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Counting Sheep Without Falling Asleep: Using Gis to Calculate the Minimum Number of Skeletal Elements (Mne) And Other Archaeozoological Measures At Schöningen 13Ii-4 'Spear Horizon'

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Abstract

In this paper, we describe a GIS-based methodology for estimating the minimum number of skeletal elements (MNE) and other archaeozoological measures, such as cut mark distribution and density. As a case study, we present a preliminary application to the Middle Pleistocene site of Schöningen 13II-4, the so-called "Spear Horizon", where a large and exceptionally preserved faunal assemblage imposes difficulties for quantifying skeletal element abundances. We base our methodology on a series of digital templates introduced in a GIS, where each identifiable bone specimen is drawn and the number of overlapping bone fragments is calculated. This methodology yields a direct and accurate calculation of MNE and provides a foundation for assessing other critical archaeozoological measures. Analysis and interpretation of these measures is essential for understanding Palaeolithic subsistence strategies and hominin behaviour.

Keywords*:* GIS, Archaeozoology, Schöningen, Middle Pleistocene.

Introduction

In the last decades, the application of Geographical Information Systems (GIS) and computing has led to great developments in Spatial and Landscape Archaeology, Heritage Management, predictive modelling and Virtual Archaeology. Today, GIS capacities allow for an even wider range of applications in Archaeology (Scianna & Villa, 2011). The combination of database management and image or vector entities representation makes GIS a useful tool for documentation and management of archaeological collections over a variety of scales. The multi-scalar capacities of GIS make possible its application to different types of analysis, from continent-wide to regional, local and intra-site comparisons, and even the study of single artefacts.

In this paper, we present a methodology for analysing individual bones and bone fragments in a quantitative and automatic way. The aim of such analysis is to calculate the minimum number of skeletal elements (MNE), defined as 'the minimum number of skeletal portions necessary to account for the specimens representing that portion' (Lyman, 1994:102). The calculation of MNE is important as it forms the basis of more complicated measures of abundance, such as minimum number of individuals. Together, these measures estimate the number of animals or portions of animals present at a site and provide one piece of evidence to interpret the taphonomic histories of faunal assemblages and associated human behaviours. One downfall is that the calculation of MNE is often difficult and time consuming when dealing with large assemblages. Using GIS, these calculations can be made quicker and more precise through a batch process. In addition to measuring skeletal part abundance, this methodology forms a basis for other analyses, including the location and density of bones surface modifications (cut marks, percussion marks, carnivore damage, etc.). As a case study, we applied this methodology to the Middle Pleistocene faunal accumulation from Schöningen 13II-4. However, the methodology explained here can be applied to any faunal assemblage, regardless of chronology and context.

2. Materials and methods

2.1. Case study: the Middle Pleistocene Schöningen 13II-4 'Spear Horizon'

Schöningen, located in Lower Saxony, Germany, is considered one of the most significant Palaeolithic sites from Central Europe owing to the discovery well-preserved wooden spears in association with a large assemblage of Middle Pleistocene fauna (Fig. 1). Open-cast lignite mining works led to the discovery of numerous archaeological sites within several erosional 'channels' indicating a paleolake environment. The discovery in 1995 of a series of wooden spears, considered the oldest known spears in the world (Thieme, 1997), drove worldwide attention to the so called 'Spear Horizon'. This horizon was originally dated to around 400 kaBP (Richter & Thieme, 2012), although recent U/Th dating resulted in an age of 290±5 kaBP (Sierralta, Frechen & Urban, 2012). This date places level 13II-4 with Marine Isotope Stage 9, which is consistent with biostratigraphic and environmental data (Urban & Sierralta, 2012). Excavations of the 'Spear Horizon', which continued until 2007, extended over an area of ca. 3.900 m^2 and yielded roughly 15.000 archaeological remains (Serangeli *et al.*, 2012), including a large, exceptionally preserved faunal assemblage (van Kolfschoten, 2014; Voormolen, 2008).

As part of a research theme regarding hominin adaptations to interglacial environments, ongoing archaeozoological studies conducted by the MONREPOS Archaeological Research Centre and Museum for Human Behavioural Evolution, show that the Schoningen 13II-4 faunal assemblage is overwhelmingly dominated by horse (*Equus mosbachensis*). Other ungulates, such as aurochs (*Bos primigenius*), bison (*Bison priscus*), red deer (*Cervus elaphus*), giant deer (*Megaloceros giganteus*), roe deer (*Capreolus capreolus*) and rhinoceros (*Stephanorhinus* sp.), are also present in addition to carnivores, small mammals, birds and fishes, suggesting a mosaic interglacial environment around the lakeshore site. The composition and taphonomical analysis of the faunal assemblage suggest an *in-situ*, intensive exploitation of carcasses by hominin groups, probably during several hunting episodes, followed by secondary scavenging by medium-sized carnivores.

While the exceptional preservation of faunal remains allows for extensive, high-resolution archaeozoological analyses, the thousands of identifiable bones impose difficulties for quantification. This is especially true when estimating MNE, where all bone fragments from the same skeletal element must be considered and compared to each other. For that reason, Schöningen 13II-4 is an excellent site to test and develop a GIS-based methodology for estimating archaeozoological measures, such as MNE.

2.2. Methodology: MNE calculation using GIS

The method presented in this paper is based on the previous work by Marean and colleagues (Marean *et al.*, 2001; Abe *et al.*, 2002) who first presented the possibility of using a GIS to estimate MNE using an image analysis approach using digital templates. This method proved to be very useful, but difficult to implement due to limitations in GIS software since it required extensive preparation of bone templates and GIS processing. For that reason, we decided to develop a new method by taking advantage of the newest software and tools in order to simplify the calculations. In a basic sense, this method is based on counting how many times cells with the same value overlap within a series of rasters.

As part of the documentation and archaeozoological analysis of the Schöningen 13II-4 faunal assemblage, every identifiable bone or bone fragment was drawn in a digital template. These templates include multiple views (lateral, medial, cranial, caudal, etc.) of every bone (e.g., right and left femur or mandible) for all species represented in the faunal assemblage. We used simple line drawings of each bone that include all major anatomical features for orientation. Our templates were previously created just for reference purposes, but were perfectly suited to our GIS analysis. One advantage of this new methodology is that any templates can be used; scanned images from an anatomical atlas, hand drawings, photographs, etc., can be adapted to accommodate the needs of any archaeozoological analysis. The level of template preparation is up to the user, but the only requirement is that the templates remain unchanged throughout the entire process. Templates were used as a base outline where bone fragments were drawn in their corresponding location within that skeletal element. Using a digitalizing pad and image processing software (Adobe Photoshop CS4 Extended), bone fragments were directly drawn on the blank templates (Fig. 2), using identifiable anatomical features to locate, orient and scale bone fragments and fit them to templates. The resulting drawings were recorded as a .jpg image file, using the bone's ID number as the file name. That way, an image dataset of bones and bone fragments was created, which not only documents the faunal remains, but also can be integrated directly into a GIS as a raster layer. During the drawing process, special care was taken to represent the bone or bone fragment as accurately as possible. Scaling the background template image with the zoom feature to approximate the size of the bone was helpful to create accurate drawings. The ruler or grid feature included in many graphics programs further aids in drawing bone fragments accurately. Additionally, bone modifications, such as cut marks, percussion notches, carnivore damage, etc., were also drawn. A predefined colour scheme was used in order to ensure that the same colour (defined by Red-Green-Blue values) was used for the same kinds of modifications. Image size and resolution were fixed for

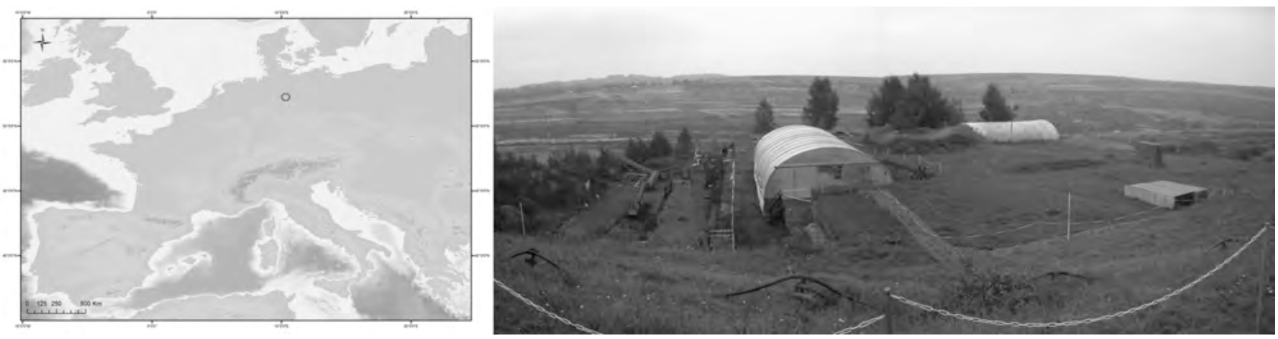

Figure 1: Location of Schöningen, and view of the 13II-4 site.

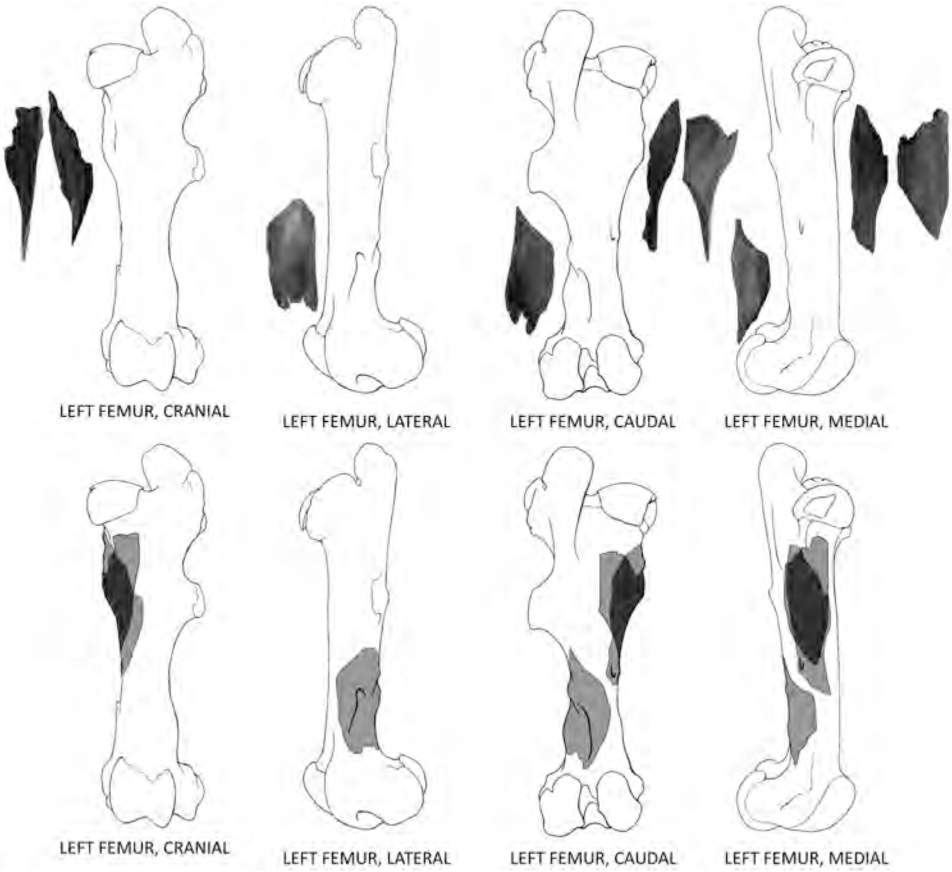

Figure 2: Example of three left femur fragments drawn onto a template. For illustrative purposes, each bone was photographed in several views relative to the template (top). Each bone was drawn onto individual templates and later combined into a single template (bottom). The darker shading represents areas of overlap between the fragments.

each template so that all raster layers included the same extension once introduced in a GIS.

Once bone fragments were drawn, image files were incorporated in a GIS as raster layers. With the fixed colour scheme, every cell corresponding to 'bone' had the same value in all rasters in the dataset, different from any other cells representing blank spaces or bone outlines. Similarly, cells corresponding to bone surface modifications, such as cut marks, had the same value in all rasters. In other words, if a colour value of R: 180, G: 180, B: 180 was used for drawing bone fragments, all cells in the raster dataset corresponding to bone fragment had a value of 180.

As explained previously, MNE is estimated by counting the number of times bone fragments overlap within a faunal assemblage, considering every skeletal element and every species separately. That is, if any portion of two or more bones or bone fragments overlap, they cannot have originated from the same bone. Since all the raster layers corresponding to the same kind of template have the same extension, every cell in the raster shares the same position with another cell in a different raster. Considering that cells representing bone fragments have the same value, overlaps can be calculated easily by counting how many times cells with that value appear in every cell location.

In order to make that calculation, the Equal to Frequency tool from ArcGIS's Spatial Analyst extension was used. This tool 'evaluates on a cell-by-cell basis the number of times the values in a set of rasters are equal to another raster' [1] (Fig. 3). As an input layer, a raster with the same extension as the templates was created, where all cells had the same value as the cells corresponding to 'bone fragment' in the raster dataset.

The resulting raster layer shows how many times the value from the input layer appears in every cell position within the raster dataset. However, since templates have three colour bands (red, green and blue), the Equal to Frequency tool considers every raster three times (the searched value appears three times in every raster, one for every colour band). For that reason, the resulting raster layer must be divided by three (using the Raster Calculation tool). The final raster shows the number of times bone fragments from the template data set overlap (Fig. 4). Each cell records a maximum value that corresponds to the maximum number of times cells corresponding to bone fragments overlap, and therefore to MNE. To avoid negligible overlaps that could overestimate MNE, the raster histogram was checked, and highest values represented in very low frequency (just in a few cells) were ignored (Fig. 5). Ignoring the highest values could turn out in a less precise estimation, although the resulting MNE estimation will be more reliable, since the probability that the estimation is correct is higher when MNE value is lower and its frequency is higher.

[1] ArcGIS Help Library, 2010, access 01.07.2014.

2.3. Further developments

The method presented here can form the basis for calculating other archaeozoological measures. The use of a predefined colour scheme for drawing every bone modification is used to evaluate the location and frequency of each modification type within the raster dataset. However, with this method, templates' cells have a different value in every colour band, which impedes the use of the Equal to Frequency tool used to estimate the MNE. Due to this limitation, additional processing of drawings is required.

One solution is to reclassify, using a batch process, templates' cells values. In this case, values of cells corresponding to modifications, such as cut marks, are changed to '1', while the rest of the cells are given a value of '0'. Once all drawings have been reclassified, raster layers can be summed, using ArcGIS's Raster Calculator Addition function, which sums on a cell-by-cell basis the values of two or more rasters. The resulting raster layer shows the location of bone modifications for each bone, including any locations where modifications overlap (Fig. 6a). Once locations of bone modifications are known, further analyses can be undertaken, such as evaluating the spatial distribution of cut marks across each skeletal element. In this sense, a density analysis will show the areas where higher concentrations of modifications appear (Fig. 6b), allowing for more accurate and meaningful taphonomical analyses.

Despite the need of previous processing, this method makes possible deeper archaeozoological analysis using a single drawing for every bone fragment, instead of using different templates for every modification. Analysing the preferential locations of bone modifications allows for a better understanding of human behaviour, such as butchering techniques and exploitation of carcasses in the case of cut marks or percussion notches.

Discussion and conclusions

Estimating MNE and other zooarchaeological measures, such as cut mark frequency and location, is a rather complex and time consuming process. This is especially difficult when dealing with very large faunal assemblages where hundreds, or even thousands, of bone fragments must be compared. This is the case for the large and well-preserved faunal assemblage from the Middle Pleistocene site of Schöningen 13II-4.

In order to improve MNE estimation, a GIS-based method was developed and tested with the Schöningen 13II-4 faunal assemblage. This method was based on the use of

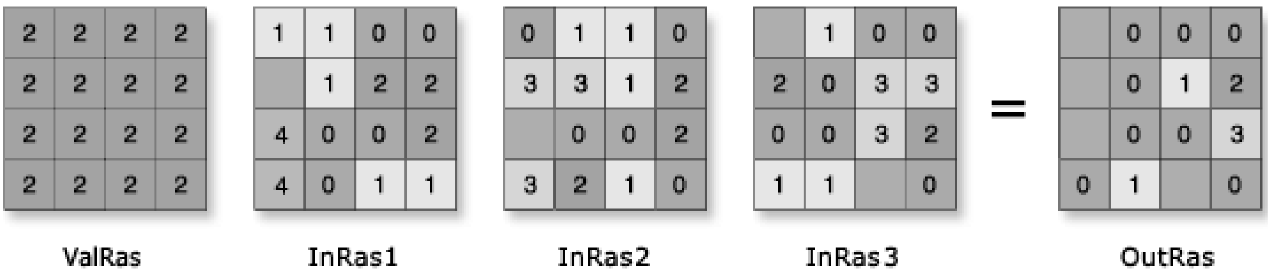

Figure 3: Schema of the Equal to Frequency tool calculation process (Image: ArcGIS Help 10.1).

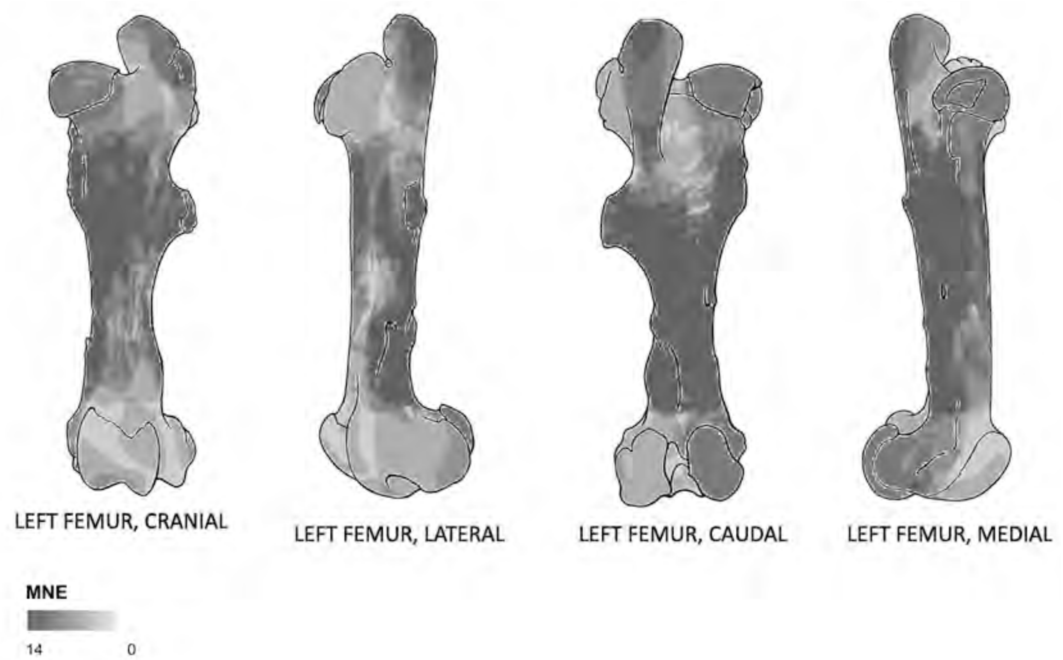

Figure 4: Raster layer showing the final number of bone fragments overlapping for Schöningen 13II-4 horse left femora.

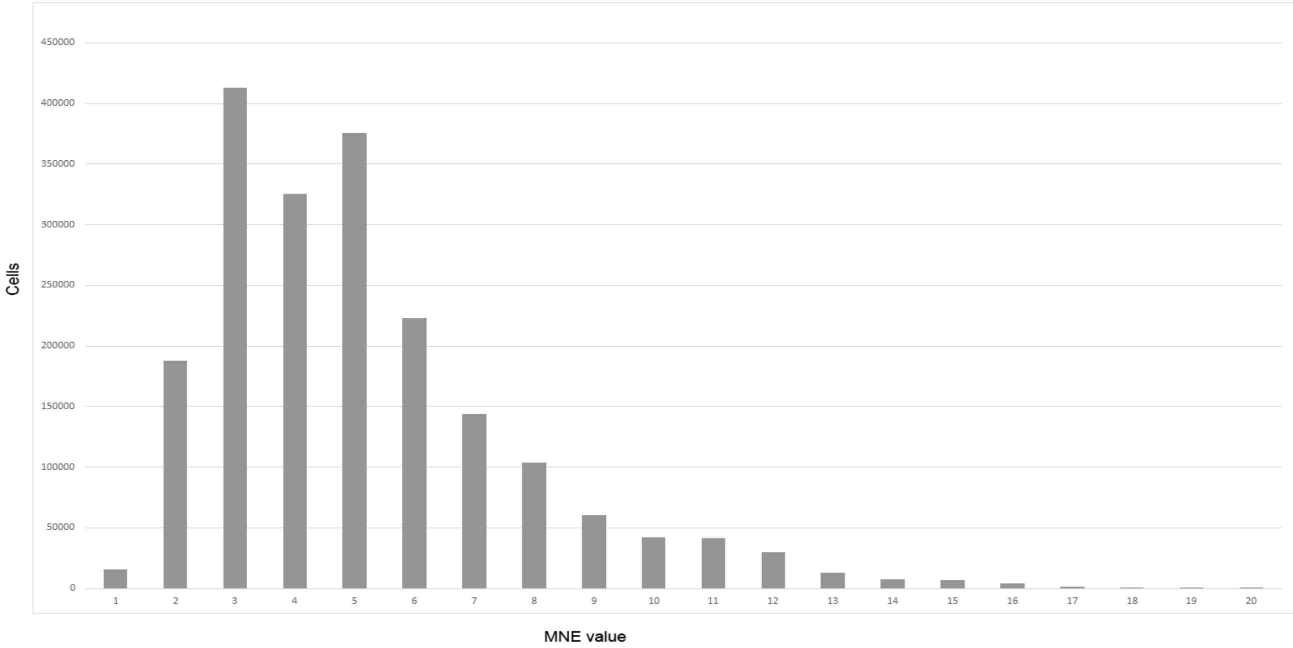

Figure 5: Raster's histogram, showing cells' value frequency. Negligible frequencies in higher values can be ignored, in order to obtain a more accurate MNE estimation.

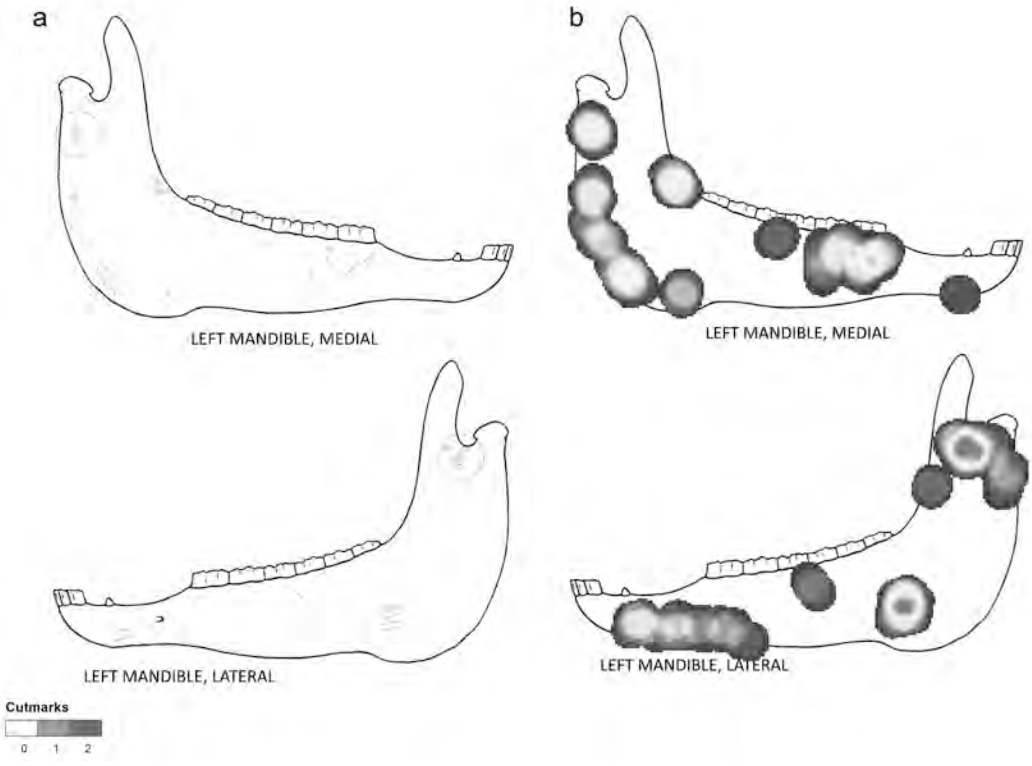

Figure 6: Raster's histogram, showing cells' value frequency. Negligible frequencies in higher values can be ignored, in order to obtain a more accurate MNE estimation.

templates, where bone fragments were drawn as part of the documentation process and the archaeological analysis. Those drawings were then introduced as raster layers in to a GIS, and the number of times cells corresponding to bone fragments overlap was calculated. Templates can also be used to evaluate bone modifications, analysing the distribution, concentration and density of alterations such as cut marks.

The application of GIS allows for the calculation of different archaeozoological measures in an easy, batch-like way using any digital template. The method presented here is not entirely automatic since it still requires a few calculations to obtain the final layer showing bone fragment overlaps. In addition, the evaluation of other archaeozoological measures, such as cut marks, needs previous processing of the templates. Despite some additional processing, the method presented here represents an improvement of traditional (manual), extremely time consuming methods and allows for more complex archaeozoological analyses of human subsistence strategies and behaviour. Further development of the methodology presented here could improve the level of automation for this procedure, for example creating a workflow model stringing together the sequence of steps and calculations required. The use of free software with similar capacities and tools as the ones used here would allow the application of this method to any archaeozoological analysis, regardless of the availability of funds. Advancing the method tested on the Schöningen 13II-4 assemblage will improve archaeozoological analyses and will allow for a better understanding of past human behaviour.

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