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# A High-Resolution Study of Bronze Age Fish Remains from Százhalombatta-Földvár, Hungary

ABSTRACT | The lack of archaeozoological data for fish exploitation in the Carpathian Basin has been explained by unsuitable collection methodologies. Due to the fragility and small size of fish bones, they can pass through hand-collection undetected, with the resulting assemblages thus disproportionately representing larger animal species. This article offers an analysis of soil samples taken over a decade from the Bronze Age Tell Site of Százhalombatta-Földvár, on the right bank of the Danube in Hungary. We carried out a comparative study of animal remains retrieved from the heavy fraction following the flotation of 10 l samples taken in randomly sampled columns over the 20 × 20 m excavation area. Constructing a standardized way of sampling methodology is at the core of this study. Column samples will be used, as they provide an in-situ section. Contrasting the quantities of fish bone finds between these parts of the excavated surface became essential to understand how collection methods improve our understanding of prehistoric fish exploitation. According to our analysis, fine recovery provides data that are more difficult to identify from a taxonomic point of view, but can be better evaluated using quantitative methods. For this reason, the heavy fraction is less suitable for reconstructing the fish fauna of the time, but rather shows the spatial regularities of fish processing and consumption. The identifiable fish remains in the heavy fraction also reflect the trend previously outlined based on the fish remains found in the entire zoological material. The dietary role of fish was minor, occasional fishing was likely most intensive during the spring and summer months. This may have coincided with the outdoor processing and consumption of fish, as confirmed by the spatial distribution of the fish bones extracted from the heavy fraction at this site.

KEYWORDS | Bronze Age fishing, fine recovery, systematic sampling, heavy fraction, taxonomic identification, seasonality

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# Százhalombatta-Földvár bronzkori halmaradványainak nagy felbontású vizsgálata

ABSZTRAKT | A Kárpát-medence őskori halászatára vonatkozó régészeti állattani adatok hiányát gyakran a nem megfelelő gyűjtési módszerekkel magyarázzák. A halcsontok törékenységük és kis méretük miatt észrevétlenek maradhatnak a kézi gyűjtés során, az így létrehozott leletegyüttesek aránytalanul jobban képviselik a nagy állatfajokat. Cikkünk a Duna jobb partján fekvő Százhalombatta-Földvár bronzkori tell lelőhelyéről egy évtizeden keresztül vett talajmintákban talált állatmaradványok elemzésén alapul. A 20 × 20 m-es feltárási területen véletlenszerűen kiválasztott oszlopokban vett 10 l-es minták flotálása után maradt nehéz frakció állattani leleteit vizsgáltuk. Tanulmányunk alapfeltétele a mintavételi módszer következetes kidolgozása volt. Oszlopmintákat vizsgáltunk, amelyek egymás fölötti, in situ állapotokat rögzítenek. A halcsontleletek mennyiségének összehasonlítása a feltárt felület ezen részei között elengedhetetlenné vált annak megértéséhez, hogyan és miként járulnak a leletgyűjtés módszerei az őskori halászat jobb megértéséhez. Elemzésünk eredményei szerint a finom feltárás rendszertanilag nehezebben meghatározható, de mennyiségileg jobban értékelhető adatokkal szolgál. Emiatt kevésbé a korabeli halfauna értékelésére alkalmas, mint inkább a halfeldolgozás és -fogyasztás térbeli szabályszerűségeinek hiteles rekonstrukciójára. A nehéz frakcióban azonosítható halmaradványok jól tükrözik a teljes állattani anyagban korábban talált halmaradványok alapján körvonalazott képet. A halak étkezési szerepe csekély volt, az alkalomszerű halászat a tavaszi és nyári hónapokban lehetett a legintenzívebb. Ez egybeeshetett a halak kültéri fogyasztásával, amit a nehéz frakcióból kinyert halcsontok térbeli eloszlása is megerősít a lelőhelyen.

KULCSSZAVAK | bronzkori halászat, finom feltárás, rendszeres mintavétel, nehéz frakció, rendszertani meghatározás, évszakosság

## Introduction

The lack of archaeozoological evidence for prehistoric fish exploitation in the Carpathian Basin has widely been explained as due to unsuitable collection methodologies, largely limited to hand-collection.[1] As a result of the small size and often-fragile structure of fish bones, most pass through hand-collection and even coarse screening undetected.[2] Consequently, fish remains tend to be underrepresented in the reconstruction of fish consumption and subsistence. This makes it difficult to establish whether few or no fish remains are indeed a sign of avoiding fish by certain communities or whether they result from biased recovery.

Remains of small vertebrates cannot be reliably retrieved by hand alone. In the mid-20th century, even prior to the emergence of New Archaeology, there was an emerging interest in explicitly quantifying animal remains recovered from archaeological sites.[3] Flotation, water sieving, and fine-mesh dry screening were gradually introduced to enhance precision in the reliable retrieval of not only these "ecofacts" but also *bona fide* archaeological artifacts.[4] In the field of European prehistoric archaeology, archaeozoologists pioneered methods of fine recovery, initially driven by their interest in reconstructing ancient environments.[5]

Water-sieving experiments in Hungary began as early as the 1980s,[6] and a decade later international prehistoric excavations led to the more systematic introduction of water-sieving and screening.[7] Although methods of fine recovery have traditionally been mostly advocated by prehistorians, even a late medieval deposit in

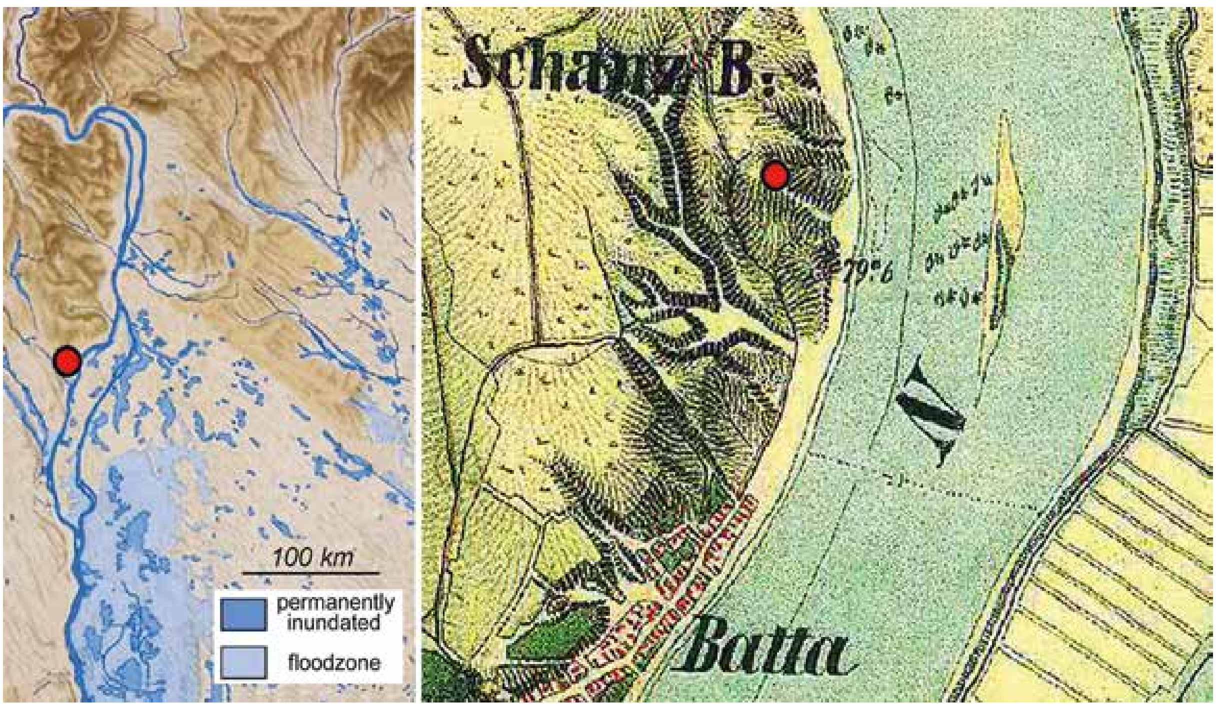


**Fig. 1.** The location of the Százhalombatta-Földvár site at the Danube (left) and on the map of the 1826–1868 Second Military Survey of Hungary (right; source: Arcanum.hu). The excavation area is marked by a red dot
**1. kép.** Százhalombatta-Földvár helyzete a Duna mentén (balra) és az 1826–1868-os Második katonai felmérés térképén (jobbra)

1 Bartosiewicz–Bonsall 2004.
2 Galik et al. 2011, 102.
3 Treganza–Cook 1948; Heizer–Squier 1953.
4 Struever 1968; Schock 1971.
5 Payne 1972; Barker 1975; Clason–Prummel 1977.
6 Bartosiewicz 1988; Takács 1988.
7 Pike-Tay et al. 2004; Vicze 2005; Kovács et al. 2010.

Hungary has recently undergone complete screening using 5 mm and 2 mm mesh sizes.[8]

Since 1998, Százhalombatta-Földvár, a multi-layer tell settlement located along the Danube River in central Hungary (Fig. 1), has been the subject of an international project initiated by the local Matrica Museum and now hosted by the Hungarian National Museum (for project details, including academic affiliations see: http://saxbronzeage.hu) (ID 11473). This work has been carried out in collaboration, among others, with various researchers from the UK and Sweden.

State-of-the-art recovery methods, including systematic dry sieving and flotation have been used from the start, resulting in substantial quantities of arte- and ecofacts. However, evaluating these extensive bodies of data is an enormous challenge and not all finds can be identified and analyzed within scope of the summer field seasons. To tackle this backlog, cooperation between the universities of Cambridge and Stockholm was established with the aim of evaluating the contribution of flotation to the analysis of fish remains. We posed the question whether the use of flotation, which separates light fragments, typically macrobotanical remains, from heavier small fragments (generally of stone, pottery and bone) would augment our knowledge of fish exploitation, which had been based on hand-collected and dry sieved find assemblages.[9] In addition, detailed identification and interpretation were carried out, answering questions about the impact of various recovery methods and the Bronze Age community's attitudes toward the river.

In order to retrieve macrobotanical remains, flotation samples have been collected systematically at the site. During their processing, the lighter, floating material is separated from the heavy fraction. Bones, including fish remains, appear in the latter, the residue left behind after the process. Such bones from the heavy fraction provide the basis for this study of some 11,000 animal remains. The findings will help as a test of a largely standardised sampling methodology at a complex prehistoric settlement. Ultimately, the conclusions drawn will enhance our current understanding of fish utilisation in Bronze Age Hungary and raise new questions regarding the presence or scarcity of fish exploitation at sites located near riverine habitats.

## Research aims

This project aimed to further a better understanding of the previously neglected exploitation of aquatic resources at this important Bronze Age tell site, contributing to a long-standing debate concerning the representation and recoverability of relevant osteological evidence. The central aim of our investigation was to assess the effectiveness of using the heavy fraction left behind by flotation in recovering identifiable animal bones, particularly in comparison with previously identified fish remains at the site.[10] Those investigations suggested that fishing was far from being part of the subsistence base at MBA Százhalombatta. It served rather as a qualitative, possibly seasonal complement to the diet.

One of the distinct differences between materials collected through flotation versus dry sieving is that the latter probably results in the fragmentation of fragile materials. The heavy fractions samples can, therefore, be compared with materials from the same excavation units that were collected through hand picking and dry sieving. This would help ascertaining whether fragile ecofacts, such as fish bones, are present in similar or different numbers depending on recovery method. Our project sought to address the following research questions:

- How are various vertebrate classes, especially fish, represented in the heavy fraction?
- What is the proportion of identifiable remains in the studied samples?
- Are there significant patterns in the stratigraphic and spatial distribution of the animal remains retrieved from the samples?
- How do the fish remains retrieved from the heavy fraction compare with those retrieved using only hand picking and dry sieving?

8 Benkő et al. 2021.
9 Bartosiewicz 2020.
10 Bartosiewicz 2020.

## Material

The site under discussion is an Early and Middle Bronze Age (MBA) tell settlement covering an area of approximately 200 by 100 m (ID 11473). It comprises over five meters of archaeological deposits representing the Nagyrév and Vatya cultures, including the latest MBA Koszider phase. The surface was excavated after opening 2 by 2m squares, forming a grid with a hundred units. During the excavation of these units, their identifying number (id) changes along with the stratigraphy. All the material from that excavation unit will be labelled accordingly. For each id a 10 litre flotation sample was taken. Although higher spatial resolution of single square meter units was used when features, such as pits, houses, or fireplaces, were excavated, such features were not included in the samples for this study. To suit the aims of our project we wanted to work with as comparable samples as possible and thus decided to analyse only samples from general fills. The lack of samples from the southeast corner is due to a large pit being located there and the samples, therefore, are not included.

Before excavation began, ten percent of the hundred units were randomly selected to act as 'columns' running down through the sequence. These column samples consisted of small subsamples of midden material used in the systematic and detailed examination of the micro-faunal remains as suggested by Richard Casteel.[11] While these were not always columns in a physical sense, they served as a standard random sample for various data against which additional information collected from other sections of the excavation could be compared. As these columns went down through different deposits, they would have varied in numbers of id numbers.

The flotation samples discussed in this study represent the complex stratigraphy of the tell, spanning a time interval between approximately 2000 to 1450 BCE. The site is still under excavation, and the Early Bronze Age phase has not yet been fully recovered. For this study, samples of the heavy fraction data have been extracted from the four phases distinguished so far, although finds from these phases were available in very different numbers.

### Vertical distribution and phasing

During the excavation, a deep sequence of deposits was revealed, with variable characteristics and levels of interconnected features and layers. As of today, this sequence has been divided into four major phases.

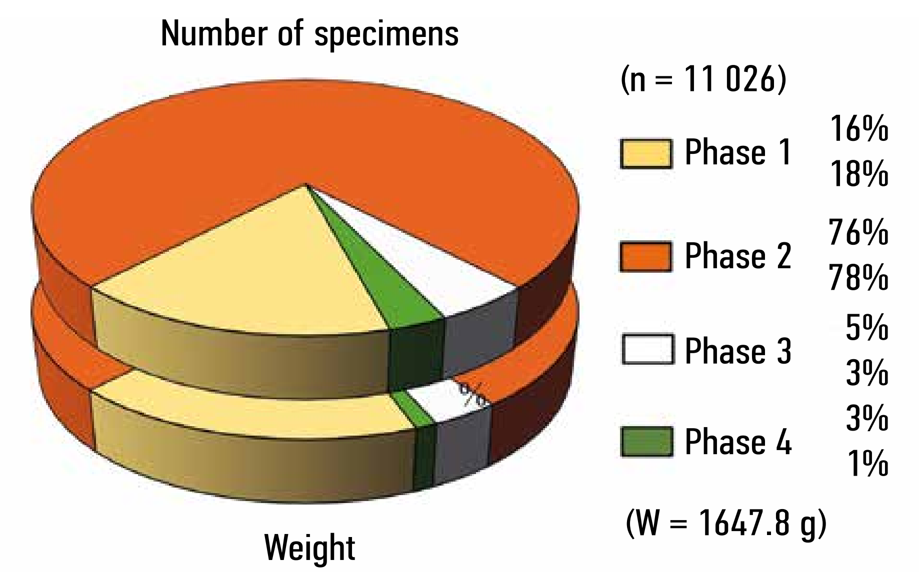


**Fig. 2.** The percentual distribution of animal remains by absolute number (top) and weight (bottom) attributable to phases in the column samples
**2. kép.** Az állatmaradványok százalékos eloszlása abszolút darabszám (fent) és súly szerint (lent) a minták korszakhoz köthető részeiben

11 Casteel 1976, 193.

Archaeological results for Phase I on the top of the deposit were already published,[12] with the rest of the material currently being analysed or under excavation. The phases identified to date, listed in sequential order from top to bottom, are as follows:

1. Abandonment phase, Levels 1–6
2. Middle Bronze Age houses and street
3. Early Middle Bronze Age layers without households
4. Transition between Early Bronze Age/Middle Bronze Age (possibly including Early Bronze Age elements)

The set of heavy fraction samples discussed in this paper contained a total of 11,026 pieces of animal remains weighing 1647.8 g. The distribution of these remains associated with each of the four phases is summarized in Fig. 2. This diagram shows that the majority of animal remains recovered from the selected heavy fraction samples originate from the Middle Bronze Age houses and street phase. This means that, in part due to the different numbers of samples from each phase, when all samples are combined and analysed together, Phase 2 significantly influences the overall results.

## Horizontal sampling

The area excavated was strategically chosen in the central section of the tell, based on the results of prior borehole investigations.[13] It encompasses a 20 by 20 m area, with its walls aligned to the four cardinal directions. In comparison to previously excavated trenches at other major Bronze Age tell settlements in Hungary,[14] this excavation area is the largest to date (Fig. 3).

The northwestern corner of the excavation area corresponds to the coordinates N: 244953 and E: 344840 (UTM). The surface was excavated using 2 by 2m squares, forming a grid with a hundred (10 by 10) horizontal units. Although occasionally a higher spatial resolution of single square meter units was used, it was not taken into consideration during the collection of flotation samples for this study: our samples were uniformly designated, based on the 2 by 2m squares.

Sixty heavy fraction samples, each representing 10 litres of soil, were randomly selected from the columns. Additionally, 21 samples were selected from the southwestern quarter of the area excavated to enable extensive horizontal comparison. These samples represent "general fill" corresponding to a hypothetical midden area, especially at Level 7, Phase 2 (Fig. 4).

Phasing information, summarised in Fig. 2, was available for the samples originating from the column samples marked by shading in Fig. 4. Comparing this sub-set of randomly selected 2 by 2m squares in Table 1, bone concentrations were measured by the weight of remains (not divided by number of samples, each of which represent 10 litre of soil). The spatial distribution of the animal remains was uneven, with no demonstrable correlation between the number of samples and the weight of bone recovered from the selected column samples. Notably, there were no samples available from column 2147.

## Taxonomic distribution

While dental fragments within the studied small size range can still be relatively safely identified among the remains shown in Fig. 5, many splinters of skeletal bone can only tentatively be assigned to size categories such as large (e.g. cattle, horse) or medium size mammals.


**Fig. 3.** Satellite image of the excavation area opened on the top of the tell in relation to the Danube (right); wooded areas mark steep slopes toward the riverbank (source: Google maps)
**3. kép.** A tell tetején nyitott ásatási terület műholdképe a Duna partjához viszonyítva (jobbra); az erdőborítás a meredek partszakaszt mutatja a folyó irányában (forrás: Google maps)

12 Vicze – Stig Sørensen 2023.
13 Vicze 2005, 68.
14 Meier-Arendt 1992.

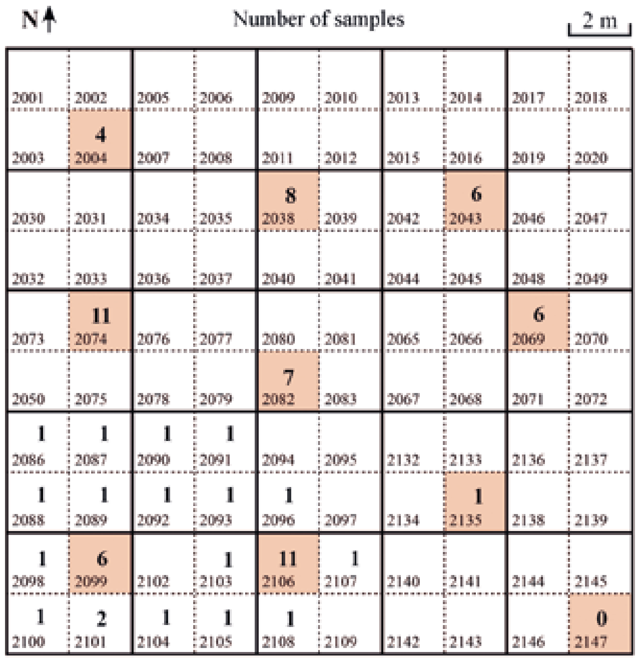


**Fig. 4.** The spatial distribution of the randomly selected column samples indicated by shading and the number of 10 litre samples taken from various 2 by 2 m squares (boldface numbers; the 4 digit number for each square is the identification used in the master grid)
**4. kép.** A véletlenszerűen kiválasztott oszlopminták térbeli eloszlása (árnyalt négyzetek), valamint az egyes 2 × 2 méteres területeken vett 10 literes minták száma (félkövér szedés; a négyzetek négyjegyű számai a felvázolt hálón belüli azonosító kódok)


**Fig. 5.** Set of mammalian remains from Sample 3331, containing caprine and pig tooth fragments, a rib splinter as well as tiny flat and long bone fragments from medium size mammals; scale = 10 mm (photo: Piers Cummings)
**5. kép.** Emlősmaradványok a 3331. mintából: juh- vagy kecske- és sertésfogtöredékek, bordaszilánk, valamint közepes méretű emlősök apró lapos- és hosszúcsonttöredékei; lépték = 10 mm (fotó: Piers Cummings)

This latter category includes bones of ungulates (sheep, goat, and pig), but potentially even skeletal fragments of large dogs, albeit with a lower probability given the lesser dietary role of carnivores.

The monotonous sets of small bone splinters from mammals provide limited information on their own but serve as a valuable backdrop against which the presence and absence of fish bones can be quantitatively evaluated. They are, therefore, of interest for analyses of site formation activities and rubbish management.

The previously analysed bulk material samples[15] may exhibit greater taxonomic diversity, contributing additional taxa to the zoological evaluation of the site. Some of these animals may represent natural additions to the assemblage, originating from animals such as frogs, toads and micromammals that also inhabited the human settlement (Fig. 6). In the case of Százhalombatta, fish represent a distinct category. Due to the elevated position of the Bronze Age tell, the natural deposition of fish bones can be confidently ruled out, unlike for prehistoric settlements located on floodplains. The sample types illustrated by the two examples shown in Figs. 5 and 6 determine the methods chosen for evaluating the data. Varying levels of taxonomic resolution must be considered when grouping and comparing a range of excavation units and animals, as the characteristics of sub-assemblages influence both the analysis and interpretation of the eventual findings.

## Methods

First, the samples and corresponding information were systematically organised by provenance, and a standardised Excel database was created. This dataset was subsequently enhanced by incorporating species and anatomical identification, along with additional comments on aspects such as preservation quality.


**Fig. 6.** Set of animal remains from Sample 6748, showing the supracleithrum and caudal vertebra of a cyprinid fish, the presacral vertebra and pelvis of a frog, the mandible fragment of a wood mouse among the rib and flat bone fragments from medium size mammals; scale = 10 mm (photo: Piers Cummings)
**6. kép.** Állatmaradványok a 6748. mintából: pontyféle *supracleithrum* és farokcsigolya, béka csigolya és medencecsont, erdei egér állkapocstöredéke és közepes méretű emlősök laposcsont töredékei; lépték = 10 mm (fotó: Piers Cummings)

15 Bartosiewicz 2020.

In addition to the number of remains, their weights were also recorded. Since the material was thoroughly washed during the flotation process and contained hardly any tubular fragments, the resulting weights were not inflated by soil contamination, a potential source of bias in using bone weights. The expanded and refined database was then subjected to quantitative and qualitative analyses, aiming to assess the distribution of zoological information across various parameters, including sampling method, vertical stratigraphy, and spatial distribution.

## Recovery

The heavy fraction studied results from the flotation of soil samples (10 litre each) during which light and heavy material are separated. During the flotation process water-sieving was carried out using a 0.3 mm mesh size. The remaining heavy fraction was then screened through decreasing mesh sizes (4 mm, 2 mm, 1 mm, 0.5 mm). During this process, larger, visible bone fragments were not removed from the screens. Sub-samples from each fraction were measured, and portions of 100 $cm^3$ and 50 $cm^3$) were retained and sorted for specialist analyses.[16] Importantly, all finds, regardless of size, have been retained throughout this procedure. This method allowed for the inclusion of in-situ sections and finds not exceeding 100 mm in length.

Relatively large fish remains analysed from Százhalombatta in a previous study[17] were collected in a different manner. During the study of mammalian finds, fish remains were set aside for subsequent 'bulk material' analysis.[18] Those data were based on the material collected by hand during excavation plus the material retrieved from dry sieving of all excavated soil using a 15 mm mesh. The fish remains discussed in this paper, therefore, represent a different size range resulting from different techniques of both recovery and sampling.

## Identification

The identification of selected samples took place at the National Heritage Protection Centre of the Hungarian National Museum during the winter of 2022–2023. The material was examined using a 3× magnification table loupe, and bones were weighed on a laboratory scale with a precision of 0.01 g. For uniformly sized and structurally similar bones lighter than 0.01, measurements were conducted in groups of 5-10 specimens, estimating a mean weight for each. Both taxonomic and anatomical identifications were made to the closest possible level, prioritising the determination of anatomical elements over taxonomic identification. This approach allows for comparisons between different taxa by establishing which part of the skeleton is being analysed. The identification process followed a hierarchy, starting with fragments of concrete elements such as teeth and skeletal bone. The skeletal bone category included long bone diaphysis (cortical) splinters, flat bone pieces, and rib fragments. In some cases, it was challenging to separate fin rays from rib and branchyostegale corpus fragments among small fish remains. Additionally, fragments formed by the ossification of intermuscular tendons ("fish bone") were also included. These are commonly found in large numbers in the precaudal part of cyprinid fish and ossify as a consequence of mechanical force loading during swimming.

Taxonomic identifications followed a similar hierarchy, with identifications made at the exact species (e.g. cattle, *Bos taurus*), genus (e.g. Apodemus), subfamily (e.g. Caprinae), family (e.g. Cyprinidae), and class (e.g. Aves) levels. In cases where mammalian remains could not be precisely identified, a gross distinction was made between bones from large (e.g. cattle) and medium-sized (e.g. sheep) animals based on cortical thickness and trabecular structure. Such hierarchical levels of identification are difficult to reconcile during analysis. As will be shown by the findings, one may choose the appropriate resolution depending on the research hypotheses, i.e. the aspect of the assemblage chosen for analysis.

## Quantification

Animal remains were recorded in terms of the number of specimens. A specimen is defined here as a "bone or tooth, or fragment thereof"[19] not to be mistaken

16 Vicze 2005, 76, Fig. 10.
17 Bartosiewicz 2020.
18 Vretemark–Sten 2020.
19 After Donald Grayson (Grayson 1984, 16).

for an element, a term that refers to complete parts of the skeleton. The number of identifiable elements (NISP) is widely used in archaeozoology, however, in this study, non-identifiable remains were also included in the analysis, necessitating the use of the number of all specimens. Additionally, the weight of each specimen was recorded as an indicator of fragmentation, a significant factor that has influenced the assemblage recovered from the heavy fraction. The material identified by phases (Fig. 2) exhibited specimen numbers and weights whose proportions are almost identical. This consistency is attributed to the heavy fraction's nature, as it contains small pieces of relatively similar sizes due to the homogenising effects of extensive fragmentation.

The resolution of quantitative analysis can have a profound effect on results, particularly in terms of sample and sub-sample sizes. The disparity between small and large datasets affects the outcome of comparisons between avian and mammalian remains.[20] During the archaeological investigation at Százhalombatta, the increasing study of heavy fraction samples enabled the identification of 17 distinct find categories already by 2005.[21] This is likely a result of meticulous recovery methods and the substantial number of samples analysed.

Although the current excavations predominantly yielded material from Middle Bronze Age houses and street sections, limiting the potential for diachronic comparisons, the samples presented below provides a unique opportunity for a broad-based methodological assessment. For instance, it is possible to compare the ten-litre heavy fraction samples obtained through water-sieving with the bulk material previously collected following hand picking and dry sieving.

### Analysis

Both specimen numbers and weights are non-derived empirical values, measured on a ratio scale: they can be ranked, subtracted, and divided with one another. However, specimen numbers are discrete variables that are countable and directly comparable using non-parametric statistics. Weight, on the other hand, is a continuous variable that cannot be counted and needs to be evaluated through calculating statistical parameters, such as mean value and standard deviation. Consequently, testing the probability of patterns observed in these two variables required different statistical methods. The PAST software developed by Øyvind Hammer[22] was used in uni- and bivariate analyses in this study. Testing criteria were applied following Joan Welkovitz et al.,[23] and Frederick Williams.[24]

## Results

The core material of our project consists of the 60 samples retrieved from the nine column samples (most accompanied by phasing information), but as additional samples were selected from the southwestern quadrant of the trench, we begin by exploring the nature of the broader data set. The locations of samples are shown in Fig. 4. We proceeded from drafting general trends toward addressing questions that are more specific.

### General properties of the material

First, the relationship between specimen numbers and fragment weights were compared between the two major data sets representing the columns and samples gathered outside. At this point, no taxonomic or anatomical identifications were used, we were interested in the mechanics of our variables. Weights were first plotted against the number of each specimen by individual samples (Fig. 7). Sample 3084, from outside the columns, was excluded from this analysis as an outlier as it contains the heaviest bone in the entire assemblage, a robust cattle humerus diaphysis fragment, weighing over 100 g.

According to Fig. 7, the more the specimens, the more they weigh: the linear regression equation calculated using column data only is indicative of a high

20 Bartosiewicz–Gál 2007, 40, Fig. 4.
21 Vicze 2005, 76.
22 Hammer 2020.
23 Welkovitz et al. 1971.
24 Williams 1979.

and positive linear correlation between the two variables, illustrating a marked relationship.[25] The two forms of quantification thus support each other. However, the resulting diagram is indicative of relatively great dispersion in both sets of samples, depending on the size of the fragments included. Samples containing large, heavy bones fall well above the trend line in this diagram.

Given the overlap between the samples gathered within and outside the columns, it is difficult to visually appraise in this figure whether column samples and those taken outside the columns differ in statistically

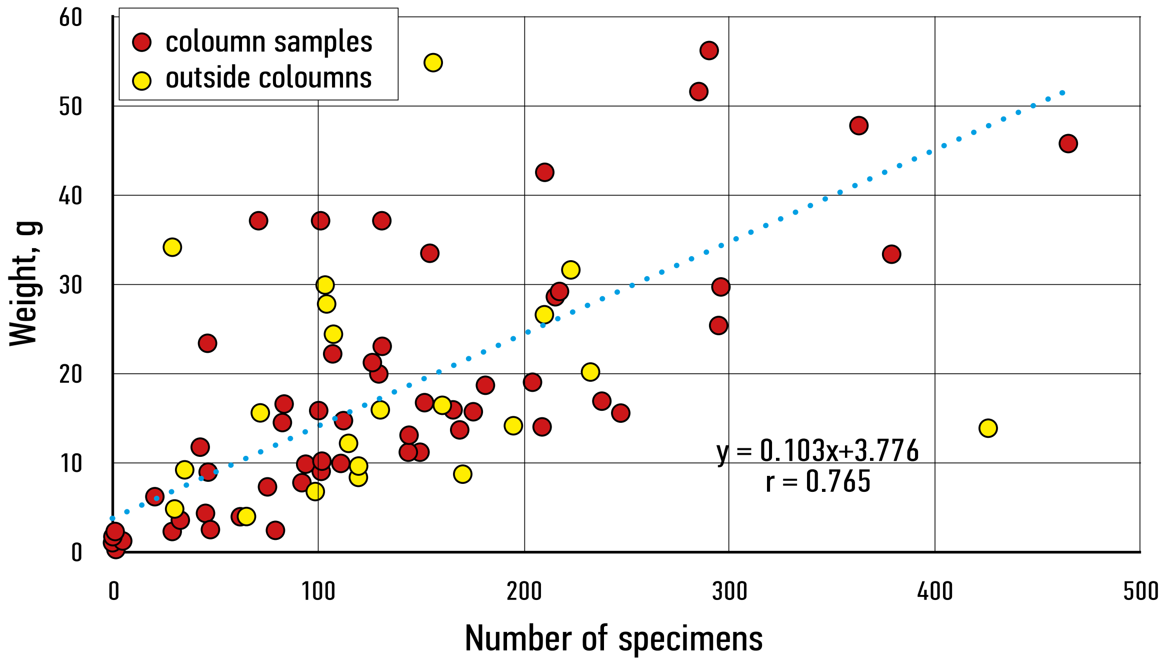


**Fig. 7.** The distribution of samples by the number and weight of bone specimens; in the regression equation: y = weight, x = n of specimens, r = coefficient of correlation
**7. kép.** A minták eloszlása az állatmaradványok abszolút darabszáma és súlya; a regressziós egyenletben: y = súly, x = darabszám, r = korrelációs együttható

| Column | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Total | Sample | | % |
|---|---|---|---|---|---|---|---|---|
| | | | | | | n | mean | |
| 2004 | | 141.8 | | | 141.8 | 4 | 41.4 | 13.5 |
| 2038 | 2.2 | 116.9 | 22.1 | | 141.2 | 8 | 18.2 | 12.0 |
| 2043 | | 65.1 | 30.4 | | 95.5 | 6 | 15.9 | 7.8 |
| 2069 | 44.5 | 19.4 | 1.6 | | 65.6 | 6 | 10.7 | 5.2 |
| 2074 | 39.2 | 142.1 | | | 181.3 | 11 | 16.9 | 15.2 |
| 2082 | 18.1 | 68.3 | 0.0 | | 86.5 | 7 | 14.2 | 8.1 |
| 2099 | 3.7 | 97.3 | | 15.6 | 116.5 | 6 | 20.7 | 10.1 |
| 2106 | 137.2 | 178.9 | 2.8 | 2.6 | 321.4 | 11 | 30.0 | 27.0 |
| 2135 | 14.0 | | | | 14.0 | 1 | 13.8 | 1.1 |
| **Total** | **258.9** | **829.7** | **57.0** | **18.1** | **1163.7** | **60** | **20.4** | **100.0** |

**Table 1.** The distribution of animal remains by weight (g) in columns by phase and the number of 10 litre samples
**1. táblázat.** Az állatmaradványok súlyának (g) oszlopmintánkénti eloszlása korszakok és a 10 l minták száma szerint

25 Williams 1979, 128.

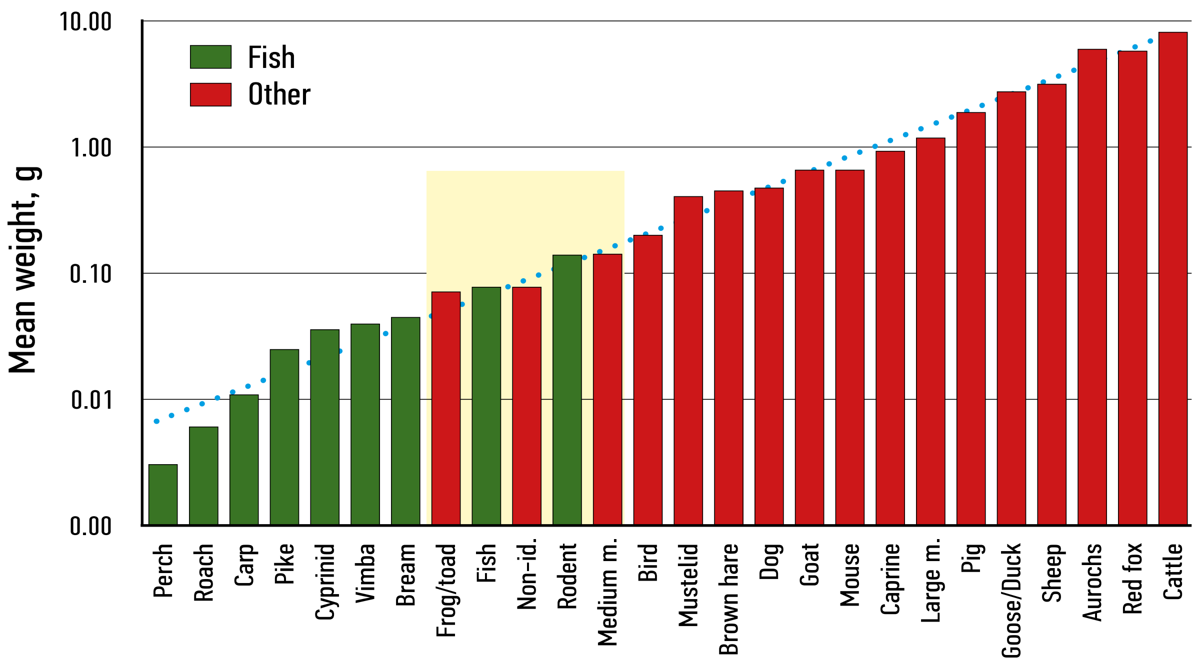


**Fig. 8.** Increasing mean specimen weights (left to right) by taxa, shown in decimal logarithms
**8. kép.** A rendszertani csoportok szerint balról jobbra növekvő átlagos töredéksúlyok tízes alapú logaritmusa

| Parameter | Column samples | Outside columns |
|---|---|---|
| Number of specimens | 8505 | 2520* |
| Minimum weight, g | 0.001 | 0.001 |
| Maximum weight, g | 26.210 | 28.118 |
| Mean weight, g | 0.137 | 0.151 |
| Median weight, g | 0.083 | 0.049 |
| Standard deviation, g | 0.347 | 0.938 |
| Skewness | 29.780 | 23.878 |

**Table 2.** Comparison between bone weights from column samples and outside columns
*Not including the large cattle humerus fragment
**2. táblázat.** Az állatmaradványok súlyának összehasonlítása oszlopmintákon belül és kívül
*Az összehasonlítás nem tartalmazza a nagyméretű szarvasmarha-karcsonttöredéket

significant terms. In the next step we compared the weight of animal remains between these two major groups of samples (Table 2).

In both types of samples, the median weight is smaller than the mean weight, indicative of strong asymmetry in the weight distribution also expressed in the high degree of skewness. This means that small fragments are far more numerous than heavy specimens, resulting in a positively skewed distribution.[26]

A Student's t-test performed on these weight data ($t = 1.165$, $p = 0.244$) has shown that the 0.014 g difference between the two mean values in Table 2 is not significant on the conventionally required $p=0.05$ level of probability. This means that size-wise samples within and outside the column samples do not differ significantly and may be pooled, i.e. will be treated as part of the same assemblage during the rest of the analysis.

26 Williams 1979, 29.

| Taxon | n | % | Mean W, g |
|---|---|---|---|
| Cattle (*Bos taurus* L., 1758) | 16 | 0.145 | 7.578 |
| Aurochs (*Bos primigenius* L. 1758) | 1 | 0.009 | 5.591 |
| Sheep (*Ovis aries* L., 1758) | 2 | 0.018 | 3.070 |
| Goat (*Capra hircus* L., 1758) | 2 | 0.018 | 0.622 |
| Caprine (Caprinae Gray 1852) | 175 | 1.587 | 0.902 |
| Pig (*Sus domesticus* Erxl. 1777) | 24 | 0.218 | 1.787 |
| Dog (*Canis familiaris* L., 1758) | 6 | 0.054 | 0.456 |
| Red fox (*Vulpes vulpes* L., 1758) | 1 | 0.009 | 5.481 |
| Mustelid (Mustelidae Fischer, 1817) | 1 | 0.009 | 0.389 |
| Wood mouse (Apodemus Kaup, 1829) | 1 | 0.009 | 0.641 |
| Brown hare (*Lepus europeaus* Pall., 1778) | 2 | 0.018 | 0.429 |
| Rodent (Rodentia Bowdich, 1821) | 3 | 0.027 | 0.134 |
| Goose/Duck (Anseriformes Wagler, 1831) | 1 | 0.009 | 2.621 |
| Bird (Aves L., 1758) | 8 | 0.073 | 0.200 |
| Frog/toad (Anura Duméril, 1806) | 7 | 0.063 | 0.070 |
| Large mammal | 46 | 0.417 | 1.249 |
| Medium mammal | 5248 | 47.597 | 0.139 |
| Non-identifiable | 4467 | 40.513 | 0.078 |
| Pike (*Esox lucius* L., 1758) | 7 | 0.063 | 0.024 |
| Perch (*Perca perca* L., 1758) | 2 | 0.018 | 0.003 |
| Carp (*Cyprinus carpio* L., 1758) | 9 | 0.082 | 0.011 |
| Roach (*Rutilus rutilus* L., 1758) | 1 | 0.009 | 0.006 |
| Vimba (*Vimba vimba* L., 1758) | 1 | 0.009 | 0.038 |
| Bream (*Abramis brama* L., 1758) | 2 | 0.018 | 0.045 |
| Cyprinid fish (Cyprinidae L., 1758) | 67 | 0.608 | 0.035 |
| Fish (Pisces L., 1758) | 926 | 8.398 | 0.075 |
| **Total** | **11026** | **100.000** | |

**Table 3.** The composition of the assemblage by specimen numbers (n, %) and mean weight of remains in the studied taxa
**3. táblázat.** A leletegyüttes összetétele darabszám (abszolút és %) és a rendszertani kategóriák szerinti átlagos töredéksúlyok szerint

## Zoological content

Part of the variability in bone weights between samples is caused by their differing zoological compositions. The largest difference is expected between fish bones and remains originating from the rest of the vertebrate classes (predominantly mammals) identified in the samples (Table 3). A closer look at this table reveals that only 324 specimens (2.9%) were taxonomically identifiable on at least the family level. Unsurprisingly, the precision of zoological identification decreases with the weight of the specimens. It is also important to note that while the identifiable remains reliably reflect the composition of the assemblage of dry-screened remains in the bulk material,[27] the small number of such specimens recovered from the heavy fraction is largely unsuitable for in-depth taxonomic analysis.

Fig. 8 shows the distribution of mean specimen weights by taxa arranged in an increasing order from

27 Vretemark–Sten 2020; Bartosiewicz 2020.

| Parameter | Fish | Non-piscine |
|---|---|---|
| Number of specimens | 1015 | 10010* |
| Minimum weight, g | 0.001 | 0.001 |
| Maximum weight, g | 0.799 | 28.118 |
| Mean weight, g | 0.072 | 0.147 |
| Median weight, g | 0.062 | 0.078 |
| Standard deviation, g | 0.097 | 0.567 |
| Skewness | 6.261 | 29.747 |

**Table 4.** Comparison between bone weights of fish remains and of other, non-piscine classes based on all the samples
*Not including the large cattle humerus fragment
**4. táblázat.** A halcsontok és egyéb állatmaradványok súlyának összehasonlítása valamennyi minta alapján
*Az összehasonlítás nem tartalmazza a nagyméretű szarvasmarha-karcsonttöredéket

left to right. (Due to the extreme differences in weight, the diagram shows decimal logarithms). Comparing the rank order of mean weights listed in Table 3 and sorted by weight in Fig. 8 taxon using Spearman's rank correlation resulted in a $r_s = -0.844$ ($p = 0.000$) coefficient, confirming the trend that the inverse association between identifiability and specimen size is statistically significant. Deviations from the ideal $r_s = 1$ value are caused by a few fish remains which are identifiable to species in spite of their tiny size.

A remarkable feature of this diagram is the rather clear cut-point between fish and other categories at approximately 0.1 g. The only taxon not fitting this trend is that of frogs and toads, morphologically very different from mammals. Non-identifiable bones from fish and mammals are of comparable mean weights. Vertebrate remains from the heavy fraction samples have shown that, contrary to the optimistic assertion by Lewis Binford and Jack Bertram[28] (presumably concerning hand-collected animal bones), there is a size range below which no training would be of help in the morphological identification of mammalian remains in the heavy fraction.

What is also noteworthy is that, in addition to a few rodent bones, the large group of remains originating from non-identifiable medium size mammals also falls near these categories. The zone around 0.1 g mean weight, encompassed by these taxa, is shaded in Fig. 8. In order to fine-tune this distinction, the weights of fish remains are compared to those representing other vertebrate classes presented in Table 4. On average, fish bones are half the weight of specimens originating from non-piscine taxa. The student's t-test ($t = 4.230$, $p = 0.000$) has shown that this major difference between the mean values evident in Table 4 is significant.

While it is logical that animals as large as cattle are represented by larger bones among the remains from "other", non-piscine taxa, this broader group also displays a greater standard deviation and a higher positive skew due to large fragments from animals far exceeding any fish in size, most notably cattle. However, the number of such large remains was extremely small in the heavy fraction samples studied so far. In their study of the animal remains included under bulk finds, Maria Vretemark and Sabine Sten reported a mean weight of 6.1 g for the 89,302 non-piscine specimens (retrieved by hand picking and dry-sieving using a mesh-size of 15 mm). On average the mean weight varied between 4 and 7 g in the bulk samples originating from the various layers they studied.[29]

The largest specimens that skewed the weight distribution of non-piscine remains from the heavy fraction samples are listed in Table 5. A minimum weight of 5 g was chosen as a criterion for inclusion in this summary. The list of fish skeletal elements in Table 6 shows a clear dominance of fragile, small elements that are difficult, usually impossible to precisely identify by species.

28 Binford–Bertram 1977, 125.
29 Vretemark–Sten 2020, 19, Table 1.

| Taxon | Element | 2038 | 2082 | 2088 | 2094 | 2098 | 2099 | 2101 | 2104 | 2106 | 2107 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| cattle | tooth | | | | | | | | 28.1 | | 27.3 |
| cattle | humerus | 6.4 | | | | 103.2 | | | | | |
| cattle | radius | | | | | | | 18.4 | | | |
| aurochs | v. cervicalis | | 5.6 | | | | | | | | |
| caprine | tooth | | | | | | | | 5.5 | | |
| caprine | humerus | | | | | | 7.6 | | | | |
| caprine | acetabulum | | | 8.5 | | | | | | | |
| caprine | femur | | 5.1 | | | | | | | | |
| caprine | tibia | | | | 6.9 | | | | | | |
| pig | tooth | | | | | | | | | 8.9 | |
| red fox | atlas | | 5.5 | | | | | | | | |

**Table 5.** List of specimens heavier than 5 g identified in the assemblage
**5. táblázat.** A leletegyüttesben meghatározott, 5 g súlyt meghaladó csonttöredékek meghatározásai

| Element | Pike | Perch | Carp | Roach | Vimba | Bream | Cyorinid | Fish indet. | Total |
|---|---|---|---|---|---|---|---|---|---|
| parasphenoideum | | | | | | 1 | 1 | | **2** |
| vomer | | | | | | | 1 | | **1** |
| basioccipitale | | | | | | 1 | 1 | | **2** |
| metapterigoideum | | | | | | | 1 | | **1** |
| quadratum | | | | | | | 1 | | **1** |
| articulare | | | | | | | 2 | | **2** |
| dentale | | | | | | | 2 | | **2** |
| tooth | 3 | | 5 | 1 | 1 | | 1 | | **11** |
| hyomandibulare | | | | | | | 1 | | **1** |
| ceratohyale | 1 | | | | | | 1 | | **2** |
| branchyostegale | 2 | | | | | | 1 | 1 | **4** |
| praeoperculare | | 1 | | | | | | | **1** |
| operculare | | | 1 | | | | 1 | | **2** |
| supracleithrale | | | | | | | 1 | | **1** |
| vertebra precaudalis | | | 1 | | | | 8 | 2 | **11** |
| vertebra caudalis | | 1 | | | | | 13 | 7 | **21** |
| vertebra indet. | | | | | | | 5 | 5 | **10** |
| neurapophysis | | | | | | | 1 | 2 | **3** |
| haemapophysis | | | | | | | 2 | | **2** |
| costa | | | | | | | 15 | 87 | **102** |
| acanthotrich | | | | | | | | 2 | **2** |
| lepidotrich | | | 1 | | | | | 3 | **4** |
| fin ray | | | | | | | | 88 | **88** |
| ossa plana | | | | | | | | 41 | **41** |
| non-identifiable | | | | | | | | 554 | **554** |
| intermuscular bone | | | | | | | | 128 | **128** |
| scale | 1 | | 2 | | | | 7 | 6 | **16** |
| **Total** | 7 | 2 | 10 | 1 | 1 | 2 | 66 | 926 | **1015** |

**Table 6.** Specimen numbers of various anatomical elements of the fish skeleton
**6. táblázat.** A halcsontváz különböző elemeinek darabszámai

## Archaeological applications

In light of this difference between fish bones and the rest of the vertebrate remains, bone weights of these two groups are plotted against each other, summarized for column samples and those gathered outside the columns (Fig. 9). This diagram clearly illustrates the differences between the larger quantities included in cumulated column samples and individual samples gathered outside the columns, regardless of the fact that larger volumes of soil were analysed from within some column samples (esp. 2074 and 2016; cf. Fig. 4).

The regression equation describing the pattern shown by column samples shows a high correlation between the weights of fish bones and non-piscine remains, but also expresses the larger size of the latter (regression coefficient: b = 0.066 as opposed to 1). What is important in this figure is that the data points of column samples 2004, 2082 and 2016 fall above the trend line, directing attention to relatively higher accumulations of fish bone by weight in these units.

**Spatial distribution.** In Fig. 9, a tight cluster of small, individual samples is formed by those taken outside the columns in the southwestern section of the area excavated. These samples were designated to help illustrate the horizontal distribution of animal remains recovered from the heavy fraction. They are largely associated with Level 7 within Phase 2. Fig. 9, however, shows that due to their smaller size they may be less representative in statistical terms than large, cumulated column samples.

Considering this information, the percentual contributions of fish bone weights within the total weight of animal remains were plotted by 2 by 2 m squares across the area excavated (Fig. 10). This figure is indicative of a heterogeneous spatial distribution, with differences in fish bone weight concentrations ranging between the total absence of fish up to 11.8% of weight. While some extremes occur outside column samples and may be slightly exaggerated by small sample sizes (total number of specimens < 100), they are contiguous with the high values in column samples

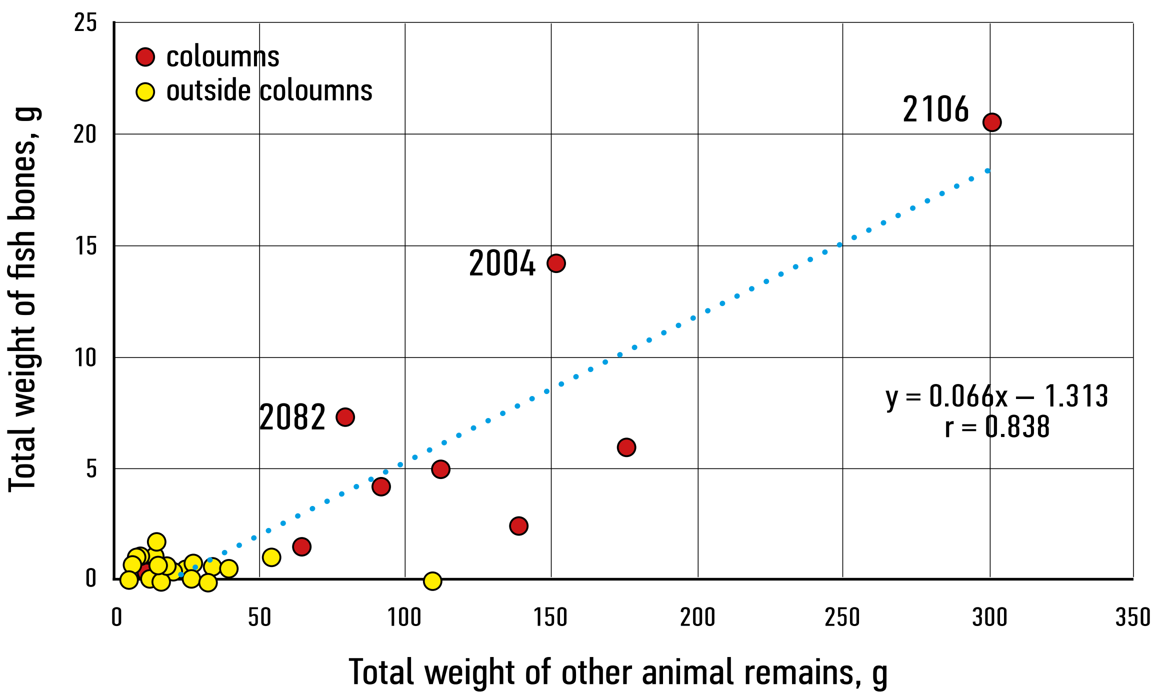


**Fig. 9.** Comparing the weight of fish bones and other animal remains by columns and samples taken from other locations
**9. kép.** A halcsontok és egyéb állatmaradványok súlya mintánként és az oszlopmintákon kívüli négyzetekben

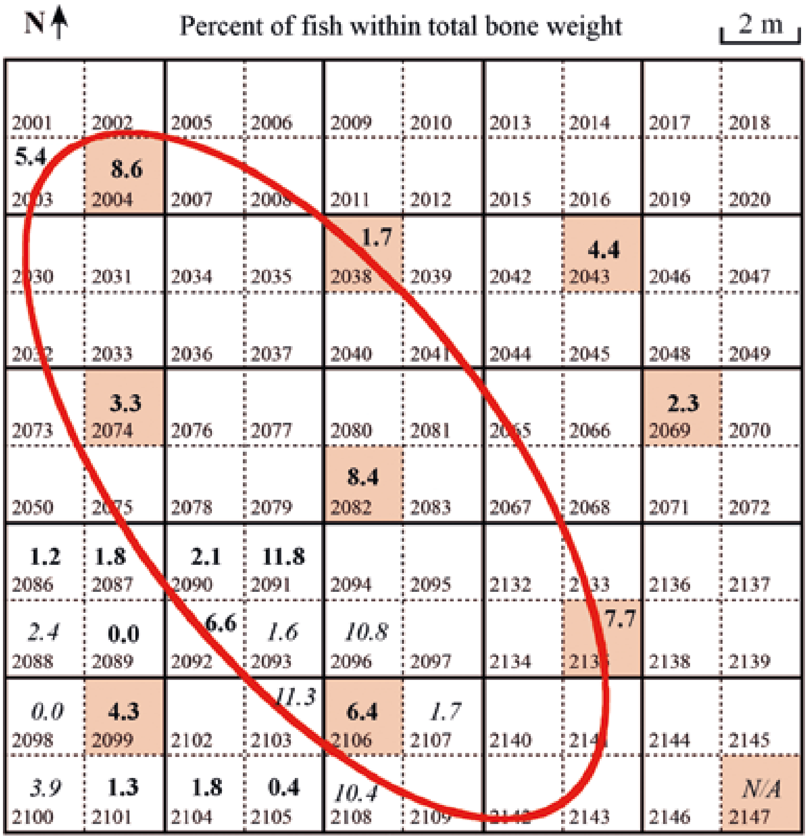


**Fig. 10.** The percentage of fish bones within the total weight of remains across the excavation area; higher relative contributions of fish remains occur approximately within the elliptical area; values based on n < 100 specimens are printed in italics; column samples are indicated by shading

**10. kép.** A halcsontok százalékos aránya az összes állatmaradvány súlyán belül az ásatási területen; a halmaradványok nagyobb aránya zömmel az ellipszis területén belül látható; a 100 darabnál több leletre alapozott értékeket kurzív szedés jelzi; az oszlopminták helyét árnyalt négyzetek jelzik

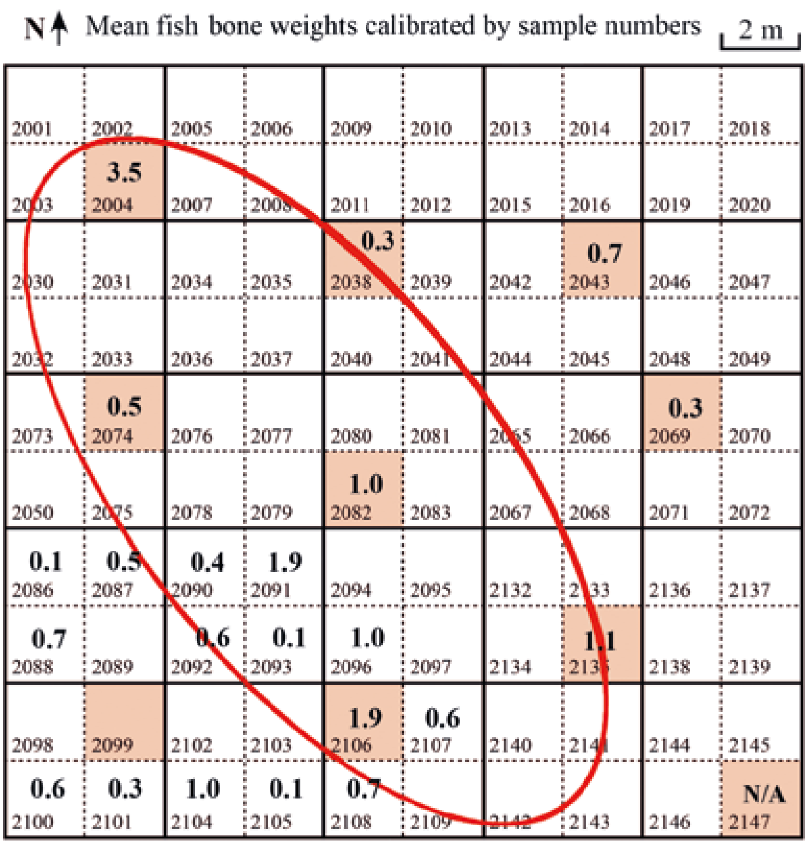


**Fig. 11.** Mean fish bone weights (g/10 litre) calibrated by the number of samples

**11. kép.** A halcsontok átlagos súlya (g/10 l) a minták számával egységesítve

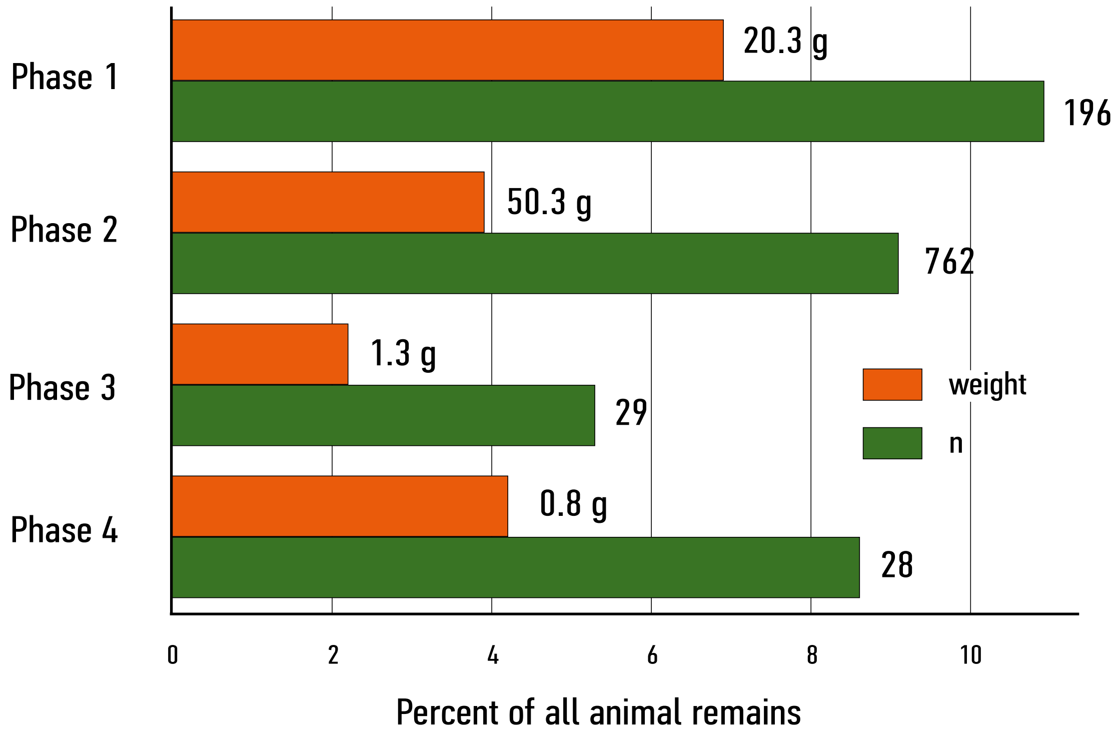


**Fig. 12.** The percentage of fish bones within the total weight and number of animal remains by phase
**12. kép.** A halcsontok százalékos aránya az összes állatmaradvány súlyán belül az egyes korszakokban

2004, 2082 and 2016 that convincingly fell above the trend line in Fig. 9.[30] Together with column samples 2135, these units outline a major concentration of relative fish bone weights (W > 5 %) in a diagonal area circled in Fig. 10. These high values were found in the proximity but outside of houses (columns 2004, 2082, and 2135). However, samples 2091, 2096, 2103, 2106, and 2108 lay in the street, even if the route of the street shifted over time.

Percentage values are relative and may thus be misleading. For example, two fishbones and non-piscine bone would yield a very high percentage. Therefore, it was of interest to see the absolute weight of fishbones/per volume of soil (the number of remains would have been more biased by fragmentation). To review the spatial distribution in absolute terms, mean fish bone weights (g/10 litre), i.e. calibrated by the number of samples in each 2 by 2 m square, were plotted in (Fig. 11). This form of presentation has the potential to show whether the areas displaying relatively high percentages of fish remains are indeed richer in fish bones. In Fig. 11, the highest concentrations of fish bone weights (W > 1 g/10 litre) are largely concentrated within the same ellipse, drafted on the basis of fish bone percentages relative to the weight of all animal remains. This pattern confirms not only the results shown in Fig. 10, but also supports the hypothesis that most fish were processed and/or consumed outdoors, that is the street area.

**Revisiting stratigraphy.** Although at this stage of research at the site far-reaching conclusions regarding diachronic trends are still beyond reach, the relative representation of fish in the previously discussed comprehensive phases identified so far is worth considering. Aside from Phase 1 (abandonment phase, Levels 1–6) and Phase 2 (Middle Bronze Age houses and street), earlier Bronze Age phases (3 and 4) are not yet sufficiently representative to allow drawing conclusions in

30 N.B. Figure 9 shows absolute weights, while Figure 10 the percentage of fish bone weights.

| | Fish | Non-piscine | Total | Fish % |
|---|---|---|---|---|
| Phase 1 | 196 | 1607 | 1803 | 10.8 |
| Phase 2 | 762 | 7587 | 8349 | 9.1 |
| Phase2/Phase 1 | 3.89 | 4.72 | 4.62 | |
| **Total** | **958** | **9192** | **10150** | |

**Table 7.** Specimen numbers and percentages of fish remains by phase
**7. táblázat.** A halmaradványok darabszáma és százalékos aránya korszakok szerint

| Parameter | Fish | | Non-piscine | |
|---|---|---|---|---|
| | Phase 1 | Phase 2 | Phase 1 | Phase 2 |
| Number of specimens | 196 | 762 | 1607 | 7586 |
| Minimum weight, g | 0.001 | 0.001 | 0.011 | 0.001 |
| Maximum weight, g | 0.796 | 0.799 | 18.439 | 28.118 |
| Mean weight, g | 0.104 | 0.066 | 0.170 | 0.148 |
| Median weight, g | 0.053 | 0.062 | 0.074 | 0.083 |
| Standard deviation, g | 0.191 | 0.052 | 0.580 | 0.593 |
| Skewness | 3.225 | 7.287 | 22.390 | 29.985 |
| Difference, g | 0.038 | | 0.021 | |
| t-value | 4.814 | | 1.302 | |
| P-value | 0.000 | | 0.193 | |

**Table 8.** Student's t-tests comparing specimen weights between Phases 1 and 2
**8. táblázat.** Az 1. és 2. korszak átlagos csontsúlyainak összehasonlítása Student-féle t-próbával

themselves. They are orders of magnitude smaller than the material available from Phases 1 and 2.

Even within Phase 2, the best represented Level 7 (even including Levels 7/8 and uncertain Level 7–14 stratigraphies) would have resulted in only 2939 bone specimens from the heavy fractions to study as a coherent unit. In addition, the spatial distribution of these finds covered only part of the designated column samples. Therefore, using the data at our disposal, Level 7 cannot yet be studied separately.

Fig. 12 shows the relative contribution of fish bones to all animal remains both by weight and specimen numbers based on heavy fraction samples. The two best represented phases could be compared in terms of their gross composition of fish versus other, non-piscine animal remains as summarized in Table 7. As shown before, these two phases yielded most of the entire material (n = 11,026) from the heavy fraction samples retrieved to date. A test of homogeneity performed on these data indicated that, thanks to the large sub-assemblage sizes, the relatively small difference in the contribution of fish bones by number was statistically significant ($Chi^2 = 11.797$, df = 1, P = 0.000). However, testing the association between the presence of fish and phasing resulted in a low value (Phi = 0.034). Phi is to be interpreted as a Pearson coefficient of correlation,[31] therefore this result shows practically no relationship between phasing and the contribution of fish bones measured in specimen numbers.[32]

Bone weights of the two gross taxonomic groups, fish vs. non-piscine remains, were also compared between the two phases. It is understood that fragment size is the result of a complex of processes but it may still be regarded as a proxy for bone preservation, as fragmentation is an important aspect of the taphonomic process. This is even more so in the case of finds originating from the heavy fraction, in which many of the specimens originate from the *post-mortem* attrition

31 Welkowitz et al. 1971, 240.
32 Williams 1979, 128.

of the animal remains. Table 8 shows the results of Student's t-tests comparing specimen weights between Phases 1 and 2, respectively, in the two groups of animal remains.

The differences between the phases, in almost all parameters, reflect the fact that the number of specimens available from Phase 2 was ca 4.5 times larger (cf. Table 7). While, according to Table 8, the mean weight of fish remains was significantly larger in Phase 1, no significant difference was found between Phase 1 and 2 in terms of the mean weight of non-piscine remains. This is probably due to the far broader weight diversity of the latter, taxonomically heterogeneous group discussed in relation to the zoological characteristics of the material (Table 3, Fig. 8).

## Discussion

Due to the complex formation processes of tell settlements, resulting in a high degree of fragmentation, the impact of sieving on the representation of animals was immediately recognizable.[33] The study of heavy fraction samples left after flotation helped further refining the picture. The analysis of fish remains recovered from systematically collected samples offers an opportunity to review how information retrieved from the heavy fraction after flotation may help archaeological interpretation. The strengths and weaknesses of using this type of material have been revealed by the results.

### Fragmentation and identification

The size and information content of any bone fragment is determined by an interplay between the taxonomic and anatomical properties of the animal and site specific taphonomic conditions.[34] In the first group of factors, the size and taxonomic affiliation of the animal is a key determinant. In contrast to birds, which evolved to have fewer but more compact skeletal elements to make it easier to fly, fish enjoy static support by water. Thus, they have far more differentiated skeletons, partly composed of structurally weaker, lamellar bones.

Except for tooth enamel, the raw material of bones is identical from a chemical point of view; bone mineral content consists of hydroxyapatite up to 50% by volume and 70% by weight. Following death, however, the organic content of bone as well as the micro- and macrostructure of various skeletal elements all interact with fragmentation.

There is a tendency of large skeletal elements producing relatively smaller fragments.[35] The smaller the resulting bone specimen, the greater its relative surface, increasingly exposing it to destructive chemical agents in the deposit. Moreover, interspecific and age-related variation in the density[36] and fat content also influence bone preservation, most specifically in fish.[37]

In addition to the properties related to animal size and specific skeletal features, a host of taphonomic factors determine the degree of fragmentation, preservation and thereby the levels of possible taxonomic and anatomical identification.[38] The taphonomic process includes all *post-mortem* changes that affect the animal's body, ultimately reducing it to the fragmented and commingled find material prone to both pre- and post-depositional destruction whose quantification deserves attention.[39] In spatial comparisons the effects of discard patterns and trampling would be of particular interest. Unfortunately, this type of modification has traditionally been studied only from a qualitative point of view, with a strong emphasis on distinguishing between microscopic damage caused by trampling versus marks of incipient manufacturing.[40] In the case of intensively inhabited tell settlements such as Százhalombatta, multiple re-depositions further reduce fragment size.

Fig. 13 shows the relationships between the factors influencing the intensity of fragmentation, illustrating the joint effect of animal size and related skele-

33 Stig Sørensen et al. 2020, 14.
34 Nicholson 1996.
35 Binford–Bertram 1977, 125.
36 Butler–Chatters 1994; Symmons 2002.
37 Prummel 1986; Mézes–Bartosiewicz 1994.
38 Goffette 2020, 123.
39 Marean 1991.
40 Behrensmeyer et al. 1986; Domínguez-Rodrigo et al. 2009.

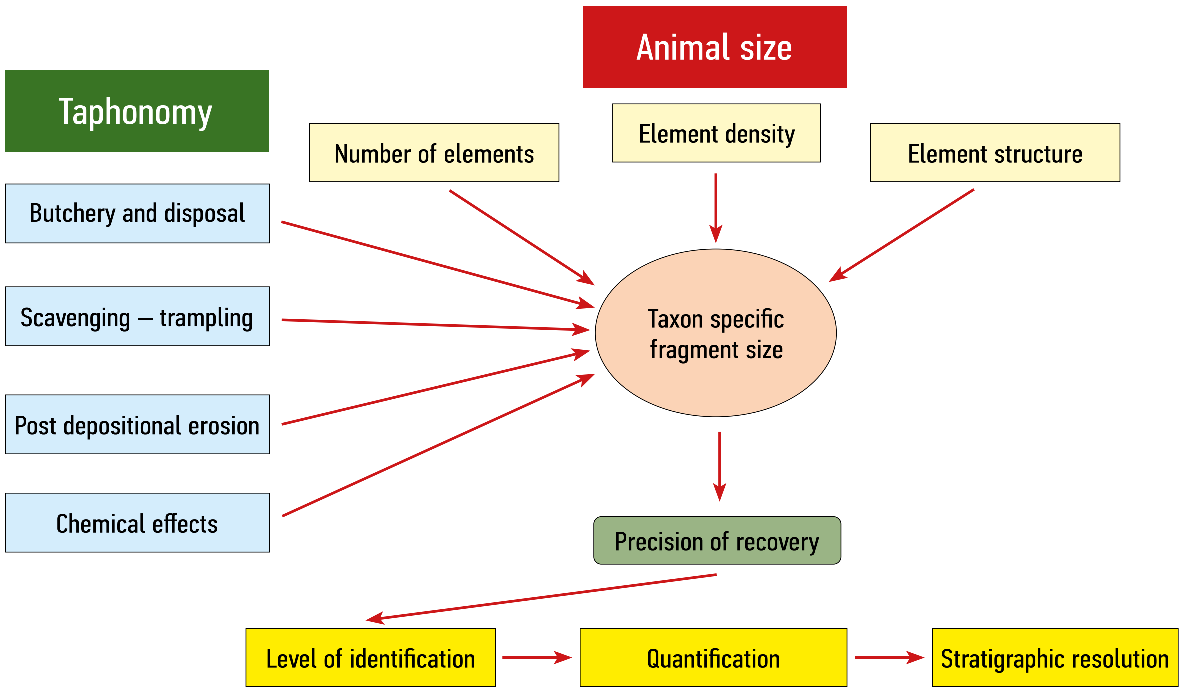


**Fig. 13.** The effect of animal size and major taphonomic factors on fragment size
**13. kép.** Az egyes állatok testméretének és különböző tafonómiai faktoroknak a hatása a csonttöredezettség mértékére

tal properties on fragment size in light of the major taphonomic factors to be reckoned with.

The narrow, original definition of the taphonomic process ("the transition … of animal remains from the biosphere into the lithosphere"[41]) focuses on how the remains of organisms change after death and prior to recovery by the paleontologist. However, from the viewpoint of information loss, it is worth explicitly considering both site formation and the contemporary recovery process, both of which influence. Our findings clearly illustrate the observation by Thomas (1969) who directed attention to potential biases related to mesh size in addition to the selective effect of site specific taphonomic processes. Thus, in addition to the previously discussed, classical taphonomic factors, the precision of recovery is the last filter determining the level of identification, quantification and the stratigraphic resolution of the assemblage.

## Quantification

Most studies of primary (i.e. non-heavy fraction) sieving/screening emphasize the increasing quantity of fish bones recovered with the use of finer mesh sizes.[42] Although sampling parameters are not detailed in all publications to help direct comparisons, the general trend is clear. An experiment on fish remains showed a 58-fold increase in the number of fish remains when screening at 1/4" (6.35 mm, n=224) was enhanced using a 1/8" mesh (3.175 mm, n = 12,893).[43] A 3 mm mesh was also instrumental in the recovery of small bird remains.[44]

The previously studied Middle Bronze Age material from Százhalombatta (dry sieved through a 15 mm

41 Efremov 1940, 85.
42 Casteel 1972; Wheeler–Jones 1989; Stahl 1996; Enghoff et al. 2007; Olson 2008; Boethius 2018; Gusick et al. 2018.
43 Peres 2001, Table 4.1.
44 Roberts et al. 2020, 73; Gál 2020.

mesh) yielded 89 302 non-piscine specimens[45] and a total of 533 fish bones,[46] the latter corresponding to 0.6 % of all animal remains. In comparison, the heavy fraction under discussion here (retrieved using 0.3 mm mesh size) contained 10 011 non-piscine specimens and 1015 fish bones amounting to 9.2 %. This corresponds to a 15-fold increase in the percentage of fish remains when the bulk material is compared to the heavy fraction at the Százhalombatta tell.

Many of the previously cited works discussing the beneficial effects of sieving on fish bone recovery mention the resulting higher species diversity. Given the positive correlation between assemblage size and the abundance of species recovered, methods of fine recovery are indeed significant in better appraising taxonomic diversity in archaeological samples.[47] The previous study of fish remains from Százhalombatta has shown a close (r=0.792) exponential relationship between the number of identifiable specimens and the number of fish taxa represented in the assemblage,[48] indicative of a degressive trend in the increase of taxa as a function of the number of specimens. Statistical parameters of this trend were comparable with those obtained for micromammals,[49] since the relationship between specimen numbers and taxonomic diversity is influenced by skeletal morphology and body size, which vary both between and within vertebrate classes.[50]

In the Bronze Age layers of Tel Dor, Israel, the contents of hand-collected and water-sieved samples differed significantly, the latter having yielded significantly higher ($Chi^2 = 435.3$. df = 9. $P \leq 0.001$) percentages of fish and microvertebrate remains. However, quantities of non-identifiable small fragments were also recovered that could only be classified by size as belonging to "large" or "medium" size mammals.[51] Such bones reduce taxonomic and anatomical resolution of zoological identifications, an effect clearly visible in our current findings. Among the 533 fish remains found in the dry-sieved bulk material from Százhalombatta, 415 (77.9 %) were identifiable representing 16 taxa.[52] While the heavy fraction under discussion here contained twice the number (1015) of fish bones, only 89 (8.4 %) of these were identifiable due to the small size of fragments recovered. Consequently, only seven taxa (less than half) were recognizable in the heavy fraction sample, in spite of the high number of fish specimens recovered.

## Stratigraphic resolution

The carefully designed sampling strategy and systematic water-sieving at the Százhalombatta tell yielded heavy fraction material whose vertical and horizontal distributions were easy to analyze. Unfortunately, the strong dominance of a single phase (Phase 2) precluded statistically reliable comparisons with the less well-represented other finds. This situation will improve in the future with the better-balanced presence of at least three phases across the area excavated. Once earlier layers of the stratigraphy can be included in the column samples, chronological resolution will improve, revealing possible evidence of diachronic differences. This will have the potential to illustrate comprehensive (longer-term) change.

At this point of research, the horizontal analysis of animal remains retrieved from heavy fraction samples has already been instrumental in delineating areas of activity that coincide with independent field observation concerning settlement structure. During previous research,[53] the site plans of Levels 8 and 10 already seem to have indicated that several squares where fish bone came to light tended to be located outside houses and coincided with the area of a diagonal (NW–SE) street between buildings within the area excavated. It became possible to confirm this observation by high-resolution analyses of the finds identified in heavy fraction samples.

45 Vretemark–Sten 2020, 19, Table 1.
46 Bartosiewicz 2020, 99.
47 Serjeantson 2001; Zohar–Belmaker 2005; Baker 2010.
48 Bartosiewicz 2020, 100–101.
49 Bartosiewicz et al. 2013, 857, Table 1.
50 Bartosiewicz–Gál 2007.
51 Bartosiewicz et al. 2018, 313.
52 Bartosiewicz 2020, 99.
53 Bartosiewicz 2020, 100, Fig. 80.

## Conclusions

The archaeozoological analysis of the selected heavy fraction samples from the Százhalombatta tell yielded over ten thousand animal remains representing a size range seldom accessible for detailed study. However, many of these remains were heavily fragmented, making even family level identification challenging. While such materials are ill-suited for the reconstruction of taxonomic diversity in the alluvial habitat or subsistence patterns, these bones showed spatial patterning indicative of trampling and the possible cleaning of indoor spaces. The evidence of such "daily events" is important in determining activity areas and linking them to potential household activities such as refuse management. These topics are of special interest at the tell settlement of Százhalombatta.[54] Various fish species can be landed with greatest probability during their variable, species-dependent spawning seasons determined depending on the dissolved oxygen content of water determined by water temperature and the velocity of the currents. Fish remains in archaeological samples may thus serve as a proxy in the study of seasonality in spatially recognizable archaeological phenomena observed at the site. Although the number of identifiable fish remains was relatively small in the heavy fraction currently under study (Fig. 14), they reflect the trend established based on fish remains recovered from the bulk material. Even if the overall contribution of fish to the diet appers to have been small, opportunistic fishing must have been concentrated to the spring and summer months. This seems to have coincided with the outdoor consumption of fish, as confirmed by the spatial distribution of even non-identifiable fish bones recovered from the heavy fraction. At the tell settlement of Százhalombatta-Földvár, fish was far from being part of the subsistence base. It served rather as a qualitative, possibly seasonal complement to the MBA protein diet.

## Acknowledgements

Funding for this project (2020–2023) was provided by the Cambridge-Stockholm Collaborative Research Grants Scheme established between the universities of Cambridge and Stockholm. Grateful thanks are due to László Schilling, who provided workspace and equipment for the analysis of animal remains at the National Institute of Archaeology of the Hungarian National Museum.

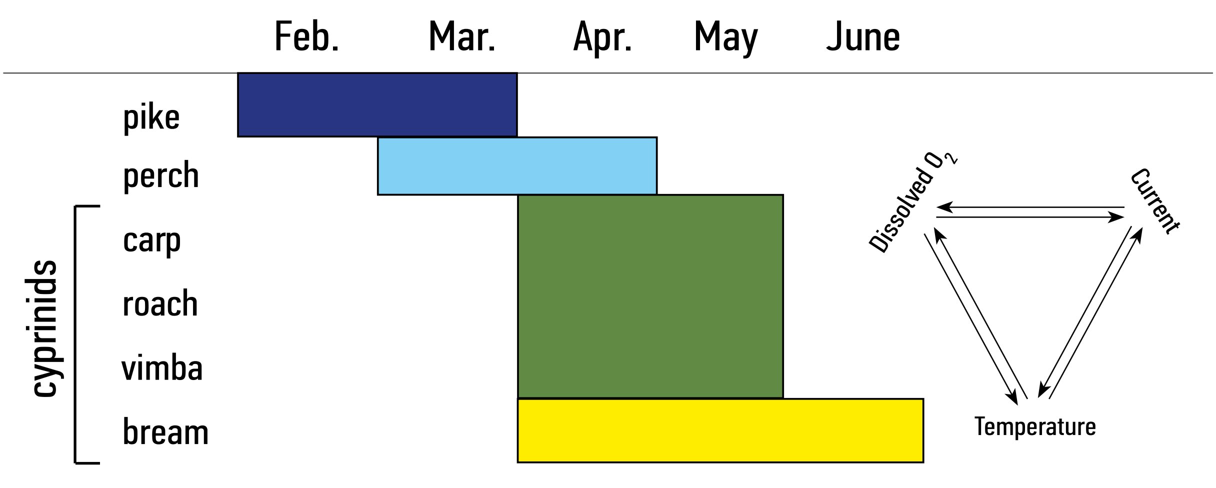


**Fig. 14.** The spawning calendar of fish species identified in the heavy fraction samples indicating the greatest probabilities of landing
**14. kép.** A nehézfrakcióban meghatározott halfajok "ívási naptára" azokat a hónapokat jelzi, amikor az egyes fajok a legnagyobb valószínűséggel foghatók

54 Vicze 2013.

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## Százhalombatta-Földvár bronzkori halmaradványainak nagy felbontású vizsgálata

Magyarországon, a Duna-parti Százhalombatta-Földvár egykori tell település területének ásatása 1998 óta a helyi Matrica Múzeum által kezdeményezett nemzetközi tudományos együttműködések tárgya (ID 11473). Ezeknek a munkálatoknak jelenleg a Magyar Nemzeti Múzeum ad otthont. A hazai régészek ezeket a feltárásokat kezdettől fogva többek között az Egyesült Királyságból és Svédországból érkezett vendégkutatókkal együttműködve végzik.

A vizsgált lelőhely egy többrétegű, kora és középső bronzkori tell település. Ez körülbelül 200 × 100 méteres területen fekszik, és több mint öt méter vastagságú rétegsorral rendelkező régészeti lelőhelyet foglal magában. Rétegsora a bronzkori nagyrévi és a vatyai kultúrát reprezentálja, beleértve a legvégső középső bronzkori koszideri fázist is.

A százhalombattai ásatáson 1998-tól fogva a legmodernebb feltárási módszereket alkalmazzuk, beleértve a rendszeres száraz rostálást és flotációt. Ezek az eljárások jelentős mennyiségű környezetrégészeti és kulturális jelentőségű régészeti leletet eredményeztek. A kiterjedt leletcsoportok értékelése azonban óriási kihívást jelent, hiszen nem minden darab határozható meg és elemezhető a terepi ásatási évadok szűkös időkeretein belül.

A felgyülemlett anyag által előidézett helyzet enyhítésére sikeres kutatási együttműködést hoztunk létre a cambridge-i (Egyesült Királyság) és a stockholmi (Svédország) egyetem között azzal a céllal, hogy felmérjük a módszer, azaz a flotáció hatását az állatmaradványok (elsősorban a halcsontok) feltárására a flotációs maradék, az úgynevezett nehéz frakció alapján. A nemzetközi projekt keretében a következő kutatási kérdésekre kerestünk választ:

- Hogyan jelennek meg a különböző gerinces állatok maradványai a flotálás után visszamaradt nehéz frakcióban?
- Mekkora a rendszertanilag meghatározható állatmaradványok aránya az így vizsgált mintákban?
- Vannak-e statisztikailag kimutatható szignifikáns mintázatok az így előkerült állatmaradványok rétegtani és térbeli eloszlásában?
- Hogyan viszonyulnak a nehéz frakcióból kinyert halmaradványok a kézi gyűjtésből és száraz rostálásból származó halmaradványokhoz mennyiségükben és rendszertani összetételükben?

A százhalombattai tell leletanyagából kiválasztott nehézfrakció-minták régészeti állattani vizsgálata során több mint tízezer állatmaradvány feldolgozását kellett elvégezni. Ezek olyan mérettartományt képviselnek, amely iszapolás híján részletes vizsgálatok céljára hozzáférhetetlen. Azonban az ezzel a módszerrel kinyert csont- és fogleletek közül sok erősen töredezett volt, ami gyakran még a rendszertani család azonosításában is komoly kihívást jelentett, az ennél pontosabb állattani meghatározás súlyos nehézségeiről nem is beszélve.

Míg az ilyen finomságú leletanyagok természetüknél fogva alkalmatlanok az alluviális élőhelyek taxonómiai sokféleségének vagy az őskori megélhetésmódok rekonstruálására, az itt vizsgált csonttöredékek a taposásra, a bel- és a kültéri terek lehetséges tisztítására utaló térbeli mintázatot mutattak. Az ilyen „napi események" bizonyítékai fontosak a tevékenységi területek meghatározásában és az olyan háztartási tevékenységekkel való összekapcsolásukban, mint a főzés, étkezés vagy napi szemétkezelés. Ezek a témák különösen érdekesek a százhalombattai településen.

Továbbá, mivel a különböző halak kifogásának esélye – a fajonként változó – ívási időszakokban a legnagyobb, a nehéz frakció mintáiban található halmaradványok a helyszínen megfigyelhető, térben felismerhető régészeti jelenségek szezonalitásának vizsgálatát is segíthetik. Az itt bemutatott számítások arra utalnak, hogy az ilyen finomságú feltárás nehezebben meghatározható, de mennyiségi szempontból jobban értékelhető, nagyobb mennyiségű adattal szolgál. Emiatt a korabeli halfauna változatosságának értékelésére kevésbé alkalmas, ám hasznos a halfeldolgozás és -fogyasztás térbeli szabályszerűségeinek körvonalazásában, más szóval az itt élő közösség mindennapjainak jobb megismerésében.

Noha az itt vizsgált nehéz frakcióban a pontosan meghatározható halmaradványok száma viszonylag kicsi, eredményeink a teljes anyagból kinyert halmaradványok alapján korábban megállapított tendenciát tükrözik. A százhalombatta-földvári településen a halászat korántsem tartozott a megélhetés alapját képező tevékenységek közé. Inkább a középső bronzkori állatifehérje-ellátás minőségi, esetleg szezonális kiegészítéseként szolgált. Ha a halak étrendben betöltött szerepe csekély volt is, az alkalomszerű halászat minden bizonnyal a tavaszi és nyári hónapokban volt a legintenzívebb. Ez a jelek szerint egybeesett a halak kültéri fogyasztásával, amit a nehéz frakcióból itt kinyert, rendszertanilag nem azonosítható halcsontok térbeli eloszlása is megerősít.