SIZE OF THE CAVE BEAR POPULATION AND SKELETAL DISTRIBUTION FROM URŞILOR CAVE, ROMANIA

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Abstract. Spatial distribution analyses of fossil bones are often used in cave taphonomy for i) assessing directly the size of a given fossil population and ii) indirectly, for palaeo-environmental reconstructions. Urşilor Cave from northwestern Romania hosts one of the richest MIS 3 cave bear bone assemblages of Europe, and as the nature of the bone deposition was not settled yet, the study of the size of cave bear population and the distribution of the skeletal element was needed. More than 11,500 cave bear skeletal elements ($NISP_{total}$ = 11, 511), derived from 105 individuals ($MNI_{canines}$ = 105) were extracted from the palaeontological excavation (*ca*. 9 m^2) from the lower level of the cave and documented (photographed, mapped, and topographically measured). Almost 58% of all analyzed bones and teeth are concentrated in three quadrants of the excavation (C1, D1 and E2); the bones' density decreases in the D4 and A1 quadrants. Based on the obtained results on the spatial distribution of the cave bear bones, we assume that the studied bone assemblage should be now regarded as a consequence of a cave trap (deposition *in situ*) while the hypothesis of fluvial transport (previously assumed) becomes questionable.

Key words: taphonomy, MIS 3 cave bears, spatial distribution analyses, Romanian Carpathians.

1. INTRODUCTION

In taphonomy spatial analyses are used for better understanding the mechanisms and processes that contribute to the genesis of bone assemblages. In karst settings, the study of densities and distribution of bones recovered from paleontological excavation may provide important clues regarding the shape and the structure of a bone deposit. Moreover, taking into account data from related sciences (*e.g.*, geomorphology, sedimentology, geochronology) one can achieve a more complete picture of the initial conditions that led to the formation of a fossil reservoir (LYMAN, 2004) and indirectly, the obtained data could help in the palaeoenvironmental reconstructions (*e.g.*, ZILHÃO et al., 2013; CONSTANTIN et al., 2014).

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In Europe, the vast majority of caves prone to such investigations, are the Marine Isotopic Stage 3 (MIS 3) *Ursus spelaeus* (ROSENMÜLLER & HEINROTH, 1794) sites, where fossil bones are abundant and could be used as proxy for re-building the geologic history of a cave system throughout Upper Pleistocene and even earlier (STINER et al., 1996; PACHER, 2004; PACHER & QUILÉS, 2013; CONSTANTIN et al., 2014).

Analysis of the taphonomy of MIS 3 bone material in caves has yielded interesting results in Germany, Austria, France, Spain, Poland, Czech Republic, Slovenia, Slovakia and Serbia on the bone beds formation and on their structure (*e.g.* KLEIN, 1982; GARGETT, 1994; GRANDAL-D'ANGLADE & VIDAL,1997; STINER, 1998; STINER et al., 1998; WEINSTOCK, 2000; GERMONPRÉ & SABLIN, 2001; PACHER, 2004; SABOL, 2005; WOJTAL, 2007; ARILLA et al., 2014; DEBELJAK, 2002, 2004, 2007).

In Romanian Carpathians, one of the richest area of Europe in cave bear sites (*ca*. 160 known localities), the studies regarding the distribution and densities of fossil bones in caves and their implications on the palaeo-evolution of karst areas was long time neglected.

Urşilor Cave is one of the most complete European cave bear site, containing the full range of evidences of this vanished species [fossil bone assemblages of different typology and bioglyphs (fur imprints, footprints, claw marks etc.)]. The study of the density of bones and their distribution in a bone assemblage is needed to provide insights on the typology of the thanatocoenosis, its internal structure and genesis, previously assumed to be derived *via* reworking processes (Jurcsák et al., 1981; ROBU, 2015b).

2. MATERIALS AND METHODS

2.1. THE SITE

Urşilor Cave is situated in the northwestern side of Romania, Bihor Mountains, on the left slope of Craiasa Valley, at 491 m a.s.l. The cave, developed in Jurassic recristalized limesones, has two karstic levels: an inactive hydrologically level, touristically arranged, and an inactive one drained by an underground river (ROBU at al., 2011; CONSTANTIN et al., 2014; ROBU, 2015a,b). The excavation is located at the lower level of the cave (= *Scientific Reserve*), beneath a 18 m steep slope (= *The Shaft*; Fig. 1).

2.2. MATERIALS AND METHODS

The fossil remains from Urşilor (dated to ~47 – 40 kyrs BP; CONSTANTIN et al., 2014) were excavated on a surface of almost 9 m^2. A rich bone deposit sealed within three types of fine clay, was encountered within the first 40–80 cm below the surface (L1, L2 and L3; Fig. 1). The depositional environment for these first three sediment layers ("backswamp facies" – *sensu* BOSCH & WHITE, 2004) was a low-energy one. Level 5 (100–140 cm below surface), less rich in fossils than the first three, is marked by a higher hydraulic gradient and by the presence of more scattered cave bear bones. Since the bone bed was presumably post-depositionaly flooded and covered by sediments, all the fossil material was pooled together and analyzed as a single bone layer. The excavation undertaken in the Excavation Chamber during fieldwork campaigns between 2010 and 2013 produced *ca.* 11,500 bones and bone fragments. The bone assemblage is cave bear dominated, with the majority of bones (>99%) belonging to *Ursus spealeus* species. Most of the sediment excavated during the 2010–2013 campaigns was wet-sieved.

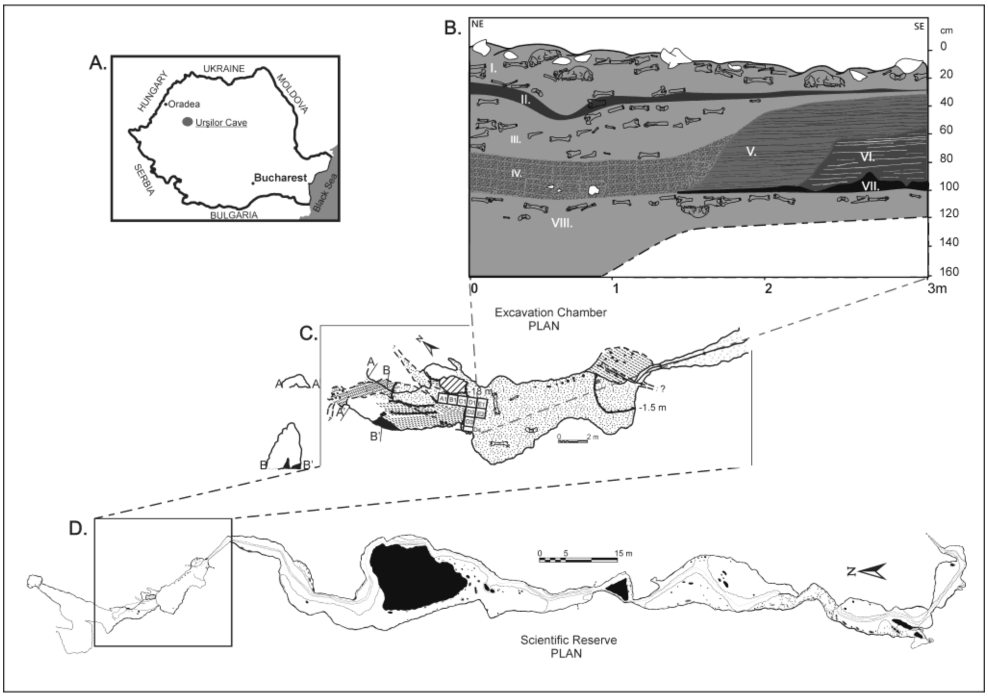

Fig. 1. A – Urşilor Cave location; B – Stratigraphy of the palaeontological excavation (section; I–VIII are stratigraphic layers); C – Excavation Chamber (plan); D – Scientific Reserve (plan).

In order to analyze the spatial distribution of the skeletal specimens, several methods were applied: Number of Indentified Specimens (NISP), Minimum Number of Individuals (MNI), Minimum Number of Animal Units (MAU), and bone surveying.

Quantitative distribution of single skeletal specimens has been calculated using NISP, an observational method for counting the *specimens sensu* GRAYSON, 1984).

The MNI method was used for assessing the minimum number of individuals within the excavated bone bed; it accounts for all the different types of skeletal elements found in the skeleton of a taxon (the humeri, the femora, the mandibles etc.).

MAU was used to standardize the frequencies of the skeletal parts (*sensu* LYMAN, 2004) and it stands for the minimum number of animal units necessary to account for the specimens from a collection.

Bone surveying (mapping, photographing and measuring the depth at which each bone was found) was applied in order to document the spatial distribution of the fossil remains from the excavation at a resolution (depth) of 10 cm for each quadrant (ROBU, 2015b).

3. RESULTS AND DISCUSSION

The excavation (missions) campaigns at Urşilor yielded a total of 11,511 ($NISP_{total}$) identified cave bear remains. The excavated assemblage comprises 9,612 identified bone remains and 1,899 teeth (both juveniles and adults; Tab. S1 and S2; ROBU, 2015b).

Among the large elements, the flat bones (*e.g.* scapula) seem to produce a higher number of fragments (NISP), since their structural density is lower than that of the smaller and more masive bones (*e.g.* metapodials; Fig. 2). The higher number of fragments in the large specimens (bones) could be explained as well by predator activity. Flat bones (*e.g.* scapulae, skulls, pelvic bones, mandibles, ribs etc.) normally have larger muscle insertions when compared with other parts of the skeleton, and therefore they are more likely to be affected by predator activity, producing high NISP values.

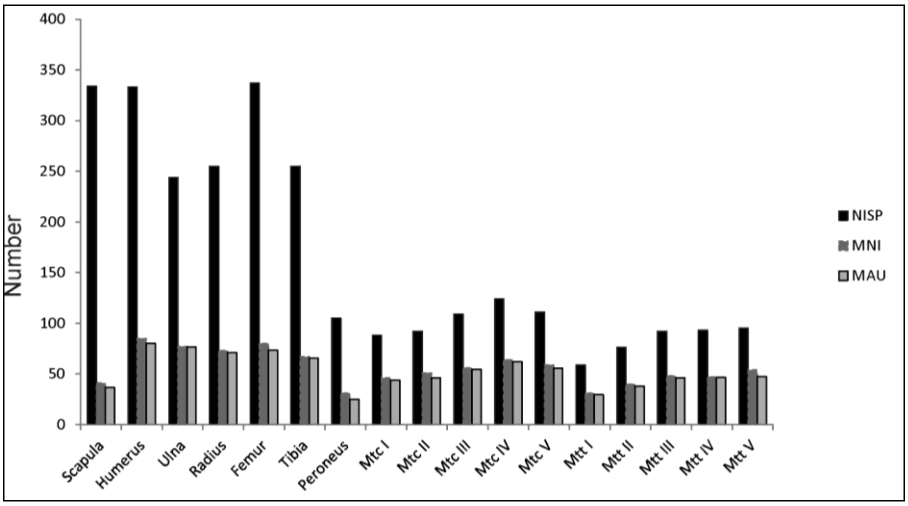

Fig. 2. The main skeletal elements from the excavation at Urşilor.
Note: Mtc = metacarpals; Mtt = metatarsals

The long bones, especially the stylopodium (humeri and femora) also had high fragmentation values, although their structural densities are relatively high. This can be explained mainly by the impact of carnivores and by post-depositional processes (*e.g.* trampling).

In metapodials, there is a similar shape to the distribution for the values of NISP, MNI and MAU. This can be explained by both the high structural density of bones and low carnivore impact.

The assemblage contains a small number of bones and teeth of neonatal individuals. Only a few individuals were recorded (*MNI* = 7) and pooled together with the adults for the NISP, MNI and MAU analyses.

The highest values for the minimum number of individuals for the long bones were obtained for the humeri and femora (*MNI* = 85 and 80, respectively). Other well represented skeletal elements are the ulnae (77 individuals), radii (73), mandibles (73) and tibiae (64). On the other hand, the skulls (*MNI* = 23), cervical vertebrae (atlas and axis, *N* = 52 and 38, respectively), and fibulae (*N* = 31) have a low representation within the cave bear bone assemblage.

The highest MNI values recorded for the cave bear bone assemblage from Urşilor were obtained for the upper canines (*MNI* = 105) and for the M_2 (*MNI* = 96; Fig. 3 and Tab. S2). High values were recorded for the lower and upper molars (*e.g.* M_3: *MNI* = 85 M^1: 84; M^2: 85 etc.). Although the wet-sieving method was performed on the sediments, a lower number of incisors were found in the palaeontological excavations.

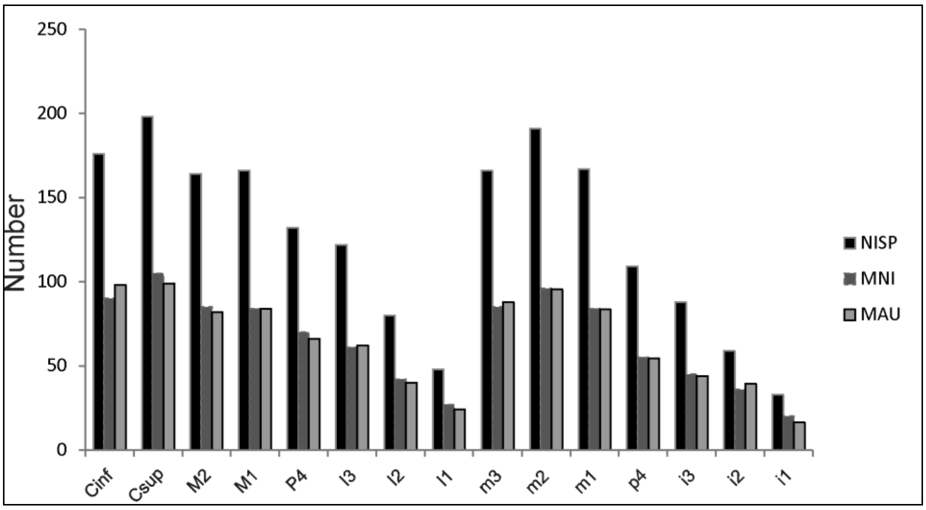

Fig. 3. Quantitative analysis of the cave bears teeth
from the palaeontological excavation within Urşilor.

The highest NISP, MNI and MAU values for the incisors were recorded for the I^3 (*MNI* = 61) and I_3 (*MNI* = 45). The lowest values were obtained for the first incisors (the lower and upper I1: I_1:20 and I^1: 27).

The higher occurence of broader teeth (*e.g*. molars, canines) in the palaeontological excavations can be explained by their structural density, which makes them more resilient to the taphonomic destruction when compared with smaller teeth, like incisors or premolars, especially when they belong to juvenile individuals.

A comparison between the occurence of teeth from jaws and alveoli was undertaken for the left and right sides of the skeleton (Fig. 4). Small differences were encountered between the left and the right sides, while both curves show an almost identical pattern. Nonetheless, the left side is slightly better represented with respect to the I^3, C^{sup}, P^4 and C_{inf}, P_4, M_1, M_2 and M_3.

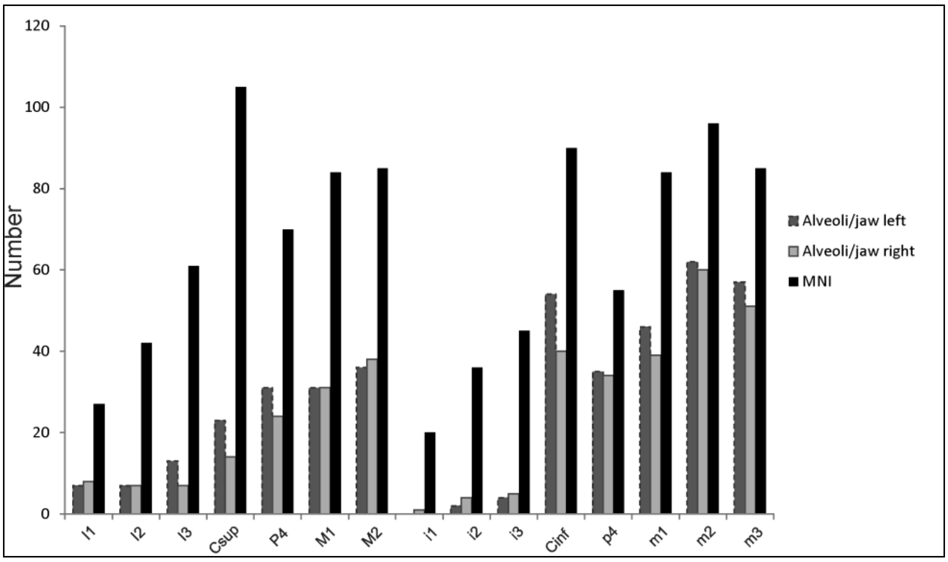

Fig. 4. Right and left teeth found in alveoli/jaws
from the palaeontological excavation within Urşilor.

Figure 5 shows a comparison between the isolated teeth on the left and right sides and points to a similar pattern as in teeth in the alveoli/jaw. The right side is slightly better represented for the I^1–I^3, M^1, M^2 and C_{inf}, P_4, M_1 and M_3. Figures 4 and 5 point to an equality between the values of the right and left sides for all cave bear dentition found within the excavated bone assemblage.

Figure 6 emphasizes the correlation between the MNI and MAU quantitative units (scapulae, humeri, ulnae, femora, tibiae etc.) when they are used to measure the frequencies of the skeletal parts (the black line is the simple, best-fit regression line; the red line is the diagonal – origin of 0, slope of 1). For the skeletal parts, the MAU values tend to be similar to the MNI values. Although all the plotted points fall above the diagonal line, the regession line is parallel with the diagonal. This result points out that the frequencies of the left and right-side skeletal fragments do not significantly differ. The simple, best-fit regression line through the scattered points (y = 1.0134x + 2.1748; R^2 = 0.99; P<0.001) has a slope = 1, suggesting that the skeletal parts have the same frequencies, and therefore, there is no significant difference between MNI and MAU values (*sensu* LYMAN, 2004; ROBU, 2015b).

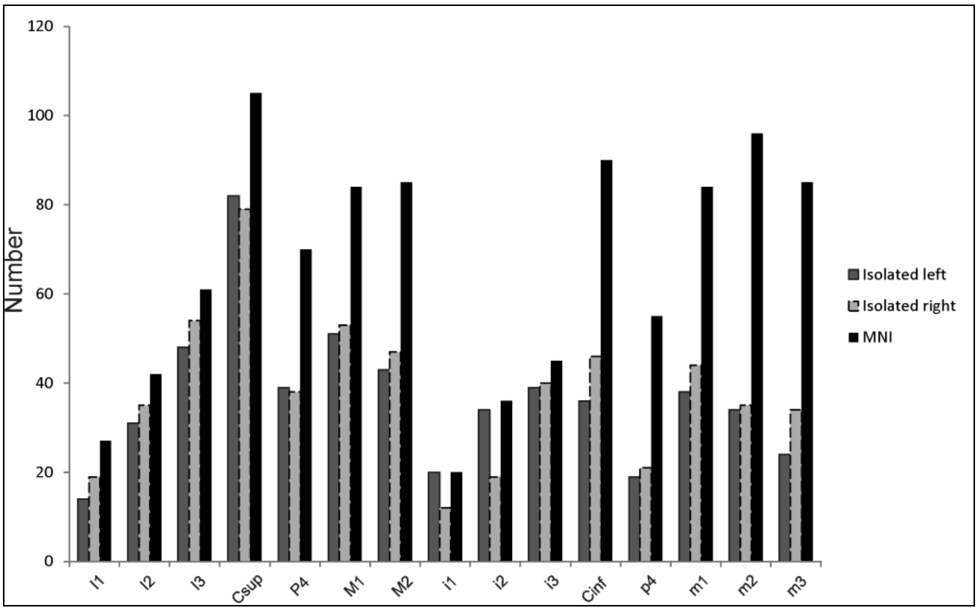

Fig. 5. Right and left isolated teeth
from the palaeontological excavation within Urşilor.

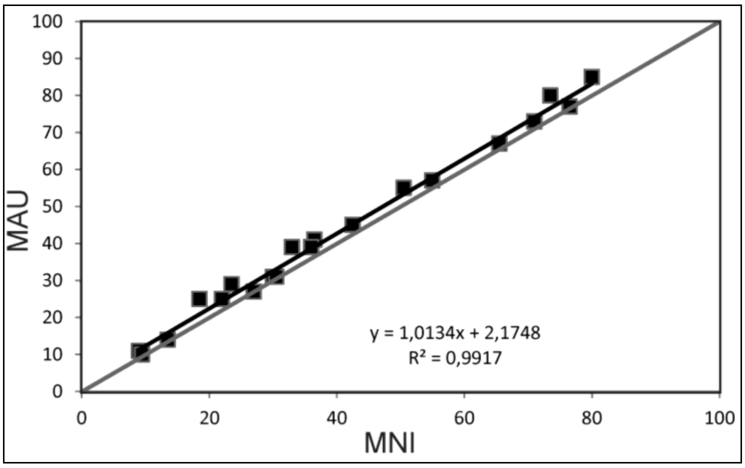

Fig. 6. MNI vs. MAU for the skeletal fragments
from the palaeontological excavation within Urşilor.

Figure 7 illustrates the differences between the frequencies of the left (N = 878) and the right (N = 932) skeletal parts within the cave bear assemblage from Urşilor. The simple, best-fit regression line (y = 0.9279 + 0.6003; R^2 = 0.9224; P<0.001), suggests increasingly larger differences between the frequencies of the left and the right-side skeletal fragments as the frequencies of the skeletal parts increase. Nonetheless, the simple, best-fit regression line (the black line) has an almost identical slope to the diagonal of the graph (the red line, origin of 0, slope of 1) which means that the elements have equal or almost equal frequencies.

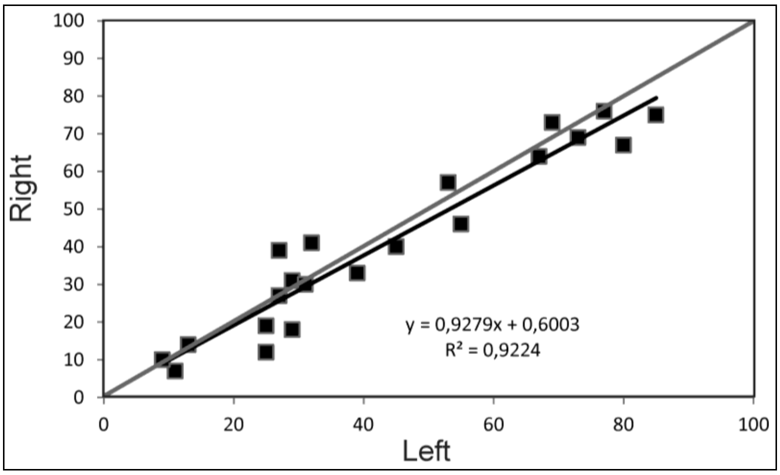

Fig. 7. MNI for the cave bear left and right-side skeletal fragments found within the palaeontological excavations at Urşilor.

Fig. 8 shows the spatial distribution and the density by quadrant of the cave bear bones (crania, mandibles, long bones and isolated teeth) found within the palaeontological excavation. It is worth mentioning that the outer border of the A1–E1 quadrants represents the wall of the Shaft, while the outer border of the D4 quadrant – the other wall of the Excavation Chamber. The bone density displayed on the three charts in Fig. 8 (crania, mandibles and long bones) is derived from the survey *folios* (therefore they do not represent the real density from the excavations; Tab. S1), while the fourth chart presents the adult isolated teeth density. The real number of crania and cranial fragments recovered from the excavation (as well as that recorded for the mandibles and long bones) largely exceeds the density presented in Fig. 57, but this figure only presents the documented (surveyed, photographed and depth-measured) remains. For reasons of consistency, in the next subchapters, the same documented fossil remains will be analyzed for dispersal, scattering and orientation.

Although several crania (N = 28) were mapped and documented within the palaeontological excavation (Fig. S1), not all of them have been fully recovered because of their poor state of preservation. Nonetheless, three quadrants – C1, D1 and E1 exhibited the highest density of crania from the excavation (60.7%).The smallest number of crania was recorded for the D3 and D4 quadrants; the low density of crania is explained by the reduced thickness of the bone assemblage in this area when compared with the other quadrants.

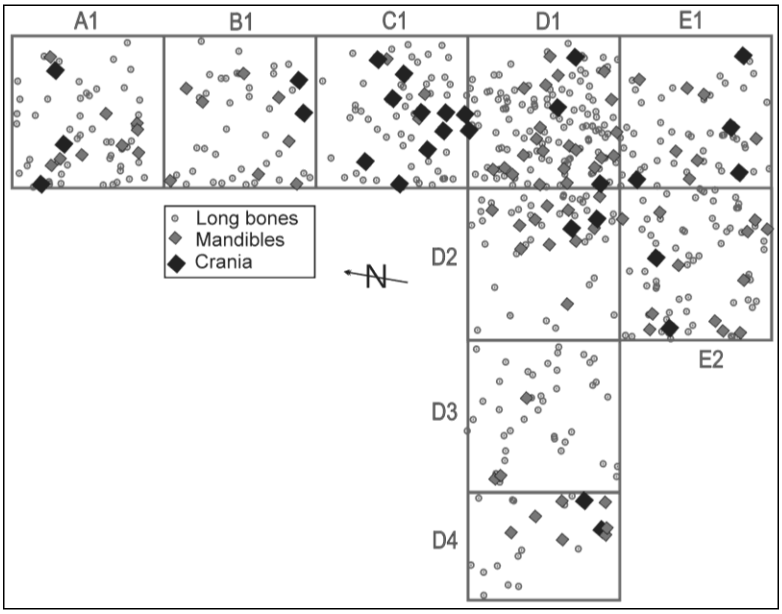

Fig. 8. Spatial distribution by quadrant of the cave bear bones recovered from the palaeontological excavation within Urşilor. Note: cranium, mandible and long bones densities are derived from the survey folios; the isolated tooth density is derived from the analysis of the entire excavated bone assemblage.

More than 80 mandibles of all age categories were mapped within the palaeontological excavation. The highest concentration of mandibles was recorded within the D1–D2–E1–E2 areas (60.5%; Fig. 9 and 10). The lowest density values were obtained for the D3 and D4 quadrants – 3.8% and 7.8%, respectively.

The documented long bones (humeri, ulnae, radii, femora and tibiae – $N = 451$) are distributed within the palaeontological excavation in a similar manner to the crania and mandibles (Fig. 10). The highest concentration of documented long bones was recorded in a north-east/south-west direction, within the C1–D1–E2 areas ($N = 225$; ~50%).

Among the surveyed cave bear long bones from the palaeontological excavations within Urşilor, *the humeri* are the most numerous ($N = 136$; 30.2%; Fig. S2). The spatial distribution of the humeri is mainly concentrated within four quadrants: C1–D1–E1–E2 (56%); a secondary concentration area has been found in the A1 quadrant (14%; Fig. S2). The *ulnae* account for 16% ($N = 71$) of the total amount of surveyed long bones. They are mainly concentrated within the C1–D1–E2 quadrants (51%; $N = 36$), while the D3–D4 quadrants have the lowest density ($N = 8$; 11%; Fig. S3).

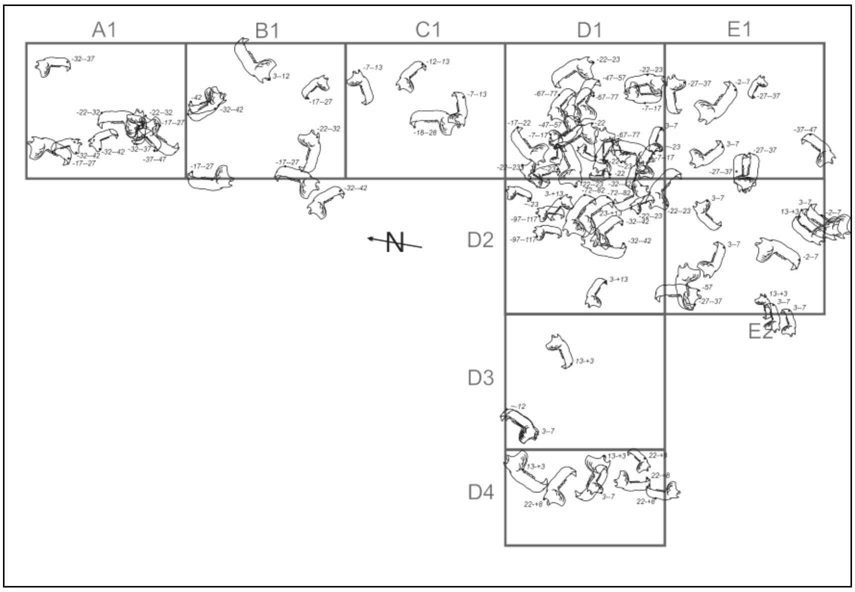

Fig. 9. Spatial distribution of the cave bear mandibles from the palaeontological excavation within Urşilor: the bones are illustrated according to scale and depth (in centimeters, respecting the “0” datum). Excepting D4, the area of each quadrant is 1 m 2.

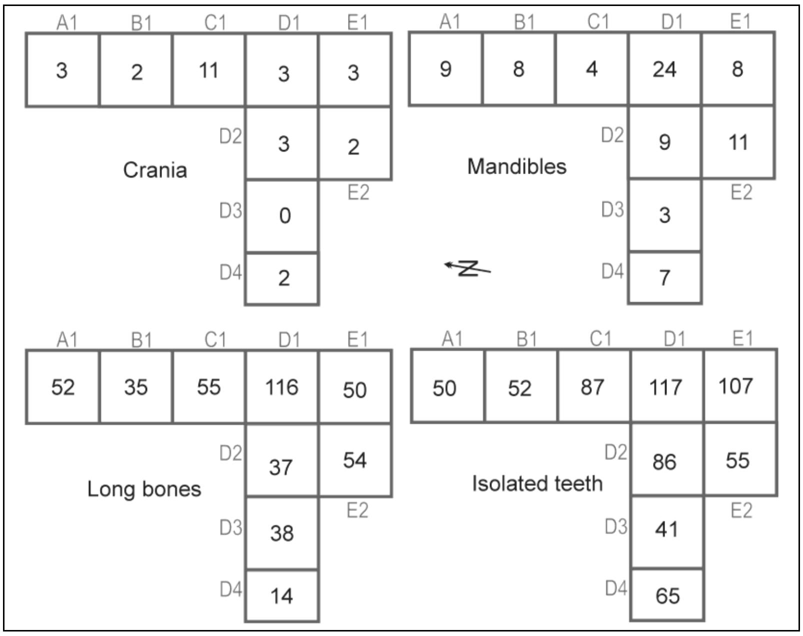

Fig. 10. Spatial distribution by quadrant of the cave bear bones within the palaeontological excavation from Urşilor.

The percentage of *radii* among the surveyed cave bear long bones is 16.9% (*N* = 76;). The highest density of radii recorded for the palaeontological excavation, was in the D1, D3 and E2 quadrants (54% of the total number of radii; *N* = 54). The lowest densities were obtained for the B1 and D4 quadrants (5.2 % and 2.6%, respectively; *N* = 6; Fig. S4).

The cave bear *femora* account for 20.4% (*N* = 92) of the total number of surveyed long bones. The highest concentration of femora within the palaeontological excavation was found in the C1–D1–E2 quadrants (44%; *N* = 40). The A1 quadrant represents a secondary pole of concentration for femora, with ~12% (*N* = 11). The lowest density was recorded for the D3 and D4 quadrants (5% and 3.3%, respectively; Fig. S5).

The cave bear *tibiae* represent the second numerous bone group, after the humeri, among the surveyed long bones (20.8%; *N* = 94). They are mainly concentrated within the C1–D1–E1–E2 areas (74.5%; *N* = 70). The lowest densities of tibiae were found in the A1 and D4 quadrants (3.2% and 2%, respectively; Fig. S6).

The chart of the distribution of the isolated adult cave teeth (Fig. 8; *N* = 660) accounted for all of the specimens (documented and undocumented *in situ*) found within the palaeontological excavation, indicate a similar pattern of spatial distribution as in the crania, mandibles and long bones emerges. The highest density of teeth was recorded within the D1 (17.7%), E1 (16.2%), C1 (13.2%) and D2 (13%) quadrants, totaling 60.1% of the total amount of the adult isolated teeth; lower values were documented in the D4 (9.8%) and E2 (8.3%) quadrants, while the lowest densities were recorded for the D3 (6.2%) and A1 (7.6%) quadrants.

4. CONCLUSIONS

After analyzing the spatial distribution of the crania, the mandibles, the long bones and the teeth found within the palaeontological excavation at Urşilor, a general pattern of bone dispersal can be drawn. Almost 58% of all analyzed bones and teeth are concentrated in three quadrants of the excavation (C1, D1 and E2); the bones' density decreases in the D4 and A1 quadrants. The high density recorded for the C1–D1–E2 quadrants is explained by the thickness of the bone assemblage, which reaches a maximum of *ca*. 100 cm. Within the D3–D4 quadrants, the bone deposit thickness is about *ca*. 35 cm. The high concentration of bones within the south-eastern part of the excavation may be explained as a consequence of this being a cave trap. As the bottom of a 17 meter deep shaft borders the excavation, it seems obvious that the highest bone density would be recorded within the C1–D1–E1–E2 quadrants; on the other hand, the lower bone density farther from the Shaft area is predictable and explainable. As the spatial distribution of the cave bear bone assemblage is now regarded as a consequence of this being a cave trap, the hypothesis that this was a result of fluvial transport becomes questionable or it could be discarded.

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Table S1

Quantitative analysis of cave bear skeletal elements from Urșilor.

Skeletal part	***NISP***	***MNI***	***MAU***
Cranium	768	23	23
Mandible	299	73	71
Hyoid	45		
Atlas	52	20	20
Axis	38	22	22
Cervical vertebrae	155		
Thoracic vertebrae	359		
Lumbar vertebrae	165		
Caudal vertebrae	64		
Vertebrae fragments	784		
1st sternum bone	27	27	27
Other sternum bones	98		
Ribs (and rib fragments)	1817		
Scapula	334	41	36.5
Humerus	333	85	80
Radius	255	73	71
Ulna	244	77	76.5
Carpals	342	45	28.5
Metacarpals	524	64	52.4
Pelvis	232	39	33
Sacrum	27	27	27
Femora	337	80	73.5
Patella	69	41	34,5
Tibia	255	67	65.5
Fibula	105	31	25
Tarsals	380	57	35.6
Metatarsals	415	54	41.5
Metapodial fragments	58		
Phalanges	940	42	25.45
Sesamoid	113		
Bacculum	5	5	5
Totals	***9612***		

Table S2
The teeth, isolated or articulated in jaws, found within the excavation from Urșilor.

	Jaws		**Isolated**		**MNI**
Tooth	***Left***	***Right***	***Left***	***Right***	
I^1	7	8	14	19	27
I^2	7	7	31	35	42
I^3	13	7	48	54	61
C^{sup}	23	14	82	79	105
P^4	31	24	39	38	70
M^1	31	31	51	53	84
M^2	36	38	43	47	85
I_1		1	20	12	20
I_2	2	4	34	19	36
I_3	4	5	39	40	45
C_{inf}	54	40	36	46	90
P_4	35	34	19	21	55
M_1	46	39	38	44	84
M_2	62	60	34	35	96
M_3	57	51	24	34	85
Totals: 1899					

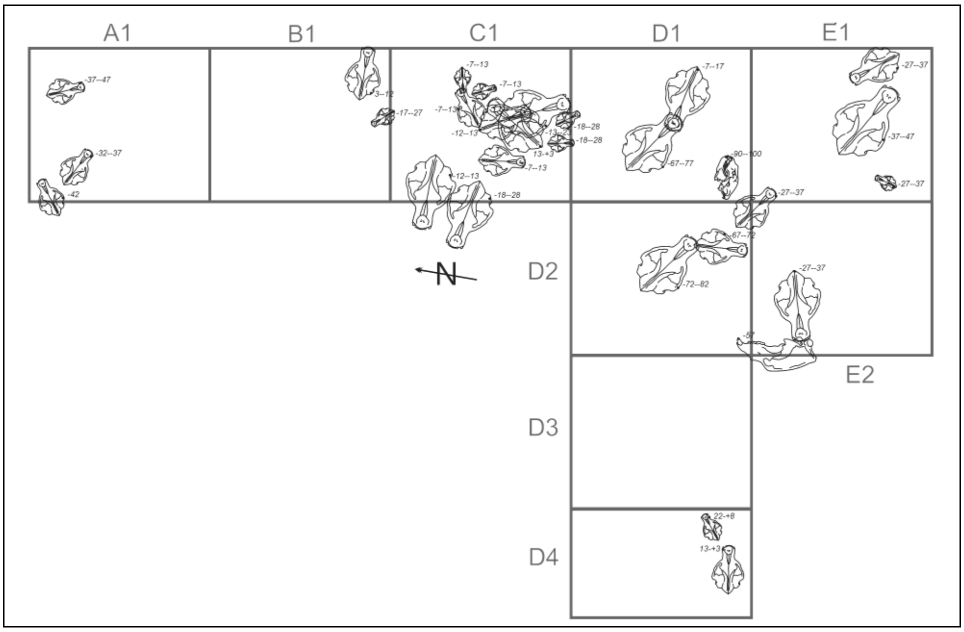

Fig. S1. Spatial distribution of the cave bear crania from the palaeontological excavation within Urșilor: the bones are illustrated according to scale and depth (in centimeters, respecting the “0” datum). Excepting D4, the area of each quadrant is 1 m2.

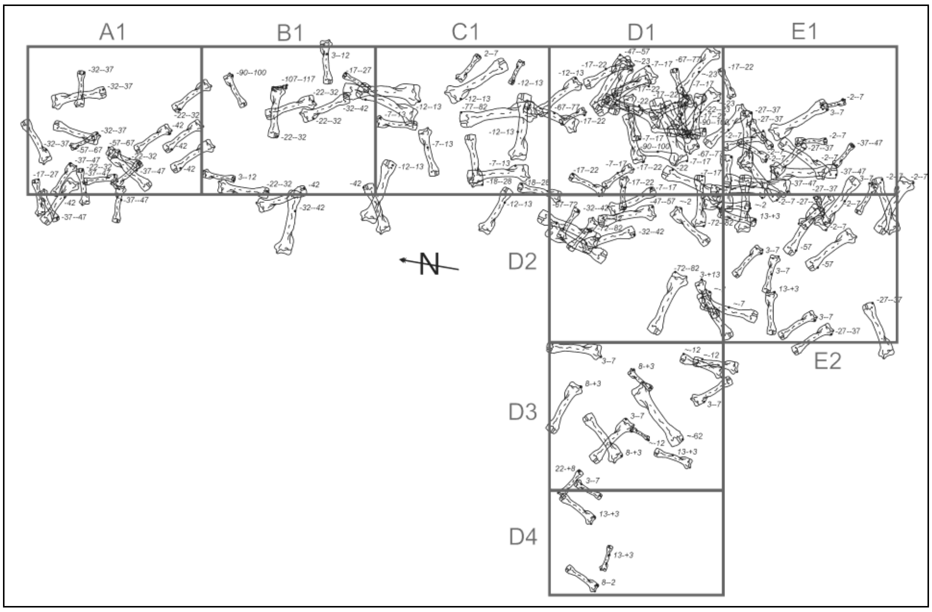

Fig. S2. Spatial distribution of the cave bear humeri from the palaeontological excavation within Urșilor: the bones are illustrated according to scale and depth (in centimeters, respecting the “0” datum). Excepting D4, the area of each quadrant is 1 m2.

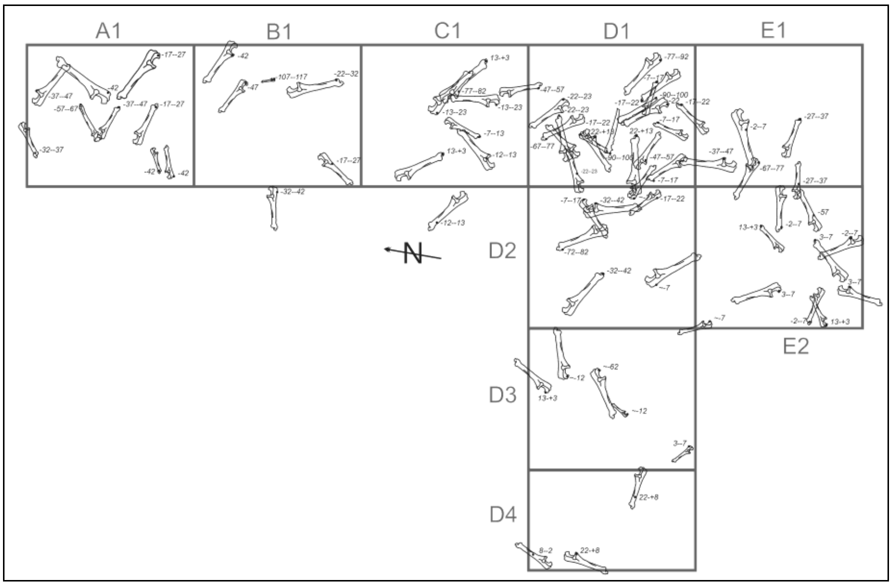

Fig. S3. Spatial distribution of the cave bear ulnae from the palaeontological excavation within Urșilor: the bones are illustrated according to scale and depth (in centimeters, respecting the “0” datum). Excepting D4, the area of each quadrant is 1 m2.

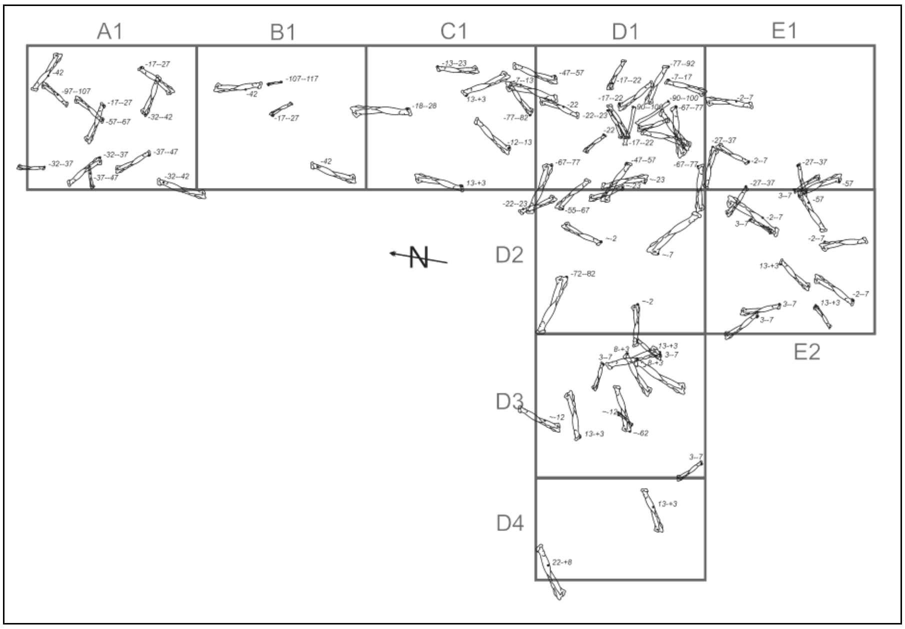

Fig. S4. Spatial distribution of the cave bear radii from the palaeontological excavation within Urșilor: the bones are illustrated according to scale and depth (in centimeters, respecting the “0” datum). Excepting D4, the area of each quadrant is 1 m2.

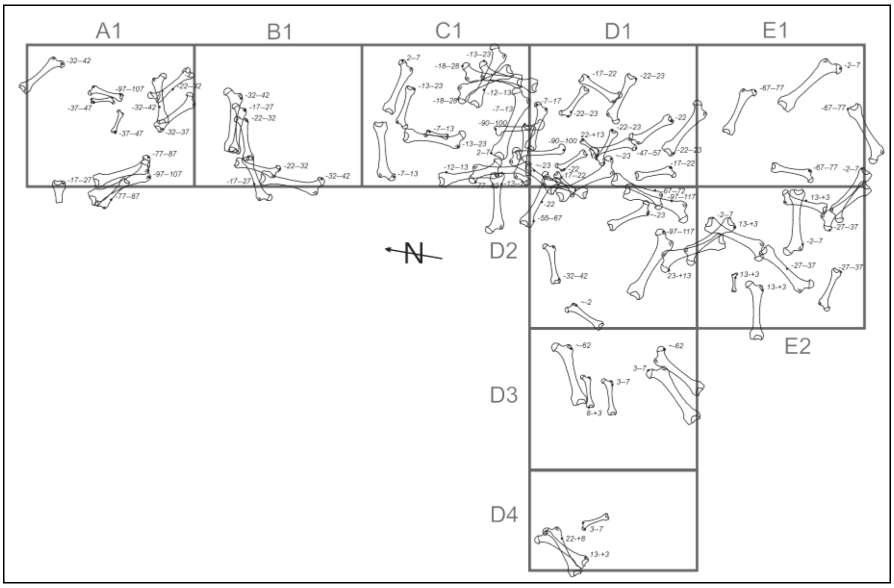

Fig. S5. Spatial distribution of the cave bear femora from the palaeontological excavation within Urșilor: the bones are illustrated according to scale and depth (in centimeters, respecting the “0” datum). Excepting D4, the area of each quadrant is 1 m2.

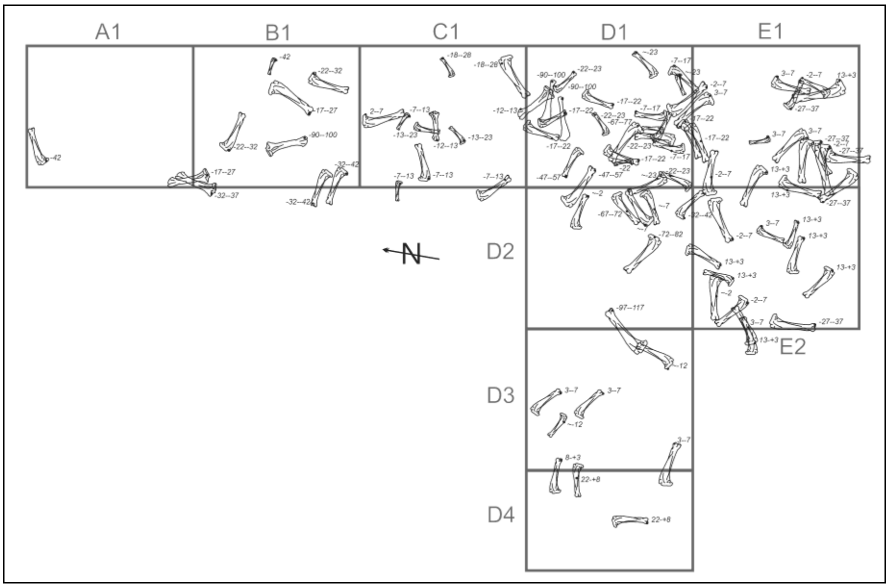

Fig. S6. Spatial distribution of the cave bear tibiae from the palaeontological excavation within Urșilor: the bones are illustrated according to scale and depth (in centimeters, respecting the “0” datum). Excepting D4, the area of each quadrant is 1 m2.

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