



## Fallow deer bone beds in Tabun Cave Layer B: Insights from renewed fieldwork

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### ABSTRACT

Tabun Cave Layer B in Mount Carmel, Israel, at the base of a deep vertical shaft, has been recognized since the 1930s for its abundance of fallow deer remains. Three explanations have been proposed for their origin: human habitation refuse, the use of the cave as a hunting trap, and the cave acting as a natural pitfall trap. Results of our zooarchaeological and taphonomic analyses of the faunal materials from the renewed excavations in the inner chamber of Tabun Cave Layer B indicate a fallow-deer-dominated assemblage with low pre-burial breakage and significant mechanical post depositional breakage. The assemblage reflects the characteristics of a natural fallow deer herd structure. However, Layer B is not homogeneous and it is subdivided into distinct units with varying characteristics. Compared with sub-Layers B1 and B2, sub-Layer B3 contains fewer fallow deer and limb bones, with greater bone breakage, and exhibits higher levels of weathering and carnivore modifications and slightly more anthropogenic modifications. Approximately one-third of the individuals in this sub-layer exhibit unfused bones, consistent with the dental age data, while the others exhibit an equal representation of juveniles and adults. However, even in this case, we lack clear evidence that its agents of accumulation changed. The fauna underwent some carnivore ravaging and displays minimal human processing. While the research of Tabun Layer B is ongoing, current analysis of the faunal remains within the inner chamber of the cave suggests that the bones primarily accumulated through natural animal falls into the cave, followed by scavenging by carnivores, and only rarely by humans.

### 1. Introduction

Understanding the accumulation processes of Pleistocene bone assemblages is crucial for Paleolithic archaeology, as it enables accurate interpretations of hominin behavior, past environments, and animal ecology (Binford, 1981; Brain, 1981). A variety of agents (e.g., humans, carnivores) and processes (e.g., pitfalls, fluvial transport) contribute to the formation of bone accumulations, which can be systematically analyzed through taphonomic methods (Lyman, 1994).

Anthropogenic bone accumulations, resulting from daily human activities, reflect subsistence strategies such as hunting, scavenging, butchery, and the manufacture of tools and ornaments. Taphonomic indicators of human involvement include cut marks from stone tools, percussion marks and fractured limb-bones from marrow extraction, and the presence of burnt bones and worked bones (Binford, 1981; Brain,

1981; Blasco et al., 2013).

Animal-related bone accumulations are commonly produced by the hunting, feeding, or collecting behaviors of carnivores, scavengers and collectors (Sutcliffe, 1970; Brain, 1981; Rabinovitch and Horwitz, 1994; O'Regan et al., 2011). These assemblages are typically marked by gnawing and digestion traces. Skeletal part representation may be skewed toward the dense bones, while smaller bones might be ingested and later regurgitated (Marean and Cleghorn, 2003; Marean et al., 2004). Predator dens, lairs, and kill sites are prime examples, offering valuable insights into ancient food webs and predator-prey dynamics.

Natural processes and traps represent non predatory mechanisms of bone accumulation. Mass mortality events (e.g., droughts, floods, freezing) and fluvial transport can move and sort bones via water currents, often resulting in abraded and disarticulated remains deposited in riverbeds or floodplains (Kahlke and Gaudzinski, 2005; Rivals et al.,

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2013; Bunn and Gurvov, 2014). Natural traps, such as sinkholes or crevices, can entrap animals, leading to their death and eventual fossilization. Assemblages from such traps often exhibit excellent preservation and may represent a taxonomically diverse sample of the local fauna (Martin and Gilbert, 1978; Brugal et al., 2006; Coumont et al., 2013).

Identifying the specific taphonomic pathways that led to the formation of a Pleistocene bone accumulation is essential for unlocking the rich paleoecological and paleoanthropological information it contains. However, many assemblages are palimpsests, complex products of multiple depositional episodes involving various agents over time. Dissecting the palimpsest (Stiner et al., 1996), i.e., disentangling these overlapping signals is fundamental to their accurate interpretation.

Tabun Cave Layer B and Chimney Units II–I were excavated extensively in the 1930s, yielding a massive accumulation of fallow deer bones. In the course of the 95-year-long research history of the cave, three scenarios were suggested to explain how the archaeological and paleontological materials got into the chimney/Layer B. The initial suggestion was that humans lived in the cave (Garrod and Bate, 1937). Although they mentioned that some materials may have entered the cave through the chimney, recognizing that the cave's inner chamber was inaccessible in its last stages, the lithic finds and the absence of complete fallow deer skeletons led them to conclude that humans still occupied the inner chamber during the time of the Middle Paleolithic units (II–I) of the chimney (Garrod and Bate, 1937:61–62). The second explanation, based on Garrod's observations of bone completeness, the absence of hearths in the inner room, the proportions of tools within the lithics, and a better understanding of the geoarchaeological sequence of the cave that suggested the enlargement of its ceiling opening, was that humans used the cave as a trap by leading fallow deer to fall through the chimney (Jelinek et al., 1973:179). The third scenario was that the faunal remains were the result of animals falling to their death through the chimney, without being chased (Garrard, 1982). This explanation was supported by Marín-Arroyo's (2013a) taphonomic analysis, which suggests that humans were not the accumulation agent but rather occasionally scavenged the carcasses of the deer that fell in accidentally.

However, all the analyses thus far have been based on the materials from Garrod's excavations, presenting considerable collection and retention biases and stratigraphic and contextual ambiguity. Our high-resolution analysis is the first to reassess the nature of the inner chamber faunal remains based on the meticulous stratigraphic documentation and systematic collection of the renewed excavations. This enables us to integrate several lines of evidence and suggest a depositional history for the outstanding fallow deer accumulation at the uppermost deposits of Tabun Cave.

In this paper, we present the analysis of faunal remains from the most recent excavations in the cave and aim to shed new light on the debate pertaining to the agents of the Tabun Layer B bone accumulation. Using the zooarchaeological materials, our objective is to reconstruct the depositional history of the bone assemblage and evaluate whether the faunal remains were deposited in the cave by humans who inhabited it or if they belong to deer that fell into the cave via the chimney, either accidentally or having been driven to their fall by humans.

Our primary line of investigation is based on the supposition that each of the three scenarios leading to the massive bone accumulation in Tabun Layer B would exhibit a different set of distinct characteristics.

In the first scenario, that of a habitation site, the assemblage is expected to present ample evidence of butchery and consumption and either all parts of the skeleton or a preference for meat-bearing skeletal parts, and to contain scarce, if any, articulated elements. Carnivore modifications are expected to be low (e.g., Speth and Tchernov, 2007; Yeshurun et al., 2007).

The second scenario, that of a natural trap, is expected to yield an exceptionally well-preserved assemblage, showing an even distribution of skeletal parts with articulated elements and minimal bone breakage (Oliver, 1989; Lubinski, 2013). Ideally, we expect accumulation in

natural traps to be random, creating a relatively uniform pattern over time. However, this ideal is not always met, and many natural traps exhibit stratified layers (e.g., Martin and Gilbert, 1978; Oliver, 1989; Wang and Martin, 1993; Moncel et al., 2008; Pelletier et al., 2020). Evidence of anthropogenic and carnivore modifications is expected to be absent or rare, in this case, due to infrequent scavenging. Taxonomic diversity is expected to be high, reflecting the natural environment. However, in some cases, it may represent a very local distribution, leading to limited diversity (e.g., Moncel et al., 2008; Sauqué et al., 2018). Herd structure reflected in natural trap deposits is expected to correspond with the natural population structure (e.g., Martin and Gilbert, 1978; Oliver, 1989; Wang and Martin, 1993).

The third scenario, that of a human-induced trap, will present low values of meat-bearing skeletal parts (due to transport away from the trap). Bone surface damage should exhibit high values of anthropogenic modifications, especially skinning and dismemberment butchery marks. Carnivore modifications are expected to be lower relative to den sites. Accumulation is expected to represent discrete or repetitive events, thus creating layers. Taxonomic diversity should be limited or monospecific with natural herd age structure (e.g., Costamagno et al., 2011; Lubinski, 2013; Rodríguez-Hidalgo et al., 2017).

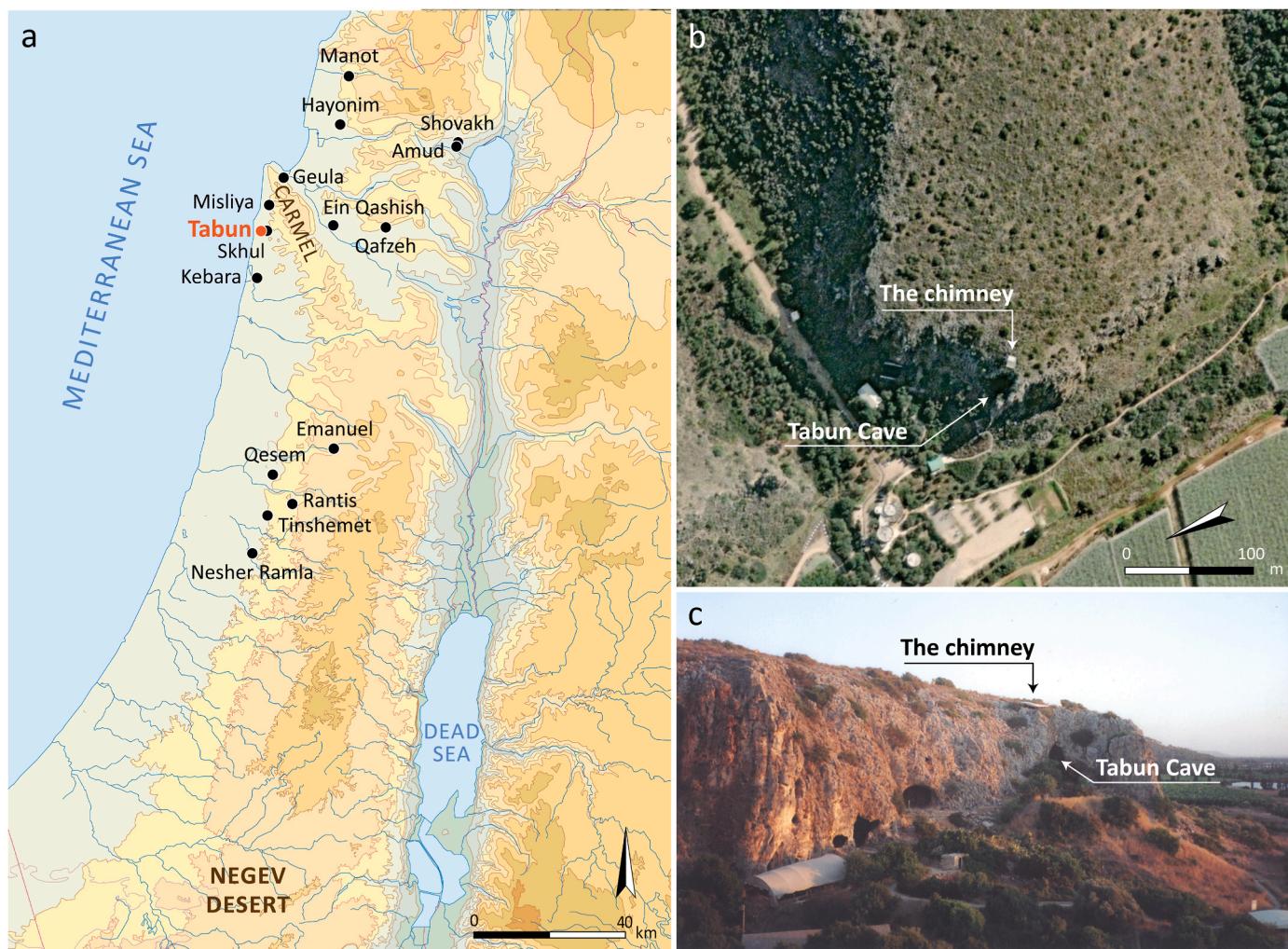
Differentiating between the latter two may be challenging, and it is also possible that both scenarios happened concurrently.

## 2. The site and its setting

Tabun Cave is a key Paleolithic site in southwestern Asia and is well-known for its 25 m thick Paleolithic layers (Garrod and Bate, 1937; Jelinek et al., 1973; Jelinek, 1982; Ronen et al., 2011), particularly as the regional stratigraphic model sequence of the Lower and Middle Paleolithic (Garrod and Bate, 1937; Copeland, 1975; Shea, 2003). Furthermore, the Middle Paleolithic layers yielded important human skeletal remains, defined as both modern humans and Neanderthal lineages (Garrod and Bate, 1937; McCown and Keith, 1939; Quam and Smith, 1998; Rak, 1998; Bar-Yosef and Callander, 1999; Coppa et al., 2005, 2007; Tillier, 2005; Harvati and Lopez, 2017).

The cave is situated on the southern slope of Nahal Me'arot (Valley of the Caves), at its opening to the Mediterranean coastal plain in Mount Carmel (Israel), about 30 m above the creek (Fig. 1). Notably, additional Middle Paleolithic occupations at the complex site of Nahal Me'arot were discovered at the nearby cave sites of el-Wad (Layers G–F) and Skhul, which are within less than 150 m from Tabun Cave (Garrod and Bate, 1937). Herpetofaunal remains deposited in this layer by raptor predation and natural deaths attest to the proliferation of Mediterranean park forest and alluvial valleys vegetation in the cave's immediate vicinity, and to a climate that was largely similar to that of the present day (mean annual precipitation of ca. 500–600 mm; mean annual temperature of 16–18°C; Lev et al., 2023).

The now largely collapsed cave was composed of three parts: an inner room, a massive outer room, and an intermediate room between them (Garrod and Bate, 1937: plate XXVIII). The cave was excavated for five seasons between 1929 and 1934 by D. Garrod, who divided the 25 m sequence into seven layers (Garrod and Bate, 1937: plates XXIX–XXX). Layer A consists mainly of material from the Bronze Age to modern times. The underlying deposits are attributed to the Middle Paleolithic (Layers D–B) and the Lower Paleolithic (Layers G–E; Garrod and Bate, 1937). Layers E–C were further investigated by A. Jelinek in 1967–1971 (Jelinek et al., 1973; Jelinek, 1982), and Layers G–E were tested by A. Ronen in 1975–2003 (Ronen and Tsatskin, 1995; Ronen et al., 2011). Jelinek et al. (1973) proposed an additional division of the cave deposits, categorizing them into three major sedimentological units (MSU III–I; Fig. 2a). MSU I, represented by Layer B, constitutes the uppermost part of the cave's sediments and is composed of terra rossa. The inner chamber, the only area where Layer B remains intact, had not been reinvestigated until the commencement of new excavations in 2017 (Fig. 2b and c), which provided the faunal materials discussed here.



**Fig. 1.** (a) Location map of Tabun Cave and other sites mentioned in the text; (b) aerial photo enlargement of the cave area; (c) Tabun Cave and the cliff, a view from northeast.

In the inner chamber, Layer A was absent, and the upper 9 m thick deposits were divided by Garrod to three subunits, each 3 m thick: Chimney I, Chimney II, and Layer B (Fig. 2b). The division between Chimney I and Chimney II was arbitrary. These three layers consisted of terra rossa soil that originated in the plateau above the cave and are similar to the extant Layer B, which was later systematically investigated (Jelinek et al., 1973; Albert et al., 1999; Friesem et al., 2021). Limestone fragments increase in number and size toward the bottom. However, apart from this, there were no noted differences in the deposits from top to bottom. Consequently, the division between Chimney II and Layer B was also not based on sedimentological change but rather determined by the level in which the deposits continued from the inner to the outer chamber along the talus. Breccia lumps that included numerous bones were found along the walls of the inner chamber in patches throughout the sequence. The lower part of the 9 m thick deposits of the inner chamber was excavated in steps from south to north toward the outer chamber (Garrod and Bate, 1937:60–62; Fig. 2b).

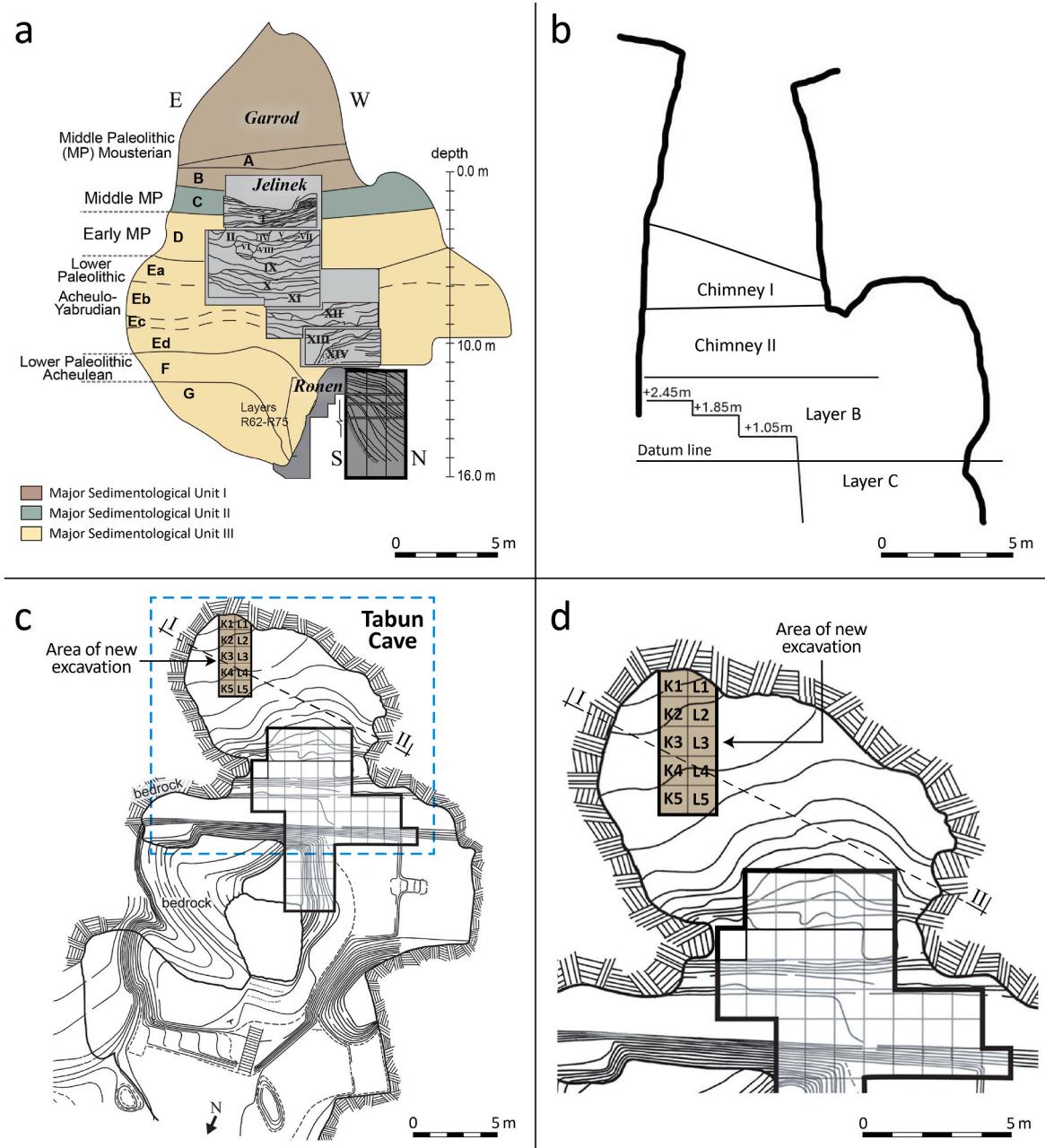
Notably, the stratigraphic division during the 1930s excavation focused primarily on major sedimentological changes, with finer differences generally overlooked. The potential for further subdivision of the layers is best demonstrated in Jelinek's subsequent work, which divided Layer C into 26 beds (1–26) and Layer D into 43 beds (27–69; Jelinek, 1982).

While some studies currently group Layer B and Chimney II–I into a single stratigraphic unit, referred to as "Tabun B" (e.g., Marín-Arroyo,

2013a, 2013b), the distinctions noted by Garrod for the 9 m thick accumulation are significant. She focused specifically on the differentiation between Chimney II–I and Layer B in the inner room, and in the case of Layer B, between the space confined within the inner room and that of the intermediate chamber.

The presence of lithic artifacts and bones in Chimney II–I led Garrod to suggest that the cave was occupied until its very last stages. This is in contrast to the lower part of the inner room, Layer B, where she noted that flint items and bones were "extremely sparse." In Layer B, however, characterized by a wider spatial distribution than Chimney II–I, artifacts were more common along the intermediate room and the talus (Garrod and Bate, 1937:60–63).

Garrod's description of Chimney II–I as representing habitation seems less likely, given that no hearths or charcoal were reported in their deposits. Her description of a high proportion of tools to waste (Garrod and Bate, 1937:60–61) also supports a locality that was not regularly occupied but rather visited by humans for short durations (Kuhn and Clark, 2015). A more solid representation of fire use, however, was reported in Layer B, where a few small hearths were identified near the area of the cave's current dripline. This is further reinforced by the area sampled by Albert et al. (1999), who detected charcoal particles within the sediments of Layer B. The spatial distribution of finds also varied within Layer B, with most artifacts reported along the talus rather than in the inner cave (Garrod and Bate, 1937:62–63). In contrast to the chimney, tools were not highly represented in Layer B. Human remains,



**Fig. 2.** (a) Tabun Cave stratigraphic and sedimentological section (b); the chimney and the inner room illustration of Garrod and Bate's Section I-II; (c) map of the excavation areas with the new excavation and [Garrod and Bate's \(1937\)](#) Section I-II marked; (d) Enlarged view of the inner room.

on the other hand, were found in both Chimney II-I and Layer B; in the latter they were confined to the inner chamber ([Garrod and Bate, 1937:62–63](#)). Teeth studied from Layer B were attributed to Neanderthals ([Coppa et al., 2005, 2007](#)). Additionally, an articulated skeleton (Tabun C1), whose stratigraphic attribution to either Layer C or B is debated ([Garrod and Bate, 1937; Bar-Yosef and Callander, 1999; Grün and Stringer, 2000, 2023](#)), is commonly considered a Neanderthal as well. The chronology of Layer B, based on museum-curated samples from Garrod's excavation, which lack specific contextual information and therefore also direct dosimetry, ranges from U-Series dates of  $102 \pm 17$  ka to  $122 \pm 16$  ka, providing a US/ESR date of  $104 + 33/-18$  ka ([Grün and Stringer, 2000, 2023](#)).

Within the limitations of preserving the iconic section of Tabun Cave, the renewed excavations, directed by R. Shimelmitz, M. Weinstein-Evron, and I. Hershkovitz, concentrated in the southeastern part of the inner chamber. This enabled us to keep the main section intact, but

dictated the nature of the area sampled. While it forms a clear portion of Layer B and possibly the base of the chimney, its location, deep at the rear of the cave, may have affected the extent of available evidence of human occupation. As seen at other Levantine Paleolithic sites, humans tended to inhabit the drip zone more intensively than the inner caves (e.g., [Ronen, 1984; Weinstein-Evron et al., 2012; Orbach and Yeshurun, 2021](#)).

The area sampled consists of a  $2 \times 5$  m trench laid out on the eroded stepped section of Layer B, which Garrod had cut in the inner room ([Fig. 2c](#)). Of the  $10 \text{ m}^2$  probed,  $4 \text{ m}^2$  were excavated down for approximately 2 m, to an elevation that was still higher than the highest one reached by Jelinek. The sedimentological sequence was divided into six sub-layers. The three upper ones (hence Layers B3–B1) form an internal division of Layer B, while the lower sub-layers (B6–B4) probably represent a transition to Layer C. The uppermost part of the sequence, Layer B1, consists of partially cemented sediments that likely represent

the base of the chimney. It was found in a very limited portion of the sampled area, specifically in Squares K1–K2, parts of Square K3 (sub-Squares B, D), and Square L2 (sub-Squares C, D). This layer reaches a thickness of approximately 30 cm. Layer B2 extends across much of the remaining area, particularly where Layer B1 had already been removed during Garrod's excavation. However, this layer has been subject to some recent erosion, which occurred between its initial excavation in the 1930s and the placement of an artificial roof over the chimney opening by Jelinek in 1967. This layer is approximately 10–20 cm thick. Layer B3 is distributed throughout the excavation area and consists of a massive accumulation of limestone fragments. Its maximum thickness is about 1 m.

## 2.1. Paleozoological research in Tabun

The site displays one of the longest research histories in paleozoology worldwide (Lyman, 2008; Yeshurun, 2016), starting with Bate's (1937) paleontological account of the materials from the first excavations (1929–1934), which she used to describe the Levantine Pleistocene faunal succession, offering a pioneering faunal-based climatic reconstruction. Here we focus on the pertinent issues raised by the ungulate remains. Based on the disappearance of "primitive" species such as rhinoceros (*Stephanorhinus hemitoechus*) and hippopotamus (*Hippopotamus amphibius*), Bate argued for a great faunal break between Layers C and B (Bate, 1937:226). This conclusion was later refuted by showing some of these species are synonymous with others and some were extant in later periods (e.g., Tchernov, 1981; Garrard, 1982). In her renowned *Dama–Gazella* curve, Bate (1937) used the changing frequencies of fallow deer and gazelle as indicators of environmental fluctuations. She proposed that elevated frequencies of fallow deer indicated increased rainfall, which led to the expansion of forests. As a result, the forest-dwelling deer population became more prevalent, and vice versa when gazelle frequencies increased (Bate, 1937:141–142). Hooijer (1961), based on fauna at Ksar Akil, suggested that Bate's findings and the differences in the faunal composition were better explained by hunters' choices than by climatic fluctuations.

Layer B and the chimney units, stood out among the Tabun Cave faunal succession in a heavy dominance of fallow deer. Its context, however, was difficult to explain. Garrod and Bate (1937:61) noted the low lithic proportions, the predominance of tools, and the absence of burning, alongside the bone completeness within Chimney II–I and pondered over this complexity, stating that "the question then arises whether the bones and flints which it contained represent the remains of a true occupation level or whether they also came in from above." The absence of complete skeletons and the abundance of finds and their equal distribution along the inner room deposits eventually led the scholars to conclude that humans lived in the cave when the chimney sediments were deposited (Garrod and Bate, 1937:61–62). However, they did not explain why they unified the study of the faunal material while describing the flint items from the chimney units and Layer B separately. Based on the same evidence and on sedimentological research that showed the Layer B sediments to be colluvial, consisting of terra rossa soil, Jelinek et al. (1973) proposed that the cave was occasionally used by human hunters as a trap. In this scenario, the game would be driven by humans into the chimney and then processed. Garrard (1982:174) later argued that the bone accumulation was natural. He based his conclusion on Bate's (1937:150) suggestion that some materials may have washed into the cave from above, through the chimney, and on the natural character of the faunal remains, as well as on Jelinek et al.'s (1973) observation on the changing sources of the cave sediments. Garrard (1982) additionally argued that since the cave became smaller following the collapse, the ancient inhabitants would have preferred the adjacent Skhul and el-Wad Caves. None of these studies incorporated taphonomic or demographic observations of the original faunal materials until Marín-Arroyo's (2013a, 2013b) investigation. She quantitatively confirmed the overwhelming abundance of

fallow deer in the Tabun Layer B assemblage, markedly differing from the underlying Middle Paleolithic layers. Moreover, she found that the bones exhibited a low degree of human processing and thermal alteration, as opposed to the Tabun C gazelle-rich assemblages. The cumulative evidence suggests that the cave was a natural trap that was sporadically visited by humans who took advantage of the naturally fallen deer).

However, Marín-Arroyo's (2013a, 2013b) study also showed the highly biased nature of the field collection, composed almost entirely of complete epiphyses and jaws that were initially saved and deriving from a variety of contexts within the Tabun Layer B/chimney complex of the 1930s excavations. Given that each scenario suggested above can offer significant insights into human behavior and environment during the Middle Paleolithic, a reassessment of the Tabun Layer B assemblages, utilizing newly excavated materials and employing modern excavation, zooarchaeological, and taphonomic methodologies, is of paramount importance.

## 3. Materials and methods

This study focuses on the materials from the renewed excavations in the upper layers of Tabun Layer B (B3–B1, the 2017–2020 seasons), employing zooarchaeological and taphonomic analyses of all material from Column L (Squares L2–5; Fig. 2c) and sampling of Column K (Squares K2ab, K3a, K4–5). For the sake of constructing demographic patterns with adequate sample size, we also analyzed all specimens that could be identified to the genus level in all the unsampled squares (K1–3). Altogether, the zooarchaeological and taphonomic analyses of Layer B1 were carried out on 0.5 m<sup>2</sup>, and that of Layers B3–B2 covered an area of 6.25 m<sup>2</sup>. Though the sediments were packed with stone fragments, volume was calculated for the sediment only. The analyzed sample of material excavated until 2020 was derived from a volume of 120 L for Layer B1, 486 L for Layer B2, and 2594 L for Layer B3.

A systematic collection of the faunal remains included coordinating three dimensions of identified remains or specimens longer than 2 cm, in addition to sediment wet sieving through a 5 mm<sup>2</sup> and 1 mm<sup>2</sup> mesh. All bones were cleaned from sediments and concretions to enable the detection of bone surface modifications following the protocol developed by Yeshurun et al. (2007) for cleaning the bones without damaging the surface modifications (and practiced since e.g., Marder et al., 2011; Goder-Goldberger et al., 2012; Yeshurun et al., 2013; Orbach and Yeshurun, 2021; Crater Gershstein et al., 2022; Orbach et al., 2024). Mechanical removal of sediments and concretions was avoided because it could have damaged bone surfaces by peeling them away. The bones were immersed in diluted acetic acid solution (10%) for about 1 h. Bones were visually inspected every few minutes throughout the process to ensure effective cleaning and prevent damage. Subsequently, the bones were soaked in water, then in KOH solution and in clean water again, and finally rinsed and left to dry in a shaded area.

Faunal analysis procedures followed Yeshurun et al. (2007). Identifications were carried out in the comparative collections of the Laboratory of Zooarchaeology, University of Haifa, the National Natural History Collections at the Hebrew University of Jerusalem, and the Natural History Collections at Tel Aviv University. The analysis included all mammals except rodents, insectivores, and bats, all birds larger than Passeriformes, and all reptile remains larger than 5 mm. Red and fallow deer were separated following Lister (1996). Our basic working unit is the number of identified specimens (NISP), defined as any bone fragment that can be securely assigned to a skeletal element or precise part thereof and to a taxon or size class. This includes long-bone shaft fragments with diagnostic zones or indicative characteristics (Marean et al., 2004), epiphyses, teeth, cranial fragments, ribs, vertebrae, and all other recognizable bone fragments. The location of each element (e.g., dorsal) and the percentage of its completeness were coded according to Lam et al.'s (1999) scan site codes. Size classes include small mammal (fox- or hare-sized), small ungulate (gazelle-sized), medium ungulate

(fallow-deer-sized), and large ungulate (aurochs-sized). Body-part profiles were quantified by the minimum number of elements (MNE; Lyman, 1994), standardized by the minimum animal unit (MAU, % MAU; Binford, 1978, 1981, 1984). Taking bone Laterality and age into account produced the minimum number of individuals (MNI; Lyman, 1994).

All identified specimens were inspected for bone-surface modifications following Blumenschine et al.'s (1996) procedure, using a stereoscopic microscope (Olympus SZX7). We searched for weathering modifications (Behrensmeyer, 1978), trampling striations (Domínguez-Rodrigo et al., 2009), biochemical marks (Domínguez-Rodrigo and Barba, 2006), abrasion (Shipman, 1981), cut marks (Binford, 1981; Domínguez-Rodrigo et al., 2009; Soulier and Costamagno, 2017), hammerstone percussion marks (Pickering and Egeland, 2006), bone working (Blasco et al., 2013), bone burning (Stiner et al., 1995), carnivore gnawing damage and digestion, and rodent gnaw marks (Binford, 1981; Brain, 1981; Orbach and Yeshurun, 2021). We also recorded shaft circumference (Bunn, 1983) and long-bone and first phalanx breakage patterns, including fracture angle, fracture outline, fracture edge (Villa and Mahieu, 1991). Specimens displaying oblique fracture angle and curved or V-shaped fracture outline were defined as 'green fractures'; specimens displaying right fracture angle and transverse outline were defined as dry breakage; and specimens showing both types, or ambiguous character were assigned to the 'intermediate' class (most of the latter are probably green-fractured bones that underwent additional breakage cycles while being already dry). We recorded the maximum fragment length for each identified specimen, excluding recent breaks. Bone anatomical measurements were taken following von den Driesch (1976) and analyzed using PAST software (Hammer et al., 2001).

Mortality profiles were constructed for fallow deer by recording tooth eruption and wear (Bowen et al., 2016). The resulting age classes were then lumped into three cohorts: juvenile, prime, and old (Stiner, 1990). The dP<sub>4</sub>–P<sub>4</sub> sequence was preferred because the P<sub>4</sub> is (1) readily identifiable, (2) in the center of wear, (3) will wear to its end, and (4) a deciduous and permanent tooth providing coverage throughout the entire lifespan (Stiner, 1990:313; 1994:289). This dentition sequence was also employed by other studies in the Paleolithic Levant, thus making our results comparable (Stiner, 2005; Speth and Tchernov, 2007; Yeshurun et al., 2007; Stiner et al., 2009). Fallow deer reach maturity at the end of their second year of life, close to the dP<sub>4</sub>–P<sub>4</sub> replacement. At around 9 years of age, the male's mating success drops, and mortality sharply increases (Chapman and Chapman, 1975; Saltz, 1996; McElligott and Hayden, 2000; McElligott et al., 2002). Female reproductive success decreases at 9–10 years (Saltz, 1996; San José et al., 1999). Thus, we set the prime/old adult boundary at 9 years. Fallow deer's potential ecological longevity (PEL; equivalent to maximum potential lifetime, MPL; Stiner, 1994) in the wild is between 10 and 16 years (Saltz, 1996; McElligott and Hayden, 2000; Kleiman et al., 2004; Bowen et al., 2016); thus, we set it at 13 years. This also fits the 65% of MPL (Stiner, 1994). Consequently, we defined the juvenile cohort as 0–2 years of age, when a dP<sub>4</sub> was present (unworn P<sub>4</sub>s were not counted, to prevent double counting of the same individual). The prime and old cohorts were defined by worn P<sub>4</sub>s, and their separation was set at tooth wear Stage (TWS) g3/h (Orbach and Yeshurun, 2025); this stage and above is considered old. The results were plotted on ternary diagrams with 95% confidence intervals (Weaver et al., 2011) and interpreted according to both Stiner's (1990, 1994) and Discamps and Costamagno's (2015) zoning adapted to fallow deer life cycle as detailed above. The triangle is divided into zones that indicate the ungulate herd age structure. The Catastrophic/Living population structure/JPO (juvenile, prime-age, and old individuals) zone represents the natural ideal herd structure in the case that all herd individuals die at once or the average of unselective hunting over time. The Attritional/JOP (juvenile, old, and prime-age individuals) zone represents the death of the weak individuals, young and old, as they die more often both naturally and as

the outcome of cursorial hunting. The Prime zone represents selective hunting of the fittest individuals, indicating targeted hunting, and the Old zone represents increased scavenging in the diet (Stiner, 1990; 1994).

All statistical tests were performed by PAST software (version 4.02). Statistical significance was tested at  $\alpha=0.05$  level.

## 4. Results

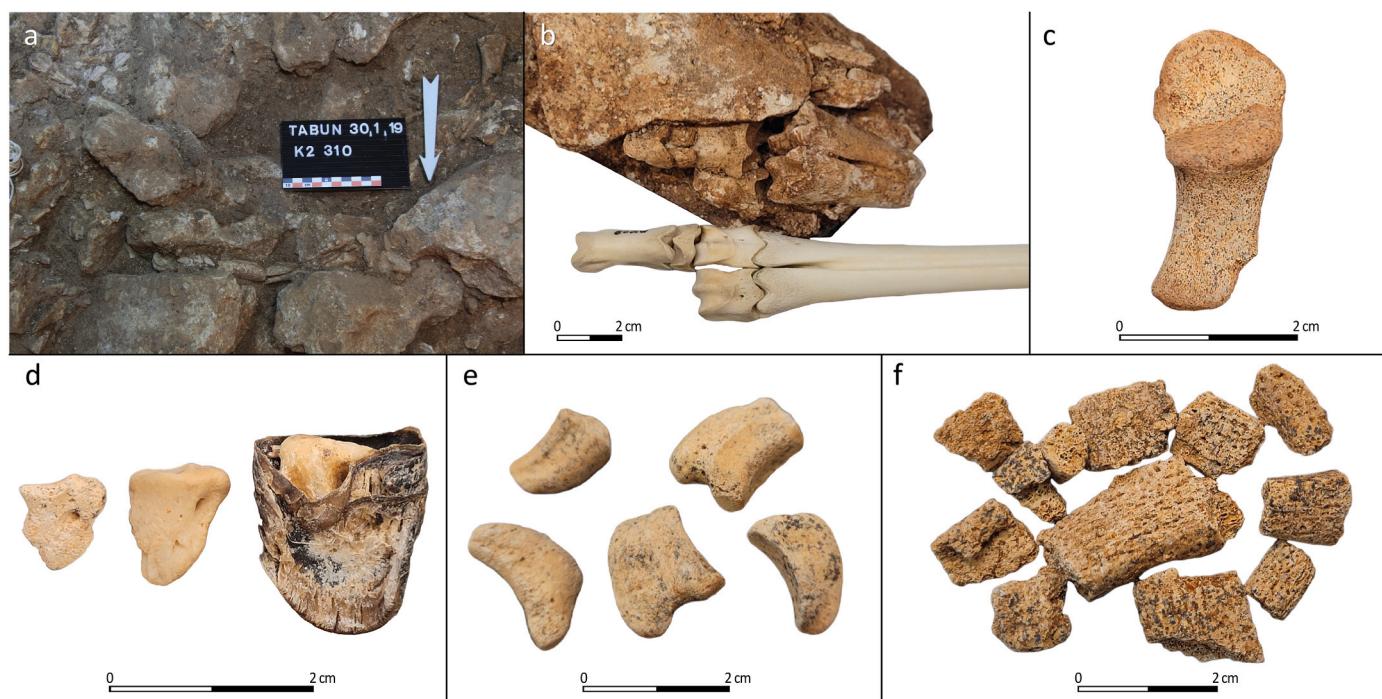
The Tabun Layer B bone assemblage consists of 2035 identified specimens (NISP) in total, comprising 653 specimens in Layer B1, 623 in Layer B2, and 759 in Layer B3. Additionally, 224 specimens from the squares that were not included in the assemblage were recorded for the demographic analysis. Three lines of evidence strongly point to *in situ* deposition: the recurrent presence of complete faunal specimens in anatomical articulation (Fig. 3a and b; supplementary online material [SOM] Table 1), constituting evidence of minimal movement (EMM; Yeshurun et al., 2014); the abundance of small, rounded bones, such as carpal, tarsal, sesamoids, and phalanges, which are expected to be swept away by postdepositional processes easily (Fig. 3b–e); and the presence of many low-density fragile elements, such as fetus bones (Fig. 3c) and "ossified" costal cartilages (OCC) (Fig. 3f).

While the analyzed assemblages of Layers B3–B1 exhibit relatively similar numbers of specimens, the volumetric density of bones per m<sup>3</sup> increases over time. The density is 5442 in Layer B1, 1282 in Layer B2, and 293 in Layer B3 (calculated as NISP [Table 1] divided by volume in liters multiplied by 1000). This results in significant variation, with the density in Layer B1 being 18 times greater than that in Layer B3.

### 4.1. Taxonomic representation

The Tabun Layer B faunal assemblage is dominated by ungulates (92% of NISP; Table 1). Sporadic carnivores and small mammals are also present, as are some remains of tortoises (*Testudo graeca*), squamates, and birds, mainly rock dove (*Columba livia/oenas*), and common quail (*Coturnix coturnix*). The squamate counts relate to the specimens from the 5 mm<sup>2</sup> mesh and bird counts here include those larger than Passeriformes in the sample squares. For full information on these taxa, see Lev et al. (2023) and Amos et al. (2025).

The total MNI count for the entire assemblage is 44. Layer B1 accounts for 14 MNI, consisting of 13 ungulates and one tortoise. Layer B2 accounts for 10 MNI, consisting of 9 ungulates and one carnivore. Layer B3 accounts for 20 MNI, consisting of 17 ungulates, two carnivores, and one tortoise. Fallow deer were the most abundant species in all layers: Layer B1 had 4 adults and 3 juveniles; Layer B2 had 4 adults and 2 juveniles; and Layer B3 had 5 adults and 3 juveniles. In terms of size groups, medium ungulates comprise 87%, 84%, and 75% (NISP), and small ungulates comprise 13%, 14%, and 22% (NISP) in layers B1, B2, and B3, respectively. Ungulates include seven species (Fig. 4): Mesopotamian fallow deer (*Dama mesopotamica*) is by far the dominant species throughout all layers, constituting 68–85% of the mammalian NISP that was identified to the genus level. The mountain gazelle is the second-best represented mammal, though far behind (10–22%). Red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), bezoar goat (*Capra cf. aegagrus*), and aurochs (*Bos primigenius*) appear sporadically. Some variation exists among stratigraphic layers; in the higher ones, Layers B1 and B2, fallow deer proportions significantly increase and gazelle proportions decrease, compared to Layer B3 (counts of *Dama*, *Gazella* and other ungulates: B1 vs. B3,  $\chi^2=10.02$ ,  $p<0.01$ ; B2 vs. B3,  $\chi^2=12.11$ ,  $p<0.01$ ), but they are not statistically different between Layers B1 and B2 ( $\chi^2=0.84$ ,  $p=0.66$ ). Nevertheless, even in Layer B3, fallow deer is still three times more abundant than gazelle. Taxonomic diversity is affected by the large fallow deer proportions, showing the most diverse (even) value in Layer B3, and lower values in the upper layers (Table 1).

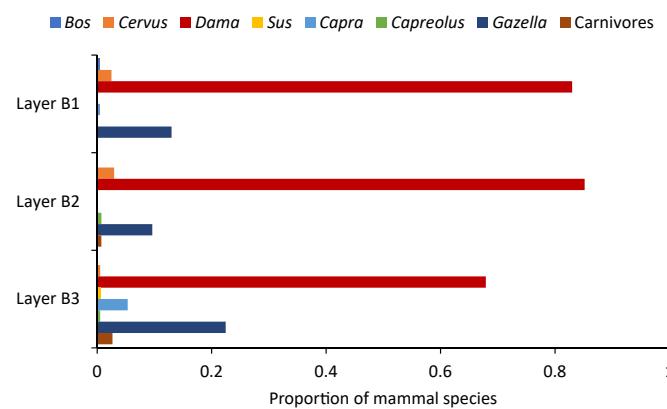


**Fig. 3.** Examples of the preservation state of the assemblage: (a) crushed medium ungulate metapodial; (b) articulated unfused fallow deer metacarpal and first phalanx as found, with modern bones for comparison; (c) fetus fallow deer calcaneus; (d) fallow deer residual phalanx with a modern comparison; (e) fallow deer sesamoids; (f) ossified costal cartilage.

**Table 1**

Taxonomic breakdown for the Tabun Layer B assemblages (in the MNI counts, juveniles are in parentheses). The bird counts are those larger than Passeriformes. The squamate counts relate to the specimens from the 5 mm mesh in the sample squares. For full information on these taxa, see [Lev et al. \(2023\)](#) and [Amos et al. \(2025\)](#).

Layer	B1		B2		B3				Total NISP	% NISP	
	NISP	%	MNI	NISP	%	MNI	NISP	%	MNI		
<b>Ungulates</b>											
<i>Bos primigenius</i>	1	0.15	1						1	0.05	
Large ungulate				3	0.48		3	0.40	6	0.29	
<i>Cervus elaphus</i>	5	0.77	1(+1)	4	0.64	1	1	0.13	10	0.49	
<i>Dama mesopotamica</i>	166	25.42	4(+3)	115	18.46	4(+2)	127	16.73	5(+3)	408	20.05
<i>Sus scrofa</i>						1	0.13	1	1	0.05	
<i>Capra</i> sp.	1	0.15	1				10	1.32	2	0.54	
Medium ungulate	383	58.65		358	57.46		354	46.64		1095	53.81
<i>Capreolus capreolus</i>				1	0.16	1	1	0.13	1	0.10	
<i>Gazella gazella</i>	26	3.98	2	13	2.09	1	42	5.53	3(+1)	81	3.98
Small ungulate	55	8.42		68	10.91		105	13.83		228	11.20
Cervid						2	0.26		2	0.10	
Fetus ungulate	4	0.61		7	1.12		14	1.84		25	1.23
Total ungulates	641	98.16	13	569	91.33	9	660	86.96	17	1870	91.89
<b>Carnivores</b>											
Large carnivore	1	0.15		1	0.16		1	0.13		3	0.15
<i>Canis aureus</i>						1	0.13	1	1	0.05	
<i>Vulpes vulpes</i>						3	0.40		3	0.15	
<i>Felis chaus</i>				1	0.16	1			1	0.05	
<i>Martes foina</i>						1	0.13	1	1	0.05	
Small carnivore						2	0.26		2	0.10	
Total carnivores	1	0.15		2	0.32	1	8	1.05	2	11	0.54
Small mammal						5	0.66		5	0.25	
<b>Reptiles</b>											
<i>Testudo graeca</i>	6	0.92	1				13	1.71	1	19	0.93
Snake	1	0.15		6	0.96		33	4.35		40	1.97
Lizard				23	3.69		7	0.92		30	1.47
Total reptiles	7	1.07		29	4.65		53	6.98		89	4.37
Birds	4	0.61		23	3.69		33	4.35		60	2.95
Grand total	653	100.00		623	100.00		759	100.00		2035	100.00
Simpson Index 1-D'	0.2864		0.2849			0.5009					



**Fig. 4.** Ungulate species representation in Layers B3–B1. Data are from Table 1.

#### 4.2. Fallow deer aging

This section focuses on fallow deer, the most prominent animal in the accumulation. The scant data for other species are presented in SOM Table 2. In the dental-based aging analysis, given the small numbers of suitable remains, we unite all data into a single sample. The less-than-ideal sample size for Tabun Layer B, as well as for most other reference assemblages from the region (Table 2; SOM Table 2), means that their 95% confidence intervals (Weaver et al., 2011) plot as large ovals on the zoned triangular graph (Stiner, 1990; Discamps and Costamagno, 2015; Orbach and Yeshurun, 2025 fig. 6b). In this form of presentation, the Tabun sample falls in the JOP-JPO zones, commonly interpreted as Attritional or natural herd/Catastrophic models, respectively (Fig. 5a). It is very similar to the fallow deer mortality profile from Rantis Cave, a quasi-contemporaneous natural pitfall trap (Marder et al., 2011; Yeshurun, 2013). The two sites are biased in favor of the weaker individuals (juvenile and senile), a trend that is even more apparent when plotted as a dot, notwithstanding the large confidence interval but supported by the consistency in our results (Fig. 5b). In contrast, the anthropogenic Middle Paleolithic sites from the region plot almost wholly in the JPO zone (Kebara and Hayonim Caves) or, considering the large confidence interval, shifting toward the prime-age zone (Misliya Cave). These latter hunting profiles largely resemble the fallow deer population structure, perhaps with more emphasis on prime adults in the case of Misliya. The Nesher Ramla pattern may resemble a drowned wildebeest population (Bunn and Gurtov, 2014) or a scavenging-biased diet (Stiner, 1994, Fig. 5b).

We were able to record fusion on 170 mammal bones (MNE). These include 79 fused specimens and 66 unfused, in addition to 25 specimens belonging to fetuses or newborns (Table 3). Layers B1 and B2 demonstrate roughly equal representation of juveniles and adults, while in Layer B3 only a third are juveniles, aligning with the dental age data (Fig. 5b; SOM Table 2). All juvenile stages are well represented, with the first year and yearlings exhibiting similar representation. Young and adult specimens are roughly equally represented (Fig. 5c), compatible with European fallow deer (*Dama dama*) observations in the wild (Chapman and Chapman, 1975) but contrasting with the evidence from Hayonim Cave, which exhibits low juvenile representation (Fig. 5d;

Stiner, 2005: tables 11.2, 11.6). Moreover, the discrepancy between dental- and fusion-based age profiles is much smaller in Tabun Layer B compared to Hayonim. In the latter case, the bone fusion is biased against juveniles, indicating different attritional processes. The abundance of the more fragile remains at Tabun, together with the relatively high numbers of neonates and juveniles, and the bone fusion rough similarity to the dental-based profile, indicates that differential bone survivorship did not bias the assemblage to a great extent. We also calculated immature bones and teeth out of the total NISP (Speth, 2019:192–193). Our result is 13% (n=195 out of 1527 medium ungulate NISP), compatible with the Kebara Cave midden assemblage.

#### 4.3. Fallow deer sexing

As a result of the bone fragmentation and the high proportion of juveniles, anatomical measurements and skeletal character traits that correspond to sexual dimorphism were few. Therefore, here as well we tested all layers as one. The element with the highest number of measurable specimens was the first phalanx (n=9; SOM Table 3). Its greatest length (GL) measurements are significantly larger in modern Mesopotamian fallow deer males compared to females (Student's t-test,  $t=9.45$ ,  $p<0.01$ ; Fig. 6a–c; SOM Table 3). A mixture analysis that we ran on 52 phalanges from 7 individual males and 44 phalanges from 6 individual females indicated that the sexes can be distinguished by this measurement; albeit, the females can be recognized with certainty much more easily than the males. Subsequently, we identified seven of the Tabun phalanges as belonging to females and two to males. Even though the latter may be under-classified by this method, most specimens are indeed significantly smaller than the modern males but similar in size to modern females (female to Tabun,  $t=1.13$ ,  $p=0.26$ ; male to Tabun  $t=3.6$ ,  $p<0.01$ ; Fig. 6c), indicating the Tabun assemblage is female dominated (Fig. 6d). In addition, the unique occurrence of fetus bones (n=4, 7, 14 in B1, B2, B3, respectively; MNI=1), indicating the presence of pregnant females, together with the scarce presentation of antler remains in the assemblage (n=6, 1, 5 in B1, B2, B3, respectively; MNI=1), strengthens this observation, although this could alternatively result from a seasonal pattern. The time-averaged female-dominated herd structure resembles the observed population structure of the reintroduced fallow deer in northern Israel. Males occupy a territory with few females foraging. Younger males might forage in this territory, as long as they are small and pose no threat to the dominant territorial male (Dolev et al., 2002:744 fig. 4).

#### 4.4. Skeletal-element profiles

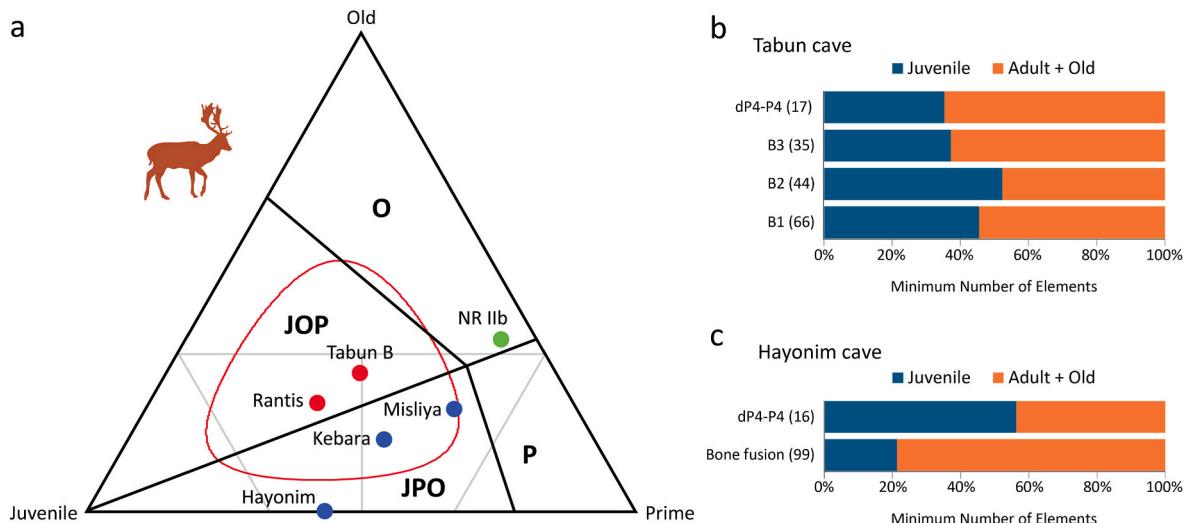
The NISP and MNE values for every element in the dominant group, the medium ungulate size class, are presented in SOM Table 4. The assemblage features numerous elements of all fluvial transport classes (Voorhies, 1969). Small and round bones, which are expected to be swept away easily (i.e., carpal, tarsal, sesamoid, and phalanges), are plentiful (NISP=460; 33% of the medium ungulate group NISP), and so are bones of low transport potential that constitute “lag deposits” (e.g., mandibles; Lyman, 1994). The skeletal-element profiles in all three layers show similar patterns, and despite less even values in Layer B3, no significant difference was found ( $\chi^2=3.0$ ,  $p=0.223$ ). The highest skeletal element values are derived from the durable teeth, but limb portions and even axial elements are also well represented (Fig. 7). The lower representation of the axial elements may be due to the mechanical destruction processes described above.

#### 4.5. Bone fragmentation and fracture patterns

The survivorship percentages of ungulate bone portions (%MAU) in Layers B1 and B3 show positive and significant, yet weak, correlations with their bone mineral density (BMD) values, while Layer B2 exhibits an insignificant correlation (Fig. 8; BMD data are from Lam et al., 1999

**Table 2**  
Fallow deer three-cohort dental ageing.

Site	Juvenile	Prime	Old	Reference
Tabun Layer B	6	6	5	This study
Kebara MP	43	53	18	Speth and Tchernov, 2007:183
Hayonim E	9	7	0	Stiner (2005):207
Misliya	2	5	2	Yeshurun et al. (2007):662
Rantis	6	4	3	Yeshurun (2013):50
NR IIb	1	8	5	Orbach et al. (2024)



**Fig. 5.** (a) Fallow deer mortality patterns in Tabun Layer B, Hayonim, Kebara, Misliya (anthropogenic sites, blue), and Rantis (natural trap, red) Caves, and the Nesher Ramla (NR) open-air site (kill site, green). Tabun is also plotted as 95% confidence interval oval (Weaver et al., 2011) (J=Juvenile, P=Prime, O=Old; Discamps and Costamago, 2015). Comparison of two age presentation techniques, bone fusion, and dental sequences of fallow deer in (b) Tabun Layer B and (c) Hayonim Cave (dP4=deciduous fourth premolar, P4=fourth premolar; data and references are from Tables 2 and 3; elements fusing before 2 years, equivalent to P<sub>4</sub> eruption; following Stiner, 2005).

**Table 3**  
Tabun Layer B fallow deer fusion data of selected elements.

Element	Age at Fusion (Months)	MNE	Unfused	Fused	Unfused	Fused
First phalanx-P	12-14	60	17	43	28%	72%
Tibia-D	18	12	7	5	58%	42%
Calcaneum-D	23-24	15	11	4	73%	27%
Femur-P (or -D)	22-24	11	5	6	45%	55%
Metapodials-D	22-24	33	18	15	55%	45%
Radius-D	24	14	8	6	57%	43%
Tibia-P	41-48	4	2	2	50%	50%
Humerus-P	64	4	2	2	50%	50%
All	22-24	73	42	31	58%	42%
All	<24	145	66	79	46%	54%
All	>24	8	4	4	50%	50%

for reindeer, *Rangifer tarandus*; medium ungulate Spearman's  $r$ ; B1  $r=0.23$ ,  $p<0.05$ ; B2  $r=0.15$ ,  $p=0.18$ ; B3  $r=0.40$ ,  $p<0.05$ ). The highest MNE values per each long bone were based either on the dense mid-shaft portion or on the denser rather than the more cancellous epiphysis portions (i.e., distal rather than proximal humerus and tibia) (Fig. 9), and the skull bones to maxillary teeth ratio (Stiner, 1994) indicates underrepresentation of bony parts relative to teeth in all layers. Thus, it seems that density-mediated attrition had some effect on bone survivorship, though not a very strong one.

Bone fragment lengths do not deviate significantly between layers and, surprisingly, nor between body-size groups, such as medium and small ungulates, except Layer B1 medium ungulate, which displays significantly larger measurements (Fig. 10a). The similarity in mean fragment lengths among small and medium ungulates may reflect an extraneous breakage factor (i.e., rocks falling) that influenced breakage patterns.

Most of the long-bone and first phalanx specimens demonstrate intermediate or dry fractures, ascribed to breakage or re-breakage by post depositional processes. Bones with green breaks, ascribed to intentional fracturing close to the time of death, either postmortem, by humans or carnivores, to retrieve marrow, or as perimortem trauma constitute one third or less of the samples, indicating high post depositional breakage

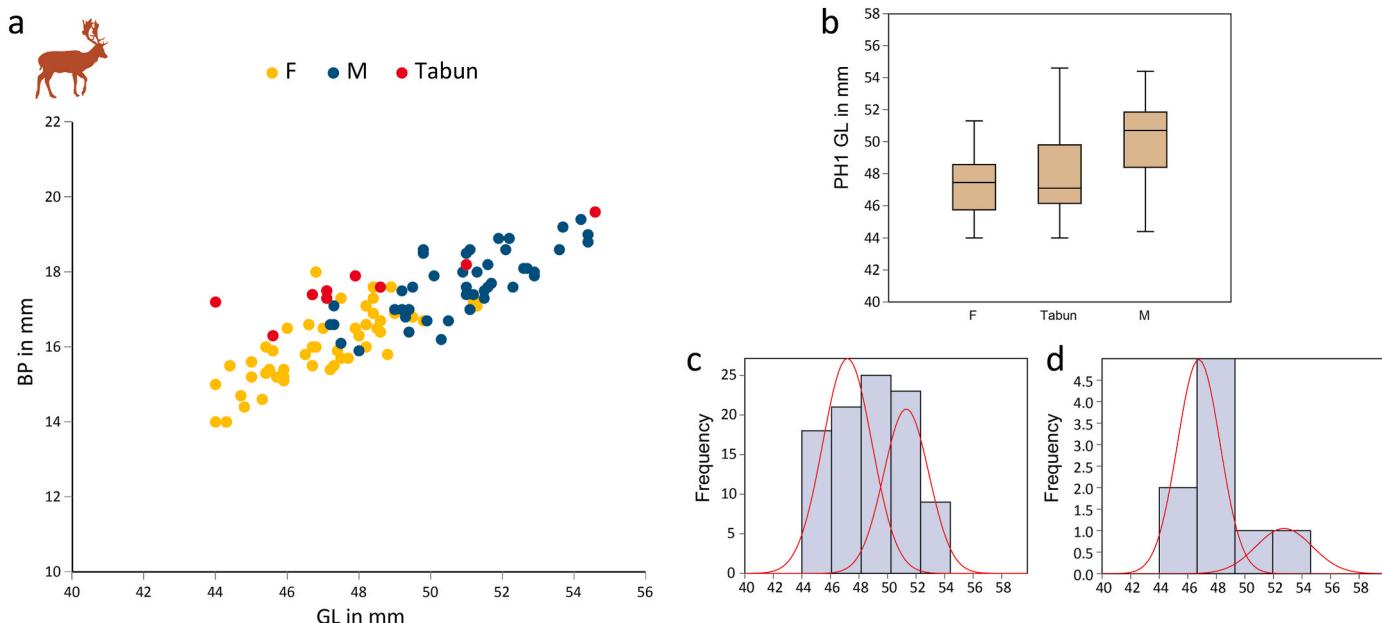
(Fig. 10d). These are more common in the case of Layer B3. However, limb bone shafts preserving their complete circumference are prevalent and more numerous at the top of the sequence.

The species-to-size group ratio is another proxy of bone fragmentation, whereby more complete bones, enabling assignment to a species/genus level, are present over fragmented ones that can only be assigned to a size group. This test indicates that bones are more complete ascending up the sequence (Fig. 10b). The mean completeness index (MNE to NISP) is congruent with the species-to-size group ratio. Both indicate moderate bone breakage (Fig. 10b). The old excavation finds consist of very few incomplete elements (Marín-Arroyo, 2013a); while we made additional effort to collect and identify bone shafts (Marean et al., 2004), almost all the 1930s assemblage was identifiable to at least the genus level, and the MNE/NISP ratio nearly reached 1 (i.e., near-perfect bone completeness; SOM Table 6; Marín-Arroyo, 2013a:62–63). In the new excavation, just one third of the ungulate NISP was complete or diagnostic enough to be identified to the genus level, and the bone completeness index is at about 0.4 (Fig. 10b). Naturally, our taphonomic counts diverge slightly from Marín-Arroyo's (2013a).

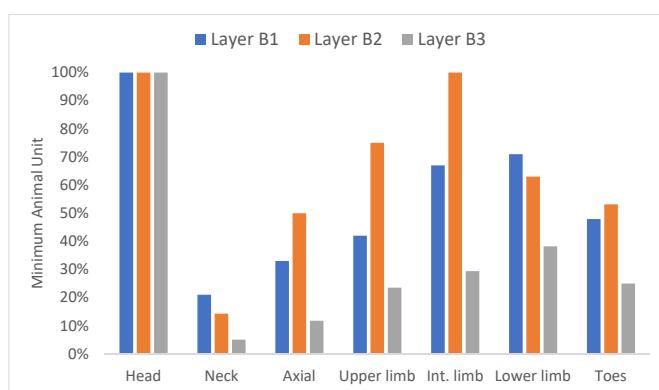
To conclude, although green breakage is not rare in the Tabun Layer B bone assemblage (Fig. 10d), the bones show a significant sign of mechanical breakage, perhaps resulting from the impact of large stones that fell from the chimney (Bate, 1937) or sediment pressure building up over time (Marín-Arroyo, 2013a). Some of the bones became trapped between the stones, which led to their preservation in complete form (Fig. 3a and b), while others were crushed by the stones in their original location. Density-mediated attrition was present, though not severe, as attested by our tests, and also by the presence of low-density elements as fetus bones and ossified costal cartilages, mentioned above (e.g., Stiner et al., 2011 fig. 6; Egeland et al., 2014 fig. 7).

#### *4.6. Bone surface modifications*

Bone surface modifications that may shed light on the depositional histories of the small and medium ungulates, the two major ungulate groups represented in the assemblage, are summarized in Table 4. Anthropogenic modifications are extremely rare, with only one cut mark (in B3) and seven hammerstone-percussion marks ( $n=1, 2, 4$  in B1, B2, and B3, respectively). Burning is absent in the NISP but was observed on a few unidentified specimens. It was also observed on bird bones from



**Fig. 6.** First phalanx measurements of Tabun Layer B compared with modern female (F) and male (M) fallow deer: (a) greatest length (GL) vs. proximal breadth (Bp); (b) boxplot showing the ranges of GL measurements. The box plot represents the 25–75% quartiles, the horizontal line inside the box represents the median, and the short vertical lines (“whiskers”) show the minimal and maximal values; (c) GL measurements normal probability plots histograms of modern females and males; (d) Tabun Layer B GL measurements (data are from SOM Table 3).



**Fig. 7.** Skeletal-element profiles: comparison between the medium ungulates in all layers. Bones are lumped to body parts as follows: Head=antler, skull, and mandible bones and teeth; neck=atlas, axis, and cervical vertebrae; axial=thoracic and lumbar vertebrae, ribs, and pelvis; upper limb=scapula, humerus, femur, and patella; intermediate limb=radius, ulna, tibia, carpal, and tarsals; lower limb=metapodials; toes=phalanges and sesamoids. Data are from SOM Table 4.

these layers ( $n=4$ ; ca. 2%; Amos et al., 2025). Carnivore modifications appear on 90 specimens in all layers (2%, 8%, and 7%, in B1, B2, and B3, respectively). Root marks are present sporadically in each layer. Weathering damage seems to have had a strong effect on the assemblage, and its abundance increases over time (Fig. 11). Aside from this and the lower carnivore gnawing abundance in the uppermost layer, the bone modifications that reflect either depositional agents or attritional processes do not change much throughout the sequence (Fig. 11). Concretions and manganese oxide staining, both characteristic of karstic environments, were identified but not quantified.

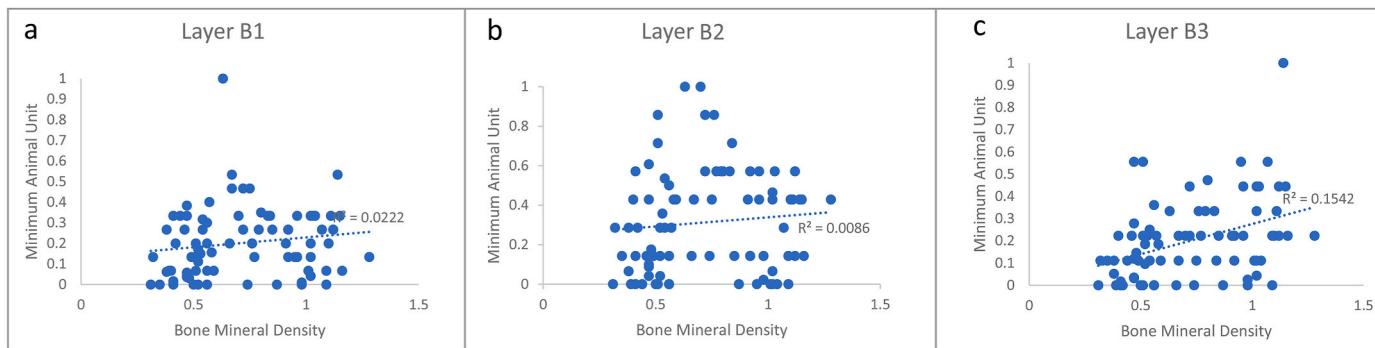
Two fallow deer first phalanges exhibit the same unique pathology seen in the 1930s excavation material (Marín-Arroyo et al., 2015; SOM Fig. 1), which was not found in any other layer in Tabun Cave nor at any other Middle Paleolithic site in the southern Levant.

## 5. Discussion

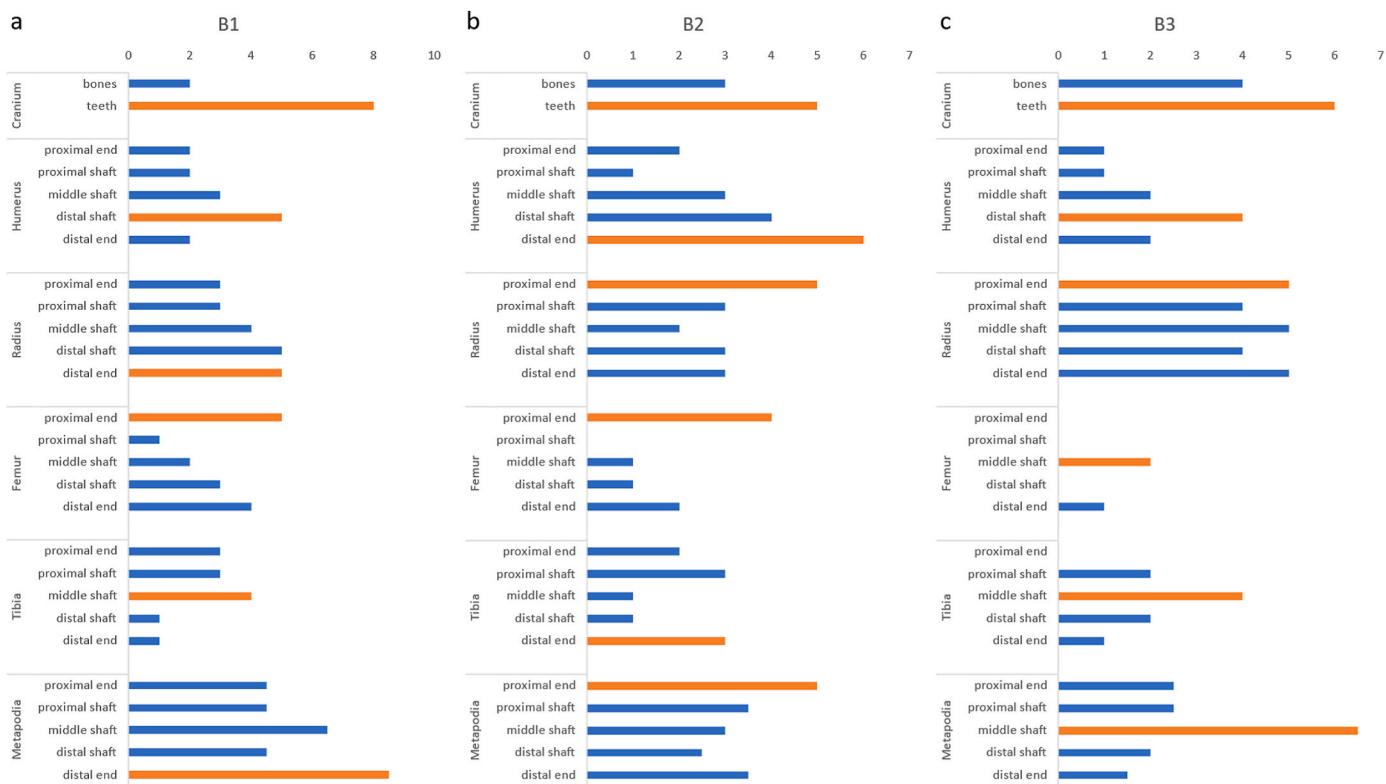
The faunal assemblage from Tabun Cave Layer B is dominated by ungulates, particularly fallow deer, with occasional occurrences of carnivores, small mammals, reptiles, and birds. This composition closely resembles that of natural pitfall traps, such as the roughly contemporaneous Rantis Cave (Marder et al., 2011; Yeshurun, 2013), and contrasts with the faunal profiles typically recovered from anthropogenic cave sites in the Levant (e.g., Rabinovich and Hovers, 2004; Speth and Tchernov, 2007; Yeshurun et al., 2007). Evidence for anthropogenic modification, such as cut marks and burning, is extremely rare or entirely absent, a pattern also observed at Rantis Cave (Marder et al., 2011; Yeshurun, 2013). In contrast, the proportion of carnivore gnawing on bones from Layers B2 and B3 (8–7%) lies between the values typical of carnivore dens (e.g., Manot Cave Area D: Orbach and Yeshurun, 2021) and those of well-documented human occupation sites (e.g., Amud Cave, Misliya Cave, Nesher Ramla lower sequence: Rabinovich and Hovers, 2004; Yeshurun et al., 2007; Crater Gershstein et al., 2022). In the southern Levant, a consistent pattern emerges: anthropogenic modifications are prevalent in strata rich in lithics and combustion features, while carnivore modifications dominate assemblages lacking these features but associated with carnivore remains and coprolites in dark cave chambers (SOM Table 7).

The fallow deer assemblage exhibits a mortality bias toward vulnerable individuals, juvenile and senile, mirroring the fallow deer mortality profile of the Rantis Cave, a natural trap (Marder et al., 2011; Yeshurun, 2013), as well as the hyena den in Manot Cave Area D (Orbach and Yeshurun, 2025). In contrast, Middle Paleolithic anthropogenic sites in the region generally reflect the structure of a natural fallow deer population. Additionally, the Tabun assemblage is female-biased, consistent with a natural herd structure (Dolev et al., 2002).

The skeletal-element representation is relatively even across anatomical regions. This somewhat differs from patterns observed at nearby anthropogenic sites, where selective carcass transport often results in an overrepresentation of limb elements compared to cranial and axial parts in medium-sized ungulates (e.g., Speth and Tchernov, 2007; Yeshurun et al., 2007). Although kill or butchery sites do not always



**Fig. 8.** Relationship between bone mineral density (BMD1, 2 values for *Rangifer tarandus*; Lam et al., 1999) and bone survivorship (%MAU) for all medium ungulate elements: (a) Layer B1, (b) Layer B2, (c) Layer B3.



**Fig. 9.** Medium ungulate intra-element comparisons of cancellous vs. dense bone portions: the bony cranium vs. maxillary teeth; limb bone ends vs. shafts; proximal ends vs. distal ends of the humerus and tibia. Orange bars represent the highest MNE value, from which the MNE of the entire element was derived. a=Layer B1, b=Layer B2, c=Layer B3. Data are from SOM Table 5.

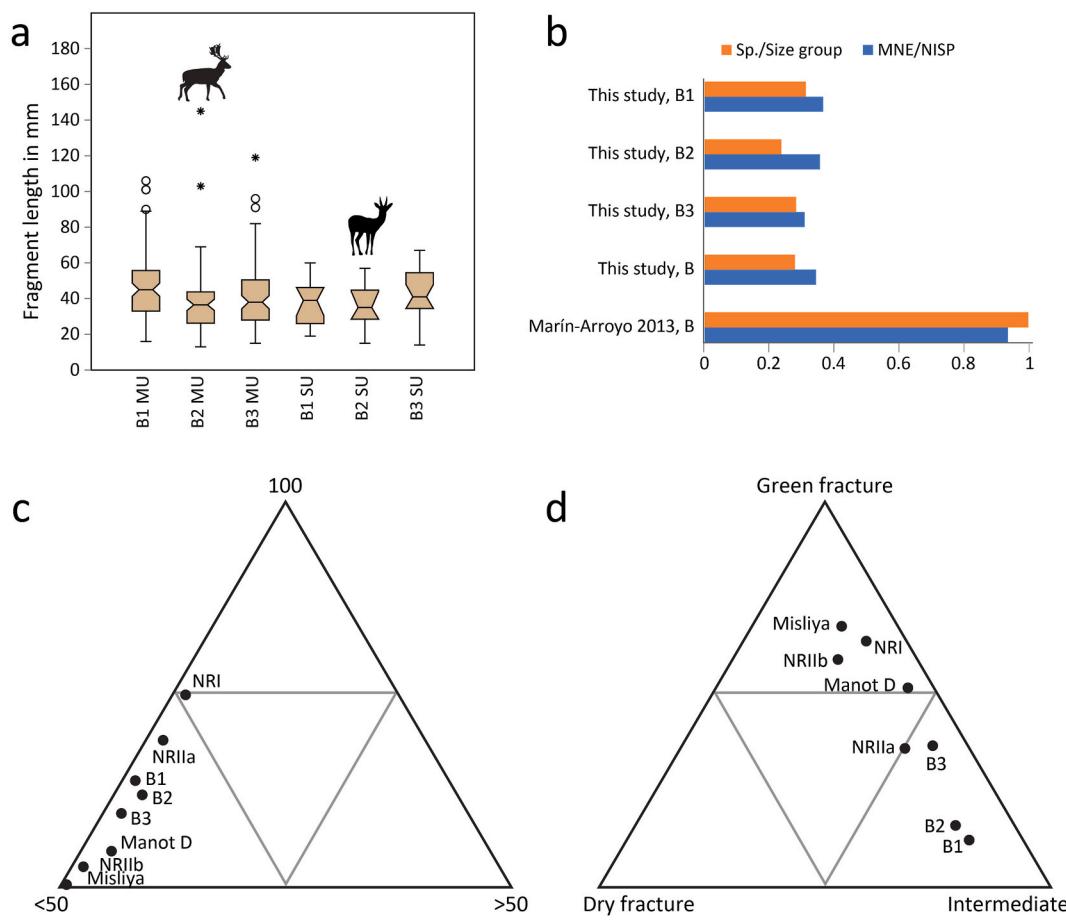
show a clear inverse pattern (e.g., Crater Gershstein et al., 2022; Orbach et al., 2024), the possibility that limbs were removed from the cave by either humans or carnivores cannot be ruled out.

Bone breakage patterns suggest extensive re-fracturing due to post-depositional processes. Complete limb shaft circumferences are relatively frequent, especially in the upper layers of the sequence. Their frequency falls within the mid-range observed in anthropogenic faunas (e.g., Misliya Cave: Yeshurun et al., 2020), carnivore dens (Manot Cave Area D: Orbach and Yeshurun, 2021), and open-air kill sites (Nesher Ramla: Orbach et al., 2024) (Fig. 10c). The abundance of small, fragile bones, which are easily displaced, and the prevalence of bones with low transport potential (forming potential “lag deposits”) argue against secondary deposition.

It is important to acknowledge the contribution of the current excavation in resolving the differences between the components that form the upper part of the Middle Paleolithic sequence at the site,

namely, Tabun Layer B, Chimney II, and Chimney I, as elaborated in the introduction. While scholars have often grouped these units together, the archaeological evidence described by Garrod indicates notable differences. For example, Jelinek, in his synthesis of the upper Middle Paleolithic sequence, unified Garrod's observations on both the chimney units and Tabun Layer B, despite their contrasting patterns. Fire, for instance, is clearly absent in the inner room (the chimney and Layer B) deposits but present in the outer room of Tabun Layer B. Another unresolved issue is why bones were reported to be sparse in the inner room of Layer B of Garrod's excavation (Garrod and Bate, 1937:62) at a level where chemical dissolution of bones is not detected (Friesem et al., 2021). Since only part of Layer B remained unexcavated after Garrod's analysis (with a possible small outskirt of the base of the chimney), we can examine whether the observed differences are attributable to the mixed nature of assemblages in the previous analyses.

The chimney units/Layer B terra rossa sediments of Tabun Cave



**Fig. 10.** (a) Comparison of medium (MU) and small (SU) ungulates fragment lengths (data are drawn from SOM Table 6). (b) MNE/NISP and Sp.-SIZE group (ungulate identified to species/genus level divided by ungulate identified to species/genus level + ungulate identified to size group; data for other sites are drawn from SOM Table 6 and Marín-Arroyo, 2013a). (c) Medium ungulate bone shaft circumference (data for B3–B1 are drawn from Table 4; data for other sites are drawn from Misliya Cave: Yeshurun et al., 2020; Manot Cave: Orbach and Yeshurun, 2021; Nesher Ramla [NR]: Orbach et al., 2024). (d) Comparison of limb fracture types (green, dry, and intermediate) (data for B3–B1 are drawn from Table 2; data for other sites are drawn from Misliya Cave: Yeshurun et al., 2020; Manot Cave: Orbach and Yeshurun, 2021; Nesher Ramla [NR]: Orbach et al., 2024).

unambiguously originated in washing above the cave down the karstic chimney (Garrod and Bate, 1937; Jelinek et al., 1973; Friesem et al., 2021). However, the question of how the faunal materials ended up there remains open. In answering this, we marshal the rich taphonomic insights from a range of human- and carnivore-generated ungulate accumulations, as well as natural (non-predation) ones, primarily from around the Mediterranean Basin.

The results indicate a fallow-deer-dominated assemblage with low pre-depositional bone breakage but significant mechanical post depositional breakage. The fallow deer herd structure appears to reflect natural characteristics. However, Layer B is not homogeneous and can be subdivided into distinct units with varying characteristics. The most pronounced differences are observed between Layers B1 and B3. Layer B3 exhibits lower bone density and fallow deer values but higher bone breakage than Layer B1. Regarding bone modifications, Layer B3 bones exhibit lower levels of weathering, more carnivore modifications, and slightly more anthropogenic modifications. Limb bone representation in Layer B3 is lower than in Layer B1. One third of the Layer B3 elements are unfused, consistent with the dental aging results, while Layer B1 exhibits an equal representation of fused and unfused bones.

The cluster of results enables us to discount easily the residential hypothesis for the inner room. The new excavations verified that the finds in it demonstrate low human presence and no evidence of combustion features. Considering the ungulate assemblages, we showed that human-generated bone modifications at Tabun Cave are extremely rare

compared to human camps in the region. Also in the case of carnivore modifications, although more numerous than the anthropic marks, they are less abundant than in hyena dens from the region (Orbach and Yeshurun, 2021), and the studied assemblages almost completely lack carnivore skeletal remains and coprolites are scarce. It is possible that the recurring fall of cobbles made the rear part of the inner room unsuitable for residential use. Additionally, the constant shifting of the surface structure and elevation further hindered horizontal access.

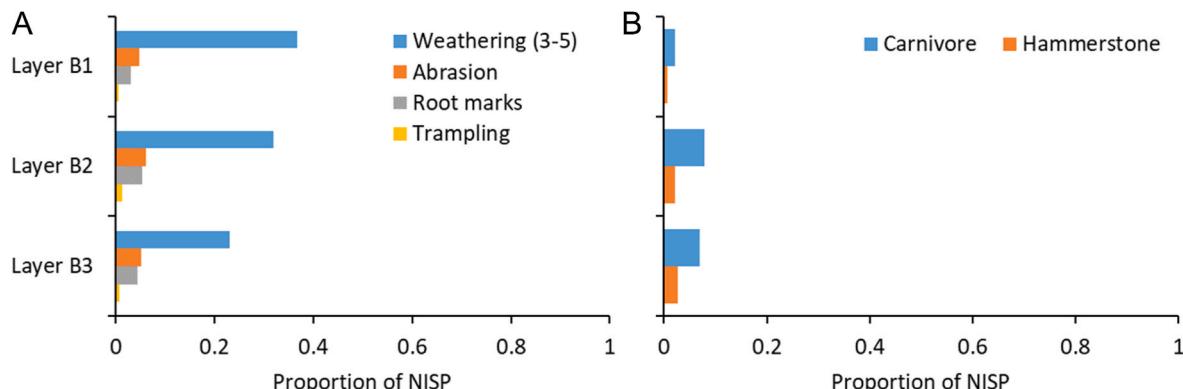
The observed differences between Layers B3 and B1, together with the decrease in both small vertebrates (mainly small carnivores and reptiles) and carnivore modifications, may indicate the transition between Garrod's Layer B (our B3) and Chimney II (B1 probably forming its base). It appears that the activity in this part of the cave had diminished as the room filled up with sediments, which progressively made its ceiling lower, until the entrance was possible only through a narrow shaft, if at all. Thus, the activity in the inner chamber of the cave was dictated by its physical condition.

We remain therefore with the pitfall trap scenario, whether animals occasionally fell into the cave by accident (second scenario) or driven to fall by humans (third scenario). The key here is to be able to identify the cave's use as a trap with certainty and assess the extent of human involvement. As in the 1930s, no complete skeletons were found in the new excavations, but recurring bone articulation and the relatively even representation of skeletal elements suggest that complete deer carcasses were introduced into the chamber, especially in Layers B1 and B2. The

**Table 4**

Bone-surface modifications and bone fracture patterns for the small and medium ungulate groups.

	n	Layer B1		Layer B2		Layer B3		Total
		Small Ungulate	Medium Ungulate	Small Ungulate	Medium Ungulate	Small Ungulate	Medium Ungulate	
NISP	n	81	555	81	477	147	495	1836
NISP without isolated teeth	n	71	475	75	430	131	397	1579
Burning	n	0	0	0	0	0	0	0
%		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Green fracture	n	1	3	1	6	6	19	36
Dry fracture	n	0	3	0	5	3	4	15
Intermediate	n	2	19	4	27	1	29	82
Limb shaft circumference	<50	9	84	5	59	17	102	276
>50	0	3	0	5	0	5	5	13
100	9	33	4	20	6	25	97	97
Weathering (3–5)	n	26	175	20	141	15	107	484
of	n	70	475	75	430	131	397	1578
%		36.6	36.8	26.7	32.8	11.5	27.0	30.7
Cut marks	n	0	0	0	0	0	1	1
%		0.0	0.0	0.0	0.0	0.0	0.3	0.0
Percussion	n	0	1	0	2	1	3	7
of	n	17	120	9	84	23	128	381
%		0.0	1.0	0.0	2.0	4.0	2.0	2.0
Working	n	0	0	0	0	0	0	0
%		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gnawing (carnivore)	n	0	12	3	37	6	31	89
%		0.0	2.5	4.0	8.6	4.6	7.8	5.6
Gnawing (rodent)	n	0	0	1	2	0	0	3
%		0.0	0.0	1.0	0.0	0.0	0.0	0.0
Root marks	n	4	13	10	17	4	19	67
%		5.6	2.7	13.3	4.0	3.1	4.8	4.2
Trampling striations	n	0	3	1	6	1	3	14
%		0.0	0.6	1.3	1.4	0.8	0.8	0.9
Abrasion	n	6	20	1	30	3	25	85
%		8.5	4.2	1.3	7.0	2.3	6.3	5.4



**Fig. 11.** Taphonomic comparisons between the stratigraphic layers; left: attritional processes; right: potential accumulation and modification agents. Note that the proportion of carnivore marks was calculated out of all NISP, excluding isolated teeth, while the hammerstone percussion abundance is out of the relevant NISP only (i.e., long-bones shaft portions and phalanges).

presence of complete skeletons cannot be a prerequisite for defining natural traps, as sites of this type often do not preserve such phenomena (e.g., Galería: Ollé et al., 2005; Rantis: Marder et al., 2011; Valdavara 3: Vaquero et al., 2018; Avetraná: Salari et al., 2019; l'Abri des Pêcheurs: Daujeard et al., 2019) or preserve them only partially, alongside numerous incomplete skeletal elements (e.g., Mora Cavorso: Salari et al., 2011). The absence or rarity of complete skeletons can be explained by postdepositional disturbance. In our case, the carcasses underwent some carnivore ravaging and were subsequently affected by the vast amount of limestone cobbles that fell from above (ca. 8 m to the top of Chimney I and ca. 17 m to the base of Layer B), breaking and smashing many of the bones.

The lithics and the few altered bones hint at occasional human visits to the inner room. Were these sporadic human visits intended for hunting or scavenging? That is, were the animals purposely driven to the

chimney by human hunters, or did they fall in naturally? The ethology of the Mesopotamian fallow deer, hiding in the forest solitarily, and its aversion to being led make it less favorable for mass procurement. Notably, fallow deer ecology has been studied from the European and Levantine (*Dama mesopotamica*) populations, each presenting its own set of challenges. The former is a species/subspecies living in different geographic settings (i.e., temperate park forest), while the latter is a reintroduced population.

Generally, fallow deer are mostly solitary, and the most frequent group size is of two or three individuals (Thirgood, 1996). Females disperse after giving birth, and the largest recorded group consisted of ten individuals. Before the rut, European fallow deer sometimes form groups as large as forty individuals (Chapman and Chapman, 1975:158; Thirgood, 1996). Mesopotamian fallow deer are primarily solitary foragers, seeking refuge in wooded patches. Despite this preference, they

sometimes form small groups, typically consisting of two or three individuals, with a maximum of five (Bar-David et al., 2005). The fallow deer's antipredatory mechanism involves hiding in the woods, making it difficult to locate (Ciuti et al., 2006; Ferretti et al., 2019; Maor Cohen et al., 2020). Communal hunting or mass procurement is usually performed on open landscape species that are gregarious and often migratory, such as bison, reindeer, goitered gazelle, *Antilocapra*, and horse (e.g., Speth, 1983; Olsen, 1989; Lubinski, 1999; Gaudzinski and Roebroeks, 2000; Costamagno et al., 2006; Bar-Oz et al., 2011; Rodríguez-Hidalgo et al., 2017; and see Smith, 2013; White et al., 2016). Furthermore, when attempts are made to drive fallow deer, they resist them by exhibiting unpredictable lateral movements instead of moving forward (Kersten, 1987).

Nonetheless, it is possible that a group of skilled hunters managed to manipulate animals toward the cave, leading them to fall into the unanticipated chimney (e.g., White et al., 2016; Rodríguez-Hidalgo et al., 2017). However, there is almost no evidence of the ensuing human manipulation of carcasses, dismembering and filleting body parts for transportation and breaking bones to extract marrow, that would be expected to follow such a scenario, which is found at similar sites (Galeria, natural trap: Huguet et al., 2001; Ollé et al., 2005; TD10.2, human trap: Rodríguez-Hidalgo et al., 2017) or in the case of butchery and kill sites (e.g., Les Pradelles: Costamagno et al., 2006; Nesher Ramla upper levels: Orbach et al., 2024; SOM Table 7). These activities leave substantial evidence on the remaining bones by percussion and cut marks. The Layer B3 skeletal-element profile exhibits lower skeletal representation, a telltale of selective transport out of the chamber. However, if humans had dismembered these carcasses *in situ*, we would expect plenty of bone modifications (e.g., Huguet et al., 2001; Ollé et al., 2005; Costamagno et al., 2006; Rodríguez-Hidalgo et al., 2017; Daujeard et al., 2019). Furthermore, the marked presence of carnivore modifications in this layer suggests that skeletal elements were more likely removed from the cave by scavenging carnivores. To conclude, given the high completeness and the lack of human manipulation of bones in contrast to numerous carnivore modifications, we reconstruct the recently excavated bone accumulation from Tabun Layer B as the result of animals falling into the cave through the chimney, with no human involvement.

Our results support and expand on Marín-Arroyo's (2013a) conclusion that the faunal remains found in Tabun Layer B were naturally deposited by falling through the chimney. The fallen carcasses were minimally exploited by carnivores and rarely by humans, until the chamber became practically inaccessible. We found no clear support for Jelinek et al.'s (1973) idea of the cave being used as a trap by Middle Paleolithic hunters. Nonetheless, the presence of lithics indicates some extent of human activity in the inner room. Tabun Cave is very close to numerous Middle Paleolithic sites (Olami, 1984), for example, Jelinek's (1982) finds the Tabun chimney units parallel those in Layers G and F at the nearby el-Wad Cave in technological characteristics, and rich Middle Paleolithic layers were unearthed also at Skhul Cave (McCown and Keith, 1939). Regardless of the proximity of Tabun to these caves, it must have been well-known to human foragers and easily accessible to them throughout the days of the Layer B deposition. Nonetheless, we have found a negligible anthropogenic impact on the bones, indicating that human presence in the cave itself, at least in the inner chamber, was scarce. The notion of humans regularly exploiting the natural trap (e.g., Brugal et al., 2006) might be exaggerated, although we cannot rule out the possibility that they did so on rare occasions. By shedding light on this classic site, this case study of Layer B in the inner room of Tabun Cave serves as an example of interpreting non-predation bone accumulations within a human exploitation landscape (Brugal and Jaubert, 1991; Brugal et al., 2006; Coumont et al., 2013) and provides a valuable comparison for anthropogenic sites (Lubinski, 2013).

Notably, two key phenomena require further investigation. First, the depositional processes within the Tabun B sub-layers are not yet fully understood. Bone, lithic, and rock densities exhibit significant variations

throughout the sequence. A deeper understanding of the factors driving these changes is crucial. Second, the fallow deer dominance is intriguing. Outstandingly, Tabun Layer B and Rantis Cave, despite their location in distinct biomes, both demonstrate a striking dominance of fallow deer, which stands in contrast to the anticipated high species diversity that would have been caused by natural accumulation.

Ongoing excavations at this significant site and future integrative studies on its finds, including lithics, will doubtless illuminate further the site's stratigraphy and activity patterns. Continued research is expected to enhance our understanding of human subsistence strategies during the Levantine Middle Paleolithic and beyond.

## 6. Conclusions

The faunal assemblages from Tabun Cave Layer B is best understood as the result of natural accumulation processes. Primarily, fallow deer accidentally fell into the cave through the chimney, and their carcasses were subsequently scavenged by carnivores, and rarely by humans. This interpretation is supported by multiple lines of evidence: minimal anthropogenic modification contrasting with frequent carnivore modifications, a relatively even skeletal-element representation, recurring bone articulation, and the natural herd demography. Our findings verify and refine previous research (Marín-Arroyo, 2013a), aligning with interpretations of a natural pitfall accumulation with only sporadic and minimal human involvement (e.g., Brugal et al., 2006; Coumont et al., 2013). It should be noted, however, that ongoing integrative analysis of the full archaeological record from Tabun Layer B is expected to further clarify this unique context.

The results of the faunal analysis of Tabun Layers B1-B3 join previous research to underscore the importance of integrating taphonomic and ecological data when interpreting faunal assemblages in karstic caves. Furthermore, they provide a valuable comparative framework for distinguishing natural from anthropogenic accumulations in Middle Paleolithic contexts in the Levant and beyond.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found online at <https://doi.org/10.1016/j.quascirev.2025.109620>.

## Data availability

All data and/or code is contained within the submission.

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