion data indicate that young animals were most frequent: mainly subadults among caprines and cattle, and individuals younger than 30 and 18 months among pigs (Fig. 9; Supplementary 1). Sex could only be determined for one domestic pig. Based on canine size and morphology, the sample included at least one female (Schmid, 1972).

Almost all skeletal elements of the economically most significant domestic species were recorded in the Upper Town archaeofaunal collection. For cattle, bones with a minimal amount of meat dominate (about 44% NISP) (Fig. 10), followed by those with small amounts (about 36%), while meat-rich elements are the least frequent (only 20%). For caprines, the situation differs somewhat – bones with a small amount of meat are most numerous (44%), followed by elements with minimal and high amounts of meat (29% and 28%, respectively). Pig remains show yet another pattern: meat-rich elements are most common (53%), followed by those with small amounts (29%), while bones with a minimal amount of meat are the rarest (18%). Anthropogenic traces occur on 15% of specimens. They are most frequent on sheep and goat bones (55%) (Fig. 11b), somewhat rarer on cattle and pig remains. These consist mostly of disarticulation marks (81%), made when carcasses were divided into smaller portions, followed by filleting/cutting marks (15%), and skinning marks (4%). Such traces were most likely produced with cleavers, saws, and knives. In addition to butchery marks, a first phalanx of a pig showed evidence of modification in the form of a circular perforation, 6 mm in diameter, on the medial side of the diaphysis.

Pathological changes were observed on only three bones. Two unidentified oval depressions appeared on the proximal articular surface of a goat metatarsus (Fig. 11d) (Rassadnikov, 2022: 28–29 Fig. 8a; Rassadnikov, 2024). On the craniomedial edge of the proximal articular surface of a cattle metatarsal, slight lipping was observed, while the caudolateral edge showed exostosis. Such changes can result from multiple factors, including inflammations, infections, age, and the heavy weight of individuals (Bartosiewicz, 2013: 105–129, 144–150). Evidence of pathological changes is also present on a cat pelvis that had fused with the sacrum. Such alterations indicate progressive ankylosis resulting from a nutritional imbalance, most likely associated with hypervitaminosis A, although not exclusively, and affecting multiple joints systemically (Ekman and Carlson, 1988; Marković, 2018; Marković et al., 2018). No comparable pathological alterations were observed on other skeletal elements. Nevertheless, a definitive diagnosis would require examination by a specialist.

Despite pronounced fragmentation, biometric data could be obtained for certain Upper Town elements (Supplementary 1). Sheep withers height could be estimated based on four astragali and one calcanei, ranging from 56.9 cm to 64.7 cm (Teichert, 1975). For goats, withers height was estimated at 68.6 cm, calculated from a single metatarsal (Schramm, 1967).

In addition to animals used for food, remains of dogs and cats were also found in the Upper Town. An equal number of fragments were recorded (NISP = 15), but the minimum number of individuals was higher for dogs (MNI = 4) than for cats (MNI = 2) (Table 1, Fig. 8c). Almost all skeletal elements of dogs were present, which made it possible to determine the age of the individuals. All specimens belonged to young animals, up to one and a half years old. Based on dental data, the age of one individual was determined more precisely, ranging between one and three months of age. Almost all skeletal elements of cats were also present, and the age data indicate that one individual was about 6.5 months old at the time of death, and the other about 11.5 months (Silver, 1969; Habermehl, 1975).

4.2.1.2. Wild mammals. According to all quantification parameters, red deer is the most common species in this faunal sample followed by hare, wild boar, and roe deer (Table 1, Fig. 8c).

Two specimens of wild boar belonged to individuals that were younger than four years at the time of death, since the proximal epiphyses of one humerus and one tibia were not fused (Zeder et al., 2015). The recovered long bones of red deer (two humeri and one radius) belonged to individuals older than 10 months, and younger than two and a half years (Heinrich, 1991). The presence of a roe deer mandible with preserved teeth enabled a more precise age estimate of that individual, which ranged between 4.5 and 6 years (Tomé and Vigne, 2003). In the case of the hare, the fused proximal epiphysis of one tibia indicates an age of more than 11 months (Cochard, 2004). Butchering traces are also present on wild game, primarily on red deer bones. They were created during meat removal, and were most likely inflicted by a cleaver.

4.2.1.3. Birds and molluscs. In the area of the Upper Town, bird remains were also discovered (Table 1), with chicken remains being the most numerous, totaling 19 specimens. In the sample, only postcranial skeletal elements of this species are present, particularly those carrying a larger amount of meat. The most frequently found elements were tibiotarsi. The presence of a spur on one tarsometatarsus indicates at least one male individual, while the absence of a spur scar may suggest the presence of at least one female in the sample (Sadler, 1991). Most of the chicken remains (68% NISP) belonged to adult individuals. Precise age determination was carried out based on the fusion of the tarsometatarsus, which showed that the material included three individuals older than 19–27 weeks, and one older than 34 weeks (Serjeantson, 2009). One duck bone was identified, belonging to an adult individual.

In the Upper Town, five shells of the vineyard snail were also found (Table 1). Considering that snails burrow into the ground during hibernation, it is possible that their shells do not represent the result of human activity, but rather a natural deposit.

4.2.2. Suburb

In the area of the Suburb, domestic mammals are also the most numerous according to all parameters, namely sheep and goats, followed by cattle, while pig remains are somewhat less common (Table 1). In addition to these species, remains of equids – horse, donkey, and mule – were found. Chicken and magpie are the only representatives of the bird class. Fragmentation of the archaeozoological material is pronounced here as well. Complete and nearly complete specimens make up only 8% of the sample, mostly consisting of isolated teeth, tarsal bones, and phalanges. Regarding traces of taphonomic processes in the Suburb material, 12.3% of specimens show dog gnawing marks and 17.7% show burning marks, and these occur throughout the investigated area (Supplementary 1).

4.2.2.1. Domestic mammals. Looking at the number of identified specimens (NISP) and the number of diagnostic zones (DZ) for domestic mammals, sheep and goats are the most frequent, followed by cattle and pigs, while equid remains are the rarest (Table 1, Fig. 8d). Considering the minimum number of individuals (MNI), cattle are the most numerous, followed by sheep, goats, and pigs, while horses, donkeys, and mules are represented by at least one individual each. Goats are more numerous than sheep in terms of NISP and DZ, with a ratio of 1.75:1 for NISP and 1.41:1 for DZ in favor of goats. The MNI is equal for both species.

The recovered mandibles of cattle and pigs belong to adult individuals (two specimens each), while for caprines, in addition to adults (NISP = 6), juvenile individuals are also present (NISP = 5) (Supplementary 1). Data on epiphyseal fusion indicate a higher representation of subadult caprines in the material, while young pigs are more common (Fig. 9a–b; Supplementary 1). In cattle, a higher percentage of specimens are fused in the first and second phases, so although no elements fused in the late phase were recovered, specimens fused during the juvenile and subadult periods could have belonged to adults (Fig. 9c; Supplementary 1). Based on the size and morphology of canines, sex could be determined for four domestic pig specimens, suggesting the Suburb material includes at least three males and one female (Schmid, 1972).

Almost all skeletal elements of cattle, sheep, goats, and pigs are present in the Suburb area. Regarding the amount of meat they carry (Fig. 10), the situation is similar to the Upper Town for pigs, while some differences are observed for caprines and cattle. In sheep and goats, the most common skeletal elements carry negligible amounts of meat (45% NISP), followed by elements carrying small amounts, with elements carrying large amounts being the rarest (26% NISP). In cattle, elements with negligible meat dominate (61% NISP), followed by those with small amounts, and lastly, those rich in meat. In pigs, most remains carry large amounts of meat (44% NISP), followed by negligible, and lastly, small amounts. Butchery marks appear on 6% of specimens, most frequently on sheep and goat bones (46%), followed by cattle and pig bones. These are primarily traces of disarticulation (85%) and meat-cutting (15%), made with cleavers and knives.

Pathological changes were observed in four domestic mammal specimens. On a sheep/goat maxilla, likely due to infection, the bone tissue had receded, exposing the root of the third molar on the buccal side. This type of disease is a major cause of tooth loss during the animal's life and often occurs when a localized bacterial infection becomes chronic (Bartosiewicz, 2013: 176–182). Exostosis was observed on the craniomedial edge of the distal articular surface of a cattle metacarpal, as well as around the proximal and distal articular surfaces of the first phalanx. Mild lipping was noted on the caudolateral edge of the proximal articular surface of the first phalanx. Such changes may result from inflammation, infection, age, and body weight (Bartosiewicz, 2013: 105–129, 144–150).

Despite pronounced fragmentation, biometric data could be recorded for certain elements from the Suburb (Supplementary 1). The withers height of sheep could be estimated from two metatarsals, yielding 53.2 cm and 57 cm (Teichert, 1975).

Aside from the animals most significant for food, equid remains were also discovered in the Suburb. All three species were confirmed – horse, donkey, and mule – each represented by a single specimen (Table 1, Fig. 8d). Among horse remains, one lower second premolar belonged to an individual aged 8–9 years at death. A donkey humerus and a mule first phalanx belonged to individuals older than 1.5 and 1 year, respectively. Due to the similarity of skeletal elements among these three species, some elements (lower permanent third incisor, two femora, a metacarpal, metatarsal, and pisiform) could only be identified to the genus level and were classified as equids. Specimens for which age could be determined belonged to adult individuals.

4.2.2.2. Birds. Among the bird remains, chicken and magpie are present (Table 1). In the case of the chicken, two femora and one ulna were found, elements that carry a significant amount of meat. Two specimens belonged to adults, and one to a young individual (Serjeantson, 2009). On the femur of the adult, butchery marks made with a knife during skeleton disarticulation were observed. As for the magpie, a humerus of an adult individual was found inside the investigated tower.

5. Discussion

5.1. Key findings from the study

The animal remains from both the Upper Town and the Suburb, across both phases, are highly fragmented. Entirely preserved are mostly carpal and tarsal bones, isolated teeth, and phalanges – skeletal elements that are neither rich in meat nor suitable for processing – as well as

bones of animal species not used for consumption. This structure of finds suggests that fragmentation was most likely the result of human activities such as carcass butchering and the use of remains as raw material for the production of objects, confirming that the majority of the sample represents food waste. The archaeofaunal material was deposited into the sediment relatively quickly, as indicated by only sporadic examples showing traces of surface weathering, as well as a small number of gnawed specimens (Supplementary 1). Slightly more frequent are traces of burning, mostly due to intentional or accidental exposure to fire, as most specimens are almost completely carbonized. Such remains were identified in both phases and at both locations. The majority of the sample from the early modern period in the Upper Town was collected after burning and discarded into Well No. 5, which at that time was apparently not in use. A much smaller number of specimens display partially charred ends, which were most likely exposed to fire during food preparation.

According to the number of identified specimens (NISP), caprines are the most numerous animals in all parts of the site and during both periods, pointing to the significant role of sheep and goats at Koznik (Fig. 8). In the Upper Town during the late medieval period, pigs outnumbered cattle, while in the Suburb the ratio was reversed. In the early modern period, there was a higher proportion of cattle in both the Upper Town and the Suburb. Cats appear exclusively in the Upper Town in the early modern period, while dogs are recorded in the Suburb during the late medieval period and in the Upper Town under Ottoman rule. Equid remains are confirmed only in the Suburb, and in both periods. These patterns indicate certain differences between parts of the settlement over time. The greater representation of pigs in the Upper Town during the late medieval period can be linked to the diet of the fortress population, while the higher number of cattle in the Suburb suggests their role not only in meat consumption but also in milk production and the use of physical strength for agricultural work and transport. Moreover, in the early modern period, the smaller number of pigs, especially in the Upper Town, may be connected to the presence of an Islamic population and the religious prohibition of pork consumption. Statistical analysis confirmed significant differences in the representation of the most economically important domestic species, with a moderate effect size ($\chi2$ (df $= 6$, n $= 717$) $= 80.358$, $p < 0.001$; Cramer's V $= 0.237$). The presence of equids exclusively in the Suburb probably reflects their economic role related to transport, trade, and daily labor. Differences in the presence of dogs and cats over time likely do not reflect real changes in their role, as these animals served as guards and pest controllers. All specimens from the early modern period come from Well No. 5, which was not in regular use at the time, explaining the higher number of remains compared to the late medieval period, when dead animals were most likely disposed of elsewhere due to the well's active use[2].

Age data show that caprines at Koznik were primarily exploited for meat, while the presence of adult individuals also points to the use of secondary products, primarily milk and wool. Only in the Suburb during the late medieval period is there a higher proportion of adult individuals, which may indicate more intensive use of secondary products, though it may also be related to the small sample size from this period (Fig. 9a; Supplementary 1). Pigs were a significant source of meat during both periods, with consumption focused on individuals aged between one and two and a half years, when meat yield is greatest and quality best (Fig. 9b; Supplementary 1). Cattle, in both the late medieval and early modern periods, were primarily exploited for meat, with occasional use of secondary products, though less pronounced than in caprines (Fig. 9c; Supplementary 1).

During the late medieval period in the Upper Town, sheep and goat remains were almost evenly represented across the meat-bearing categories, while in the Suburb skeletal elements with negligible amounts of meat dominated, generally considered kitchen refuse in the literature (Fig. 10a) (O'Connor, 2000). Similar differences are noticeable in pigs and cattle: in the Upper Town, higher-quality portions are present, while in the Suburb remains with less meat are more common (Fig. 10b–c). In the early modern period, the Upper Town shows a higher representation of meat-rich elements in pigs and caprines, whereas in cattle, elements with a minimal amount of meat predominate. In the Suburb, elements with a minimal amount of meat dominate among caprines and cattle, while in pigs, meat-rich elements are the most numerous (Fig. 10). These data suggest that the Upper Town had access to more valuable resources and higher-quality animal parts, while the Suburb likely functioned in a provisioning role.

Analysis of anthropogenic traces on animal bones provides significant insight into methods of meat processing in different parts of the settlement and across different periods. In the Upper Town, butchery marks were recorded on 14% of specimens in the late medieval period and 15% in the early modern period, while in the Suburb the values are 7% and 6%. The most common traces are those of disarticulation and filleting, while skinning is documented in the Upper Town in both periods but is absent in the Suburb during the early modern period. Tools such as cleavers, axes, and knives were most likely used for carcass processing. The use of a saw was recorded exclusively in the Upper Town during both phases, and may have been intended for preparing animal bones for the manufacture of bone artifacts, since it was only used to separate sheep horns from skulls. Nevertheless, despite these variations statistical analysis ($\chi2$ (df $= 6$, n $= 268$) $= 9.531$, $p = 0.146$; Cramer's V $= 0.133$) showed that the differences were not significant, suggesting that overall butchery practices were consistent. These findings confirm that the exploitation of animal meat was systematic, regardless of spatial or chronological context.

Based on estimated withers height, sheep at Koznik appear to have remained relatively similar in size over time. In the late medieval period, recorded heights range between 51.4 cm and 66.6 cm, while in the early modern period they range from 53.2 cm to 64.7 cm. The withers height of goats from the late medieval layers of Koznik could not be estimated, but data from contemporary sites indicate values between 63.9 cm and 67.2 cm (Mladenović and Mladenović, 2020). For the early modern period, the estimated withers height of a goat from the Upper Town is 68.8 cm – the only known value from present-day Serbia. Although the sample is small, it appears to be slightly larger than the values obtained for the medieval period. Data on cattle size at Koznik are available only from the Suburb in the late medieval layer, ranging from 96.2 cm to 98.3 cm. Similarly, the only data on horse size come from the early modern period in the Suburb, with estimated withers heights of 134.9 cm and 139.5 cm.

The application of the LSI method provided additional insights into the size variability of the four main domestic species (Fig. 12). Sheep exhibit relatively stable LSI values between the 14th–15th and 16th–17th centuries, although slightly lower values are observed in the Suburb during the later phase (Fig. 12a). Goats appear somewhat smaller in the early modern period (Fig. 12b). Cattle display generally consistent LSI values across both periods, with no clear evidence of size increase through time; however, variability remains pronounced, particularly in the Suburb during the early modern phase (Fig. 12c). Pig data are limited, but they indicate higher variability in the Upper Town during the late medieval period, while larger individuals are more evident in the Suburb during the same period, as well as in the later phase overall (Fig. 12d).

5.2. Comparative perspectives and broader historical context

Historical sources indicate that in the territory of the medieval Serbian lands, sheep were the most prevalent type of domestic animal. They represented the main support for both nutrition and clothing of the population. In addition, thanks to their modest requirements in terms of

[2] Since larger parts of these individuals' skeletons are present, it is possible that the animals either accidentally fell into the well or were thrown there after death.

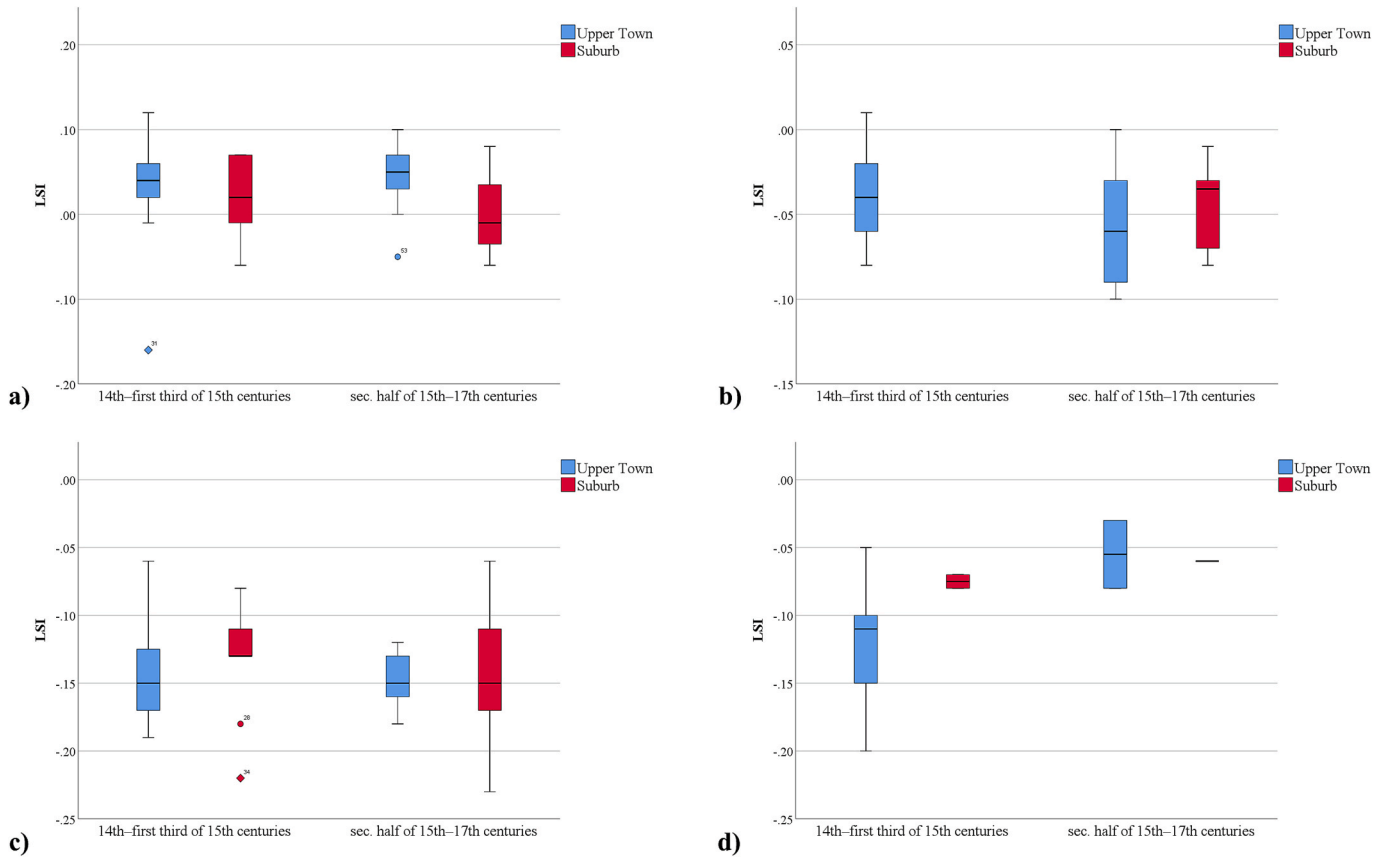

Fig. 12. Variability in log-size index values of a) Sheep; b) Goat; c) Cattle; d) Pig postcranial elements regarding the mean values of measurements of standard individuals from the Collection IPNA of University in Basel across the Upper Town and Suburb during the late medieval LM (14th–first third of the 15th c.) and early modern period EM (sec. half of the 15th–17th c.) (Sheep – LM: Upper Town n = 25, Suburb n = 6; EM: Upper Town n = 19, Suburb n = 3; Goat – LM: Upper Town n = 10, Suburb n = 0; EM – Upper Town n = 10, Suburb n = 10; Cattle – LM: Upper Town n = 11, Suburb n = 9; EM: Upper Town n = 10, Suburb n = 21; Pig – LM: Upper Town n = 10, Suburb n = 2; EM: Upper Town n = 2, Suburb n = 1).

food and shelter, sheep husbandry did not demand significant expenses or much labor (Katić, 1978: 51). Alongside sheep, goat breeding was similarly developed in medieval Serbia. Their advantage lay in modest dietary needs and greater resistance to certain diseases. It is particularly important to emphasize that their winter feeding did not present a difficulty, as with other domestic animals, since sufficient quantities of leafy fodder could be prepared. Goat meat and milk served for food, while their hide, thanks to its durability, was a valuable material for the production of sacks intended for caravan transport of goods, as well as for various covers, mats, and other objects (Katić, 1978: 57–58). Cattle represented the basic means of agricultural production, indispensable for tilling the land. In certain areas, the measure of the labor force was a farmer who possessed two oxen. Nevertheless, due to the limited development of agriculture, cattle husbandry remained underdeveloped, and their numbers were always insufficient and relatively small compared to other domestic animals (Katić, 1978: 44–45). Pig breeding held a special significance in medieval Serbia. Pork, both fresh and cured, occupied an important place in the diet of the population, but also in export trade. Pigs grazed year-round in oak forests rich in acorns. Royal, noble, and ecclesiastical estates maintained large herds and employed individuals whose permanent responsibility was to oversee pig husbandry (Katić, 1978: 58).

Archaeozoological data confirm historical sources, as almost at all late medieval sites the most represented domestic mammals were sheep and goats, which has been confirmed at Gradina in Trešnjevica (Bulatović and Marković, 2013), Rudnik (Bulatović and Marković, 2019), Kulina–Solotuša (Mladenović, 20173), and the Old Synagogue in Belgrade (Kokanović, 2022). Cattle occupied second place in terms of frequency, followed by pigs. An exception is Studenica, where pigs were the second most numerous species after caprines, with cattle in third place (Marković, 2015). The only site with the highest representation of pigs is Gornje Polje–Lajkovac (Bulatović, 2020). Data on age and pathological changes gathered from different archaeological sites also confirm that animals were bred for the use of secondary products – milk, wool, and physical strength (Mladenović and Mladenović, 2020). Regarding withers heights, sheep appear to have remained relatively consistent in size across different sites. Comparative data from other medieval contexts show a similar pattern: sheep at the Kulina–Solotuša site had a height of 59.8–65.6 cm (Mladenović, 2017), at the Old Synagogue site 59.6 cm and 62.4 cm (Kokanović, 2022), and at Studenica 56.4 cm (Marković, 2015). Estimated cattle withers heights include 116.4 cm at Gornje Polje–Lajkovac (Bulatović, 2020), 115.5 cm at Studenica Monastery (Marković, 2015) and 111 cm at the Old Synagogue (Kokanović, 2022), while at the Kulina–Solotuša site the estimated value was significantly smaller (78.3 cm) (Mladenović, 2017). Horses from the late medieval layers of the Old Synagogue site had estimated withers heights of 139.7 cm and 144.7 cm (Kokanović, 2022).

Historical data further indicate that during the early modern period

[3] Although the preliminary results indicate a dominance of cattle, the inclusion of new, unpublished finds shows that caprines are the most prevalent species at the site.

in these areas, sheep and pigs were the most widely raised animals, and consequently about which the largest amount of information survives, as small stock – sheep, goats, and pigs – were subject to taxation. Far less information survives about large mammals such as cattle, buffalo, and horses. In Balkan marketplaces, live animals could be purchased and slaughtered on site. Besides live animals, dried or smoked meat (pastirma) was also offered (Zirojević, 2005: 244). The tax Christians paid on pig raising confirms the consumption of pork throughout the Ottoman Empire. From pigs, both meat and fat were obtained, the latter forming an important part of the diet. Christians and dual-faith populations primarily relied on pigs for fat, which also included bacon, more commonly consumed than lard. In addition to lard, butter was also sold. In the law code for the town of Kruševac, one skin sack of butter equaled 20 liters (Zirojević, 2005: 246). At the palace of the Belgrade Metropolitan, butter in a skin sack, kidney suet, and bacon were all in use. Other dairy products also played an important role in the diet. Cheese was produced from milk, and from the 16th century sources also mention *kashkaval*. Whey cheese (*urda*) was considered the lowest-quality cheese, but was nevertheless consumed. The most popular dairy product among the Turks was yogurt and sour milk, consumed not only as a drink but also as an addition to numerous dishes. Alongside yogurt, milk and ayran were also drunk (Zirojević, 2005: 243–249).

Archaeozoological finds confirm that caprines – sheep and goats – were the most commonly raised livestock during the early modern period. They are the most numerous in all faunal assemblages – for example, the Old Synagogue in Belgrade (Kokanović, 2022), the Northern Bastion of the Novi Pazar fortress (Mladenović, 2024), and the Monastery of St. Barbara at Reljina Gradina near Novi Pazar (Mladenović et al., 2025). At these sites, cattle are the second most represented, followed by pigs, whose presence is absent at Novi Pazar fortress (Mladenović, 2024). The situation is similar in the Suburb of Koznik, although in the Upper Town pigs are more numerous than cattle. Evidence of age profiles and pathological changes further confirmed that animals were raised not only for meat but also for secondary products such as milk, wool, and physical strength (Kokanović, 2022; Mladenović, 2024; Mladenović et al., 2025). Regarding the withers heights, during the 16th–17th centuries, sheep at the North Bastion of the Novi Pazar fortress measured 56.5–66 cm (Mladenović, 2024), while at Old Synagogue they measured 56.1–64.3 cm (Kokanović, 2022). The only known value for cattle from the early modern period comes from the North Bastion, at 104.3 cm (Mladenović, 2024), which is consistent with medieval values (Mladenović and Mladenović, 2020).

During both periods at Koznik fortress, the most common domestic bird was the chicken, the main source of poultry meat. Adult individuals dominate in all contexts, suggesting that birds were mostly kept until maturity for egg production, further supported by the presence of medullary bone in some long bones. In the Upper Town, ducks are recorded in both the late medieval and early modern periods, whereas geese appear exclusively in late medieval layers. In all cases, only adult individuals were identified. Meat-rich skeletal elements of birds are present in all Koznik contexts, and butchery marks attest to the preparation of poultry for consumption. Besides meat and eggs, feather exploitation should not be excluded.

Although significant in the Middle Ages, poultry is only rarely mentioned in historical sources. In the coastal region, sharecroppers "gave" one or two hens to landowners alongside bread, and it is known that in Dubrovnik Serbian rulers were served poultry meat, among other foods (Spremić, 1994; 2004). Beyond Koznik, bird remains have been found at Gradina in Trešnjevica (chicken) (Bulatović and Marković, 2013), Kulina in Solotuša (chicken) (Mladenović, 2017), Rudnik (chicken) (Bulatović and Marković, 2019), the Old Synagogue in Belgrade (chicken, goose) (Kokanović, 2022), and Studenica Monastery (chicken, goose, duck) (Marković, 2015; Marković et al., 2016). Archaeozoological evidence shows that birds generally played a relatively modest role in the economy of medieval settlements in Serbia, with chickens most frequently raised and exploited mainly for secondary products such as eggs and feathers (Mladenović and Mladenović, 2020).

In sources related to the early modern period, little information exists on poultry use. Poultry meat was certainly important in the diet, and in Balkan marketplaces chickens, and occasionally pigeons, could be bought (Zirojević, 2005: 243–249). Evliya Çelebi records that famous Belgrade specialties included stuffed chicken and a casserole (ğüveç) of guinea fowl (Čelebi, 1967: 90–91). Besides meat, eggs were consumed, either added to dishes or sold separately, and feathers of chickens and geese were available in markets (Zirojević, 2005: 244–250). Aside Koznik fortress, bird remains are also recorded in faunal assemblages from the Monastery of St. Barbara at Reljina Gradina near Novi Pazar (chicken) (Mladenović et al., 2025), the Old Synagogue in Belgrade (chicken, goose, duck) (Kokanović, 2022), and from the Novi Pazar fortress (16th–19th century) (chicken, goose, duck) (Mladenović, 2024). As in the medieval period, chickens were most frequently kept, and adult individuals suggest exploitation of eggs and feathers.

During the medieval period, wild game had only a marginal role in the diet of Koznik inhabitants. In the Upper Town, wild boar and hare appear, while in the Suburb only hare is recorded. In the early modern period, the range of game species became more diverse in the Upper Town (hare, wild boar, red deer, and roe deer), with a larger number of identified specimens (Fig. 8). By contrast, no wild mammal remains were found in the Suburb, except for one magpie humerus, likely a natural deposit. These data suggest that in the Upper Town hunting gained somewhat more importance in the early modern period, while in the Suburb its role remained marginal. It is possible that the Upper Town inhabitants had privileged access to game, either through direct hunting or via supplies from the surrounding land, while in the Suburb its dietary role was limited.

Historical sources and iconographic representations indicate that wild animals played an important role in nutrition, economy, and cultural life of medieval Serbia (Mladenović and Vranić, 2024, with references therein). Hunting was an important source of meat but also of materials such as hides, furs, bones, and antlers, used for clothing, weapons, tools, and decorative objects. In medieval Serbia, the right to hunt was a regalian right of the ruler, who granted it to nobles and the church, while the broader population's access to game was limited. Besides local consumption, hides, furs, and game meat were sometimes traded and exported, especially to nearby towns and coastal areas, thus contributing to economic activity (e.g. Katić, 1978; Mišić, 1995). Spears, bows, and arrows were used in hunting, and falconry with hawks and falcons trained to catch birds and small game was practiced. This type of hunting was pursued by women and children as well, and was especially popular among the elite (Mišić, 1995). Written sources indicate that some regions of the medieval Serbian state were rich in wild fauna thanks to abundant water and diverse forests (Mišić, 1995; Ćirković, 2005). However, with population growth, expansion of arable land, and mining development, forests diminished and habitats were threatened (e.g. Vranić, 2021), likely reducing game availability.

Archaeozoological evidence indeed shows a very small proportion of wild species in Serbian faunal assemblages. Game remains have been identified, for example, in the late medieval layers of Studenica Monastery (red deer, hare, rock pigeon, eagle) (Marković, 2015), at Kulina–Solotuša (red deer, roe deer, wild boar, hare) (Mladenović, 2017), Gradina–Trešnjevica (red deer, roe deer, wild boar, hare) (Bulatović and Marković, 2013), the Old Synagogue in Belgrade (roe deer) (Kokanović 2022), Gornje Polje–Lajkovac (red deer, roe deer, hare) (Bulatović, 2020), and Rudnik (red deer, roe deer, hare, squirrel) (Bulatović and Marković, 2019), usually making up less than 10% (Mladenović and Mladenović, 2020).

In the Ottoman Empire, hunting was an integral part of state organization and considered a form of military training or war exercise. Regular hunting activities, their scale, and the amount of game captured reflected the ruler's power and prestige. In addition, hunting expeditions had a practical dimension – they provided opportunities to assess provincial conditions, supervise officials, and hear the needs of the

population (Alkan and Gökbuğa, 2015). The Empire had many hunting centers, including as many as 38 in Rumelia (the Balkan provinces). Hunting birds also had an important role in Ottoman military and social life. They were symbols of prestige, often associated with the elite, and certain bird names were given to children and rulers. The breeding, training, and maintenance of hunting birds were organized through hunting guilds, which functioned both at the central court and in the provinces, with falconers recorded also in Rumelia (Alkan and Gökbuğa, 2015). The earliest Ottoman evidence of falconry in what is today Serbia dates to the 1440s. They were classified according to the birds they trained and were obliged to raise and deliver one falcon, goshawk, or another type of hunting bird each year (Amedoski, 2014). One coracoid bone of the Accipitridae, most likely from the Eurasian goshawk (*Astur gentilis* Linnaeus, 1758), was discovered in a mixed-material layer in Upper Town (Table 1). Given the predominance of early modern portable material within this layer, the find most likely belongs to the early modern period and may be of particular interest in this context. Historical sources, such as the *Voynuk Defter of 1455*, attest to the presence of falconers in the nahiya of Koznik (Katić, 2020: 51, 98), but it cannot be ruled out that falconers were present in the region already during the medieval period. Wild species remains are generally rare at early modern period sites in Serbia. The only available data come from the Old Synagogue site (Kokanović, 2022), which yielded roe deer remains, and from the Northern Bastion of the Novi Pazar fortress (Mladenović, 2024), which produced remains of roe deer, hare, and common buzzard.

As for fish remains at Koznik, they come only from the late medieval period in the Upper Town, represented by a single specimen of beluga sturgeon (Table 1, Fig. 11f). Fish played an important role in the medieval Serbian diet, being caught in rivers, lakes, and coastal areas. Fishing was also an important economic activity, as fish from Lake Skadar and the coast were exported to Italy. Although the wider population had limited access to fish due to geographic and social factors, it held special value among rulers, nobles, and Orthodox monasteries, especially during fasts. Monasteries often had fishponds or were granted fishing rights as part of royal donations (Katić, 1978; Mišić, 2007). Written sources emphasize the ritual and ceremonial value of fish, which came from key regions such as Zeta and the Danube (Anđelković and Rakićević, 2024). Certain locations, such as Đerdap, were famous for exceptionally rich fishing grounds, particularly prized species like sturgeons. Their presence in archaeozoological assemblages often indicates high-status contexts, both in Serbia (e.g. Živaljević et al., 2019; Mladenović, 2022) and in Central Europe (e.g. Bartosiewicz and Bonsall, 2008). Fish remains are also recorded in late medieval layers at Studenica Monastery (beluga sturgeon, Russian sturgeon, sterlet, carp, pike, and catfish) (Živaljević et al., 2019), the Old Synagogue in Belgrade (carp, catfish, pike) (Kokanović, 2022), and Rudnik (carp, sterlet) (Bulatović and Marković, 2019).

During the early modern period, fish also represented a significant part of the diet in these areas– consumed for religious reasons, due to fasting, and because of its affordable price. Fish was widely eaten by the Ottomans as well, which further contributed to its everyday consumption. Danube fish such as beluga sturgeon, sterlet, and stellate sturgeon were especially valued, sold in markets, and in Belgrade were said to be exceptionally cheap (Zirojević, 2005). Historical sources from the 15th and 16th centuries confirm that Đerdap fishing grounds remained active, with main fishing sites along the Danube between the Porečka River and the Timok (Amedoski, 2006; Zirojević, 1994, 2011). Fish was eaten fresh, salted, sun-dried, or turned into aspic, while caviar had a special status as a delicacy. Written sources mention that in Novo Brdo markets, various fish – beluga sturgeon, carp, pike, eel – as well as caviar were sold (Zirojević, 2005). Although no fish remains datable with certainty to the early modern period were found at Koznik, the presence of a beluga sturgeon maxilla[4] and common barbel (*Barbus barbus* Linnaeus, 1758) opercular and subopercular bones[5] in a mixed layer[6] (Table 1) suggests that some specimens may indeed come from that time. These finds suggest that high-value species like sturgeons might have been obtained through trade networks, while freshwater fish such as common barbel could have been caught locally. Fish remains are recorded in contemporary (16th–17th century) assemblages from the Monastery of St. Barbara at Reljina Gradina near Novi Pazar (carp, conger eel) (Mladenović et al., 2025), and the Old Synagogue in Belgrade (carp, catfish, pike) (Kokanović, 2022).

6. Conclusion

The archaeozoological evidence from Koznik fortress offers a detailed insight into the dietary habits, livestock management strategies, and economic roles of domestic animals across the late medieval and early modern periods. Data on species representation, skeletal elements, fragmentation, age-at-death, and butchery marks indicate that the archaeofaunal material primarily represents food remains. Sheep and goats were consistently the most numerous species, reflecting their central role in subsistence, both for meat and secondary products such as milk and wool. Cattle and pigs complemented the caprine-based livestock system, but their distribution varied between the Upper Town and the Suburb, pointing to differences in access to resources, dietary preferences, and the functional roles of different settlement zones. Pathological changes observed on caprine and cattle bones at Koznik could reflect a combination of factors, including fattening practices, strain on the skeletal system, infections, age, and body mass. These alterations could provide insight into the conditions of livestock keeping, suggesting that animals were exposed to workloads and management practices, and could have been exploited not only for meat but also for secondary products such as milk and wool. Poultry, primarily chickens, provided meat, eggs, and feathers, while hunting played only a marginal role, despite its symbolic and social importance. The occasional presence of fish, particularly high-status species such as beluga sturgeon, further highlights both local dietary practices and long-distance connections. The combination of archaeozoological data and historical sources confirms that livestock exploitation at Koznik reflects broader regional patterns.

This study is significant as it provides a comprehensive overview of animal exploitation and subsistence strategies at a fortified settlement, covering both the late medieval and early modern periods. Based on the archaeozoological evidence, it sheds light on local economic organisation, livestock strategies, and the daily lives of the fortress inhabitants, offering a valuable reference for understanding human-animal relationships in similar contexts across the Central Balkans.

CRediT authorship contribution statement

Teodora Mladenović: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Mladen Mladenović:** Writing – original draft, Formal analysis, Data curation. **Dejan Bulić:** Writing – review & editing.

Acknowledgements

The realisation of this research was financially supported by the

[4] The mentioned specimen belonged to an individual with a total length of 293.5 cm, according to the formula proposed in I. Živaljević et al. (2021: 423).

[5] These specimens belonged to a very large common barbel, approximately 85–95 cm in total length (information provided by I. Askeyev).

[6] It is a layer that mainly contained material from the 16th–17th centuries, but fragments of medieval pottery were also observed.

Ministry of Science, Technological Development and Innovation of the Republic of Serbia, through the funding of scientific research at the University of Belgrade – Faculty of Philosophy (Contract No. 451-03-33/2026-03/200163). The authors would like to express their sincere gratitude to MSc Aarilee Lorenzen (Arizona State University, USA) for English language proofreading. They are also grateful to MA Irina Kajtez (Institute for the Protection of Cultural Monuments of Serbia) and MA Jugoslav Pendić (BioSense Institute, Novi Sad, Serbia) for preparing certain illustrations, to Dr Igor Askeyev (Institute of Problems of Ecology and Mineral Wealth, Tatarstan Academy of Sciences, Kazan, Russian Federation) for assistance in the identification of common barbel bones, and to Dr Nemanja Marković (Institute of Archaeology, Belgrade) for his help in understanding pathological changes on animal bones. Furthermore, the authors acknowledge the anonymous reviewers for their valuable comments and constructive suggestions that improved the manuscript.

Appendix A. Supplementary data

Taphonomy data, Dental age data, Toothwear data, Epiphyseal fuson data, and Bone measurements according to the standardised system of A. von den Driesch (in mm; measurements name abbreviations are given in Driesch (1976); LD4 – Length of the deciduous 4th premolar, BD4 – Breadth of the deciduous 4th premolar; LP4 – Length of the 4th premolar, BP4 – Breadth of the 4th premolar, LM1 – Length of the first molar, BM1 – Breadth of the first molar, LM2 – Length of the second molar, BM2 – Breadth of the second molar, LM3 – Length of the third molar, BM3 – Breadth of the third molar, LD – Length of the deciduous premolar row, LP2-P4 – Length of the premolar row P2-P4, LM – Length of the molar row, LP2-M3 – Length of the cheektooth row P2-M3). Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2026.105784.

Data availability

Data will be made available on request.

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