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Highlights

- New approach to understanding site formation processes through bone taphonomy.
- Statistical analysis of taphonomic data for reconstructing depositional histories.
- Especially useful for sites with thick deposits and obscured stratigraphy.
- Takes account of deposit composition and biasing effects on modification patterns.

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Reconstructing depositional histories through bone taphonomy: extending the potential of faunal data

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ABSTRACT

Reconstructing the sequences of deposition of archaeological material is central to the interpretation of archaeological sites and provides the foundations for how site chronology is understood. Generally stratigraphy provides the most direct evidence for understanding depositional histories. However, in certain instances stratigraphic relationships may be obscured or unobservable and therefore other sources of evidence must be drawn upon for defining deposits and reconstructing sequences of deposition. This is a particular problem at dark earth sites, which are homogeneous in terms of the colour and texture of deposits, and also in artefact-rich samples, which have little sedimentary matrix.

This paper explores the potential of a new approach to the analysis of bone taphonomic data for the purposes of deciphering depositional histories when stratigraphy is unobservable. Integral to this method is rigorous statistical analysis of modification data combined with an assessment of the taxonomic and anatomical composition of deposits, in terms of their susceptibility to modification. This facilitates more confident interpretation of modification patterns, as deposit composition can be discounted from responsibility for significant differences. The approach is tested on a sample area of the later prehistoric midden of Potterne, Wiltshire, UK. Through detailed recording and statistical analysis of bone modifications (weathering, gnawing and trampling), this research demonstrates that bone taphonomy is not only useful for identifying distinct depositional events in apparently homogeneous strata, but can also provide detail on the nature of processes responsible for the formation of the deposit.

1. Introduction

The study of taphonomic modification plays an increasingly important role in zooarchaeological research. It is now widely recognised as critical to the interpretation of faunal assemblages and deciphering problems of equifinality (e.g. Bartosiewicz, 2008; Behrensmeyer, 1993; Lyman, 2008: 264; Marean and Cleghorn, 2003; Outram, 2004: 181; Uerpmann, 1973). However, in spite of the recognition of the importance of taphonomic processes, it is rare that faunal data collection incorporates a comprehensive suite of taphonomic variables, especially outside of Palaeolithic zooarchaeology (exceptions include Atici, 2006; Bar-Oz and Adler, 2005; Bar-Oz and Munro, 2004; Bar-Oz et al., 2005; Gàl, 2008; Madgwick, 2008, 2010; Montalvo et al., 2008; Randall, 2010; Russell, 2010; Symmons, 2005a; Thompson, 2005; Verzi et al., 2008). When modifications are recorded, the resultant data is rarely fully exploited and is often confined to fleeting comments about preservation with little interpretation in terms of social practice. This is perhaps understandable, as taphonomic data is by its very nature concerned with poor preservation and destruction and therefore it is frequently incomplete, overprinted or ambiguous. However, these issues do not render taphonomic data obsolete. This paper argues that, through more rigorous statistical analysis of taphonomic data, new insights can be gained, not only concerning the treatment of animals and their remains but also wider social practices relating to the formation of archaeological sites.

This research involves a pilot study examining the potential of statistical analyses of taphonomic data for the purposes of reconstructing depositional histories at an artefact-rich site with no observable stratigraphy. These sites are relatively common throughout the world, with stratigraphy frequently obscured by dark earth matrices. Examples range from shell and bone middens in Brazil (e.g. Villagran et al., 2009) to urban areas in northern Europe (e.g. Devos et al., 2007, 2011; Vannieuwenhuyze et al., 2012). At such sites, excavation is frequently undertaken using arbitrary 'spits', vertical divisions usually of 5 or 10 cm in depth and 1 m/0.5 m squared in area to provide spatial control (e.g. Lawson,

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2000; Lodwick and Gwilt, 2005; Parker Pearson et al., n.d.). However, understanding of chronology, site formation and sequences of deposition is generally very limited. Therefore a new approach to reconstructing depositional histories when stratigraphy is absent is required to overcome these problems.

2. Bone taphonomy

Analyses of the taphonomy of faunal material have considerable potential for reconstructing depositional histories. Bones are resistant enough to degradation that they survive in abundance in the archaeological record (depending on the depositional environment), but are also soft and malleable to the degree that they can be altered by a range of processes, thereby taking an imprint of their taphonomic history. Far fewer processes are traceable on ceramics and lithics and the modifications which are analysed frequently have uncertain or varied aetiologies (e.g. fragmentation, abrasion).

The method presented in this paper focuses on perthotaxic processes, those which affect bone before it becomes incorporated into a deposit but after being discarded by humans (O'Connor, 2000: 20). Modifications resulting from these processes provide evidence for the sub-aerial exposure of bones and include weathering, gnawing, trampling, abrasion and mould staining. It is clear that these processes do not affect all skeletal elements to the same degree. A range of factors surrounding the structural properties of bone fragments have been cited as impacting on the prevalence of modifications including bone mineral density (see Dirrigl, 2001; Elkin, 1995; Ioannidou, 2003; Kooyman, 2001; Kreutzer, 1992; Lam et al., 1998; Lam and Pearson, 2004; Lyman 1984; Lyman et al., 1992; Pavao and Stahl, 1999; Symmons, 2005b, 2005c and others), element shape (Henderson, 1987; Lam and Pearson, 2004; Stiner, 2004) and fragment/element size (Conard et al., 2008). Whilst a useful starting point, these findings largely derive from actualistic studies conducted on modern material and do not take account of the effect of subterranean processes on modification signatures. Other studies rely on observations of small samples that are not empirically tested. Until now no large-scale analysis of archaeological material has been carried out to characterise which variables are most important in dictating modification and which classes of remains are most likely to be affected.

Only through understanding inherent susceptibilities of different classes of bones, can biases relating to the composition of samples be discounted from responsibility for variation in the prevalence and severity of modification. Once such biases are discounted, differences in bone modification can be confidently used to reconstruct depositional practice. Recent research by the authors has provided a more comprehensive understanding of the classes of remains that are most likely to be affected by modifications in a British context. This involved the multivariate statistical analysis of large samples of taphonomic data from zooarchaeological material, comprising c. [illegible]00 identifiable fragments from 11 sites (see Madgwick, 201[illegible] Madgwick and Mulville, 2012). Classification trees were used to identify which overarching variables have the greatest impact on modifications (e.g. element, taxon, site, fusion) and ordinal and binary logistic regression was employed to establish the categories of those variables (i.e. specific elements or taxa) that are most likely to be affected. Therefore patterns of modification relating to the inherent biases in the composition of a sample can be separated from those that are useful for reconstructing depositional histories.

In this paper, bias in the composition of a sample linked to increased modification is termed 'compositional susceptibility'. This oversimplifies what analysis is testing, as it is not strictly which bones are most *susceptible* to modification but rather which are most *likely* to exhibit modification in archaeological deposits. This is mediated by survival biases and the *taphonomic paradox* (see Madgwick and Mulville, 2012), whereby it is the robust fragments that survive degrading processes that in fact exhibit the greatest evidence of modification. Equipped with new data on biases affecting modification, this paper explores the potential of reconstructing depositional histories through statistical analysis of taphonomic data using a sample area of the midden site of Potterne as a case study.

3. Materials and methods

3.1. The sample area

This study is conducted on a 16 m^2 sample area of the Late Bronze Age/Early Iron Age midden site of Potterne, Wiltshire UK. This midden comprised thick, artefact-rich deposits but stratigraphy was unobservable due to the homogeneity of greensand derived soils and consequently site formation is poorly understood. The site represents a monumental accumulation of cultural debris, covering an area of c. 3.5 ha and having deposits up to 1.4 m thick (Lawson, 2000: 13). It is exceptionally artefact-rich and projections from the c. 1% excavated area indicate that the midden may comprise well in excess of 13 million bone fragments in total (see Locker, 2000). A vast ceramic assemblage was also recovered along with modest quantities of metalwork and worked stone. The vast

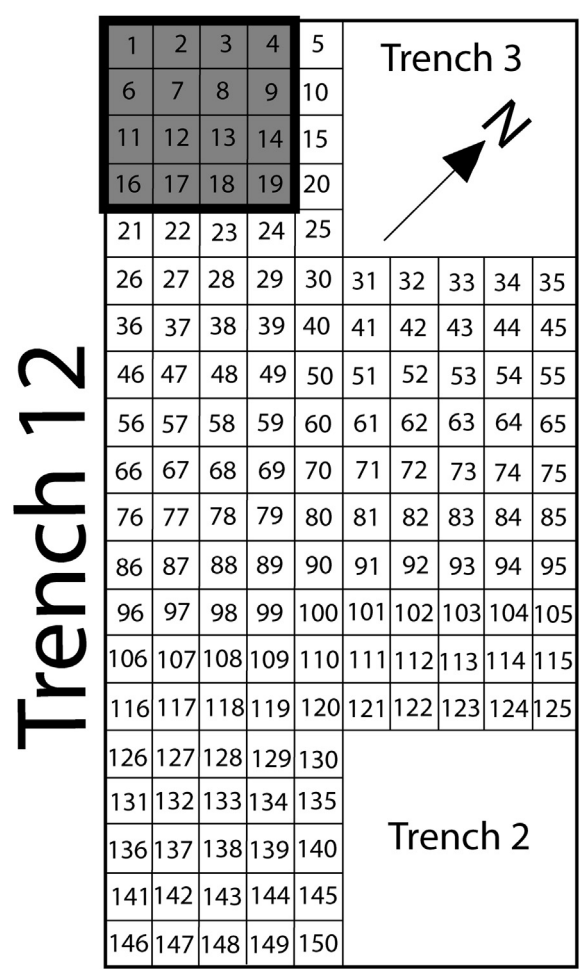

Fig. 1. Schematic diagram of trenches 2, 3 and 12, with the 16 m^2 sample area highlighted (adapted from the Potterne archive, produced by Andrew Lawson).

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accumulations, dominated by bones of caprines (41%), pigs (29%) and cattle (27%) are interpreted as resulting from periodic feasting events, but the scale and frequency of these feasts, the nature of deposition and the character of activity outside of feasting events remains poorly understood. Previous research that aimed to reconstruct depositional histories at Potterne provided problematic results. The most substantial study, which assessed ceramic type distribution and bone fragmentation, suggested a steady, gradual accumulation over the excavated area (Reilly et al., 1988). However, evidence of layering from weathered sections described in Lawson (2000) suggests that this oversimplifies patterns of accumulation. Results from soil micromorphological analysis provided improved resolution on site formation processes (Macphail, 2000); particularly surrounding animal stalling and trampling but analysis provided only limited evidence for phases of activity.

In the absence of stratigraphy, the site was excavated in 10 cm spits and 1 m squares (described as zones and columns in Lawson, 2000). The 16 m^2 sample area that this paper focuses on was at the north-west of trench 12 (Figs. 1 and 2) and benefits from having a fully analysed ceramic assemblage providing potential for future integration of data. In this area the midden comprised deposits of up to 140 cm in thickness, excavated in 14 spits (spit details in Table 1). All bones from each spit were fully analysed, with the exception of the upper three spits, which were cited as having been heavily disturbed by ploughing (Locker, 2000: 101). No bones were recovered from the bottom spit (level 14). The sampled area comprised more than 10,000 fragments of which more than 3000 were identifiable.

3.2. Taphonomic analysis

During data collection a broad range of taphonomic processes were recorded including weathering, gnawing, trampling, abrasion, mould staining and fracture patterns. These were recorded for all elements that could be identified to species except loose teeth. Previous analysis indicated that weathering, gnawing and trampling were the most effective indicators of sub-aerial exposure (Madgwick, 2011). Therefore statistical analysis focused on these modifications. Abrasion, mould staining and fracturing could have been including more complex aetiologies and may in some instances occur in subterranean environments (Madgwick, 2011). Fracture freshness (Outram, 2001) was also incorporated in testing, as it has the potential to complement perthotaxic evidence and indicate practices responsible for accumulation. However, in practice, fracture freshness scores (Outram, 2001) showed a high degree of homogeneity, had little interpretative potential in this study and are therefore not reported here. Other variables such as fragment counts were also considered in interpretation.

Weathering is arguably the most important modification, as it provides some, albeit complex, indication of the duration of sub-aerial exposure. Weathering was recorded using Behrensmeyer's (1978) six stage method for medium/large mammals. As the severity of scavenger gnawing does not reflect exposure duration, only presence/absence was recorded. Gnaw-marks were identified following published criteria by Buikstra and Ubelaker (1994: 98), Fisher (1995: 36) and Haynes (1980, 1983) and include striations, furrows, pits, punctures, square-based grooves and ragged edges. Rodent gnawing was not included as it can occur in subterranean contexts. Animal trampling generates much more subtle modifications, taking the form of closely spaced, multiple sub-parallel striations (Fig. 3). Although trampling is a major cause of fragmentation in faunal assemblages, bone breakage has a varied aetiology and cannot be directly attributed to this process. Presence/absence of striations was recorded following the guidance of Andrews and Cook (1985).

Table 1
Details of midden spits and their broad description following Lawson (2000).

Spit	Depth below topsoil (cm)	Status
1	1–10	Plough-affected
2	11–20	Plough-affected
3	21–30	Plough-affected
4	31–40	Midden
5	41–50	Midden
6	51–60	Midden
7	61–70	Midden
8	71–80	Midden
9	81–90	Midden
10	91–100	Midden
11	101–110	Midden
12	111–120	Midden
13	121–130	Midden/occupation layer
14	131–140	Occupation layer (no bone)

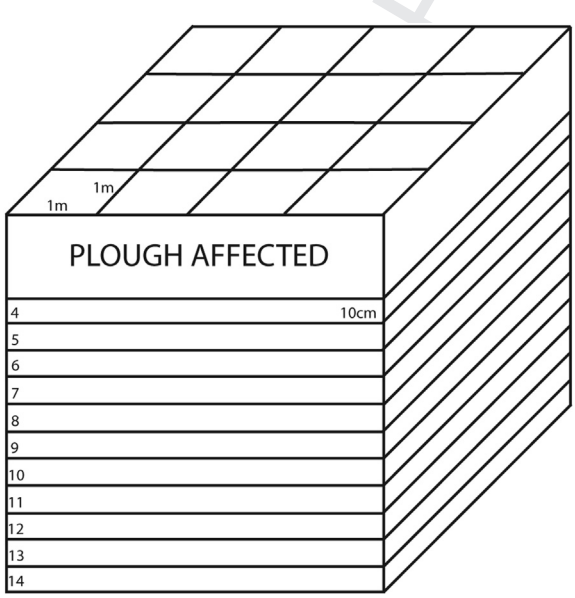

Fig. 2. Schematic diagram of the 16 m^2 sample area.

Fig. 3. Example of trampling striations on a cattle mandible. Note their close spacing and sub-parallel alignment (Photograph: R. Madgwick).

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Table 2
Summary of element and taxon categories that were identified as significantly more frequently affected by modifications in multi-site analyses (Madgwick, 2011, 2010); these categories are used in chi-square comparisons of composition.

Taphonomic Variable	Susceptible taxa	Susceptible elements
Weathering	Cattle, horse	Mandible, long bones, pelvis/scapula
Gnawing	Cattle	Long bones, pelvis/scapula/astragalus /calcaneum
Trampling	Cattle	N/A

3.3. Statistical analysis

Analysis compared the levels of modification in each spit in the sample area with all other spits to identify significant differences. Rather than just comparing those that abutted each other, multiple pair-wise comparisons were conducted, to provide both specific differences and more generalised patterns of modification throughout the layers. To retain higher resolution, spits were not amalgamated in testing, although the sixteen 1 m^2 columns in any single spit were treated as a single entity. This may mask spatial variation but the scale of deposition in evidence at the site suggests that testing a comparatively large area is more meaningful in terms of depositional practice. Further analysis has the potential to reveal spatial variation, although dividing the sample will in some instances provide prohibitively small datasets for statistical testing.

Simple tests of statistical difference were used to compare modification in the different spits. Multiple pair-wise comparisons were carried out for each modification separately: chi-square for nominal data categories (gnawing and trampling) and Mann–Whitney for ordinal data categories (weathering). Analysing weathering as an ordinal data category ensures that the intensity, as well as the frequency of the modification is assessed. In addition, chi-square pair-wise comparisons were also conducted to assess whether differences in modification could result from spit composition. This involved testing for differences in the proportion of specimens from taxa and elements demonstrated as inherently more likely to exhibit modification in previous analyses (Madgwick, 2011; Madgwick and Mulville 2012; see Table 2). For example if spit a was significantly more weathered than spit b, this may not represent more prolonged exposure, but may rather result from the spit having a higher proportion of specimens that are susceptible to modification. Therefore if tests demonstrate that there is no significant difference in the proportion of susceptible specimens between the two spits, then the variation in modification can be interpreted as resulting from genuine differences in depositional history. Seven series of pair-wise tests are presented:

Table 3
Summary results and interpretation. The number of positive (i.e. more modification or a greater susceptibility) and negative (i.e. less modification or lower susceptibility) results are noted in brackets. Pair-wise test results are graded according to the net number of significant results (v. low = <−5, low = −5 to −3, medium = −2 to +2, high = +3 to +5, v.high = >+5). The fragment density field provides a coarse indicator of the quantity of faunal remains (identified and unidentified combined, low = <600, medium = 600–1000, high = >1000).

Spit	Suscept. Weath.	Weathering	Suscept. Gnaw.	Gnawing	Suscept. Tramp.	Trampling	Frag density	Dep. Phase	Interpretation
4	v. low (-9)	high (+4)	v. low (-10)	medium (-1)	v. low (-7)	v. low (-7)	medium	4	Continued accumulation followed by probable abandonment
5	v. low (-8)	v. low (-6)	v. low (-10)	low (-4)	v. low (-7)	v. low (-7)	high	4	Intense, rapid phase of accumulation
6	v. low (-7)	v. low (-6)	v. low (-9)	medium (-2)	v. low (-6)	v. low (-6)	medium	4	Intense, rapid phase of accumulation
7	v. high (+7, -1)	low (-5)	high (+6, -1)	medium (+2)	medium (+3, -1)	medium (+3, -3)	high	4	Intense, rapid phase of accumulation
8	v. high (+9)	high (+4)	v. high (+7)	high (+3)	high (+3)	high (+6, -1)	medium	3	Continued intense deposition followed by hiatus
9	high (+6, -2)	low (-5)	high (+6, -1)	medium (0)	v. high (+6)	medium (+3, -4)	high	3	Intense, rapid phase of accumulation
10	medium (+3, -1)	high (+4)	high (+3)	medium (+1)	high (+3)	v. high (+6)	high	2	Denser occupation layer showing heavy disturbance, probably followed by hiatus
11	medium (+3, -5)	high (+4)	medium (+3, -2)	medium (+1)	medium (+3, -2)	v. high (+7)	high	2	Denser occupation layer showing heavy disturbance
12	medium (+2, -1)	high (+4)	medium (+2, -1)	medium (0)	medium (+2, -1)	medium (+2, -4)	low	1	Continuing occupation layer, followed by hiatus
13	high (+4)	medium (+2)	v. high (+7)	medium (0)	high (+4)	high (+5)	low	1	Occupation layer that accumulated rapidly through small-scale deposits

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three to test differences in modification and four to examine differences in spit composition (see Table A.1).

These statistical approaches are not flawless. Multiple pair-wise tests are crucial for understanding differences in modification across the strata. However, comparing so many categories in this way radically increases the chance of type I error, the erroneous rejection of the null hypothesis, due to the non-independence of tests. This problem is not easy to overcome in this study. The standard approach is the application of Bonferroni corrections (Rice, 1989) but this is impractical for the pair-wise comparison of ten categories, as it would mean that a P value of <0.001°, rather than <0.05 would be required to attain statistical significance. In addition, Bonferroni corrections have been criticised as over-conservative (Bland and Altman, 1995; Simes, 1986; Moran, 2003) and therefore relying purely on such a stringent level of significance may stifle interpretable results. An alternative would be to amalgamate spits to reduce the number of categories. This is not considered viable, as comparisons would cease to be archaeologically valid. Retaining the level of resolution provided by 10 cm spits is crucial, as this arbitrary spatial control inevitably already reduces the complexity of patterns of deposition. Therefore, the application of these approaches is qualitatively cautious and in results tables the most robust results which remain significant using the Bonferroni correction are highlighted separately to those which are only significant at the 0.05 level. Interpretation focuses on the more robust results but still takes account of lower levels of significance that do not attain the conservative Bonferroni corrected significance level.

4. Results and discussion

Tables summarising results for each series of pair-wise tests are presented in the appendix, as are tables showing fragment counts and summary statistics on modification prevalence.

4.1. General observations and pathways to interpretation

All modifications were relatively common in the sample area. This frequency of alteration would be expected in surface accumulating deposits, as even material relatively rapidly protected by subsequent deposits is vulnerable to disturbance. The preponderance of weathering and trampling showed considerable variation between spits. Gnawing was more evenly distributed, produced fewer significant results and had less interpretative potential.

Table 4
Summary of results of tests of difference between abutting spits for the different modifications and for compositional susceptibility. The arrow indicates a significant difference between abutting spits. > indicates that the upper spit has significantly greater than the lower spit. < indicates that the upper spit has significantly less modification or compositional susceptibility. Yellow arrows signify that the difference was significant at the Bonferroni corrected level (<0.001°), whereas grey arrows indicate that the difference attained standard confidence levels (<0.05).

Spit	Weathering	Susceptibilty	Gnawing	Susceptibility	Trampling	Susceptibility
4-5	▶		x	x	x	x
5-6	x		x	x	x	x
6-7	x	x	x	x	x	x
7-8	x	x	x	x	x	x
8-9	▶	▶	x	▶	▶	x
9-10	x	x	x	x	x	x
10-11	x	x	x	x	x	x
11-12	x	x	x	x	▶	x
12-13	x	x	x	x	◀	x

This technique uses variation in taphonomic signatures to characterise different phases of activity. Reconstructing phases of activity is a complex task in stratigraphically undifferentiated deposits, as spit excavation blurs the boundaries of activity phases and differences between every spit can be recognised. Activity phases have been identified based on two lines of evidence: statistically significant differences in modification that cannot be explained in terms of compositional susceptibility and also the quantity of faunal remains in the spit. Interpretation focuses principally on results that attain the conservative Bonferroni corrected significance level, with additional reference to those significant at the standard level (<0.05). In the interests of brevity the different significance levels are not separated in the discussion, but are presented in the appendix. A simplified summary of tests of difference, fragment densities and interpretations of accumulation history is presented in Table 3. A summary table showing results relating to only abutting levels is presented in Table 4.

Hiatuses during which little deposition occurred are reflected by high levels of all modifications, generally greater than abutting levels. An abandonment phase during which no settlement is active at the site can be similarly characterised, but would have less evidence of gnawing and trampling, which require active agents of modification. Periods of severe disturbance are identified by the homogenisation of signatures, where adjacent spits have a relatively evenly distributed, high degree of modification. This provides a similar signature from a gradual build up through small-scale deposits (e.g. by a small permanent settlement) but is likely to differ in showing greater evidence of trampling. Phases of intense accumulation are characterised by very low levels of modification, whereby material is rapidly protected by subsequent deposits.

Testing differences in composition is central to the valid interpretation of taphonomic signatures. In using this method, comparisons of composition may need to be altered to take account of prescribed modes of pre-depositional treatment. This is unlikely to be frequently necessary, but daily life will often have been structured by codes of practice throughout the human past (see Hill, 1995; Randall, 2010) and at times these rules will have extended to the depositional treatment of different classes of remains (e.g. species, Madgwick, 2008, 2010; Madgwick and Mulville, in press; Marciniak, 2005a, 2005b; Orton, 2012). Species-specific modes of treatment can be rapidly identified through site-wide testing. Preliminary pair-wise tests (MWU for weathering, chi-square for gnawing and trampling were) were undertaken for Potterne but provided no evidence for prescribed practices relating to species (see Madgwick, 2011). There was some evidence for variation in the treatment of fore- and hind-limb elements and additional compositional tests were undertaken to assess whether this could account for modification differences. None of the tests affected interpretation and consequently they are not presented here.

In total 135 pair-wise tests for modifications and 180 tests for composition are presented. A striking and relatively consistent pattern was the importance of composition in mediating modification. Results frequently reflected patterns of compositional susceptibility, thereby reaffirming the dangers of interpreting taphonomic signatures at face value. Taphonomic differences between spits that could not be accounted for by composition were used to differentiate phases of accumulation. The following discussion uses the results to identify four phases of accumulation and describes how periods of activity can be separated. Only results most pertinent to interpretation are described and Tables A.4–A.10 can be referred to for full results. The first identified phase (1) is described in greater detail to clarify the process of differentiating meaningful archaeological results from those that relate to inherent biases in the composition of a deposit.

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4.2. Phase descriptions

4.2.1. Phase 1 (spit 13–12)

This phase was identified as comprising two spits (13 and 12) and is thought to represent occupation deposits with a relatively low density of bone. Material in spit 13 was significantly more weathered than two spits (5, 6) but had higher susceptibility in terms of taxon composition than four (4–6, 11). Therefore it showed less weathering than would be expected if all spits had undergone identical depositional histories. Although gnawing tests produced no significant results, less gnawing is evident than would be expected based on composition; seven tests showed significantly higher compositional susceptibility than other spits (4–6 for both taxon and element, 11 for just element). This spit contained significantly more trampled fragments than five spits (4–6, 9, 12), but also had a significantly higher proportion of specimens from susceptible taxa than four (4–6, 11). Therefore a prevalence of trampled fragments would be expected, but differences in composition alone cannot explain the more frequent trampling compared to abutting level 12 and also level 9. Consequently results indicate that the basal deposit was subject to relatively extensive trampling.

Level 12 showed a slightly different pattern of modification but is likely to be part of the same phase of accumulation. Bone in this spit was significantly more weathered than four overlying levels (5–6, 7, 9), only one of which (5) can be explained in terms of compositional susceptibility. Significantly more trampling was present than in two levels (4, 5) but significantly less was evident than adjacent spits (10, 11, 13 and also 8). Compositional susceptibility results were mixed but cannot explain differences between level 12 and adjacent spits and therefore, overall less trampling is present than would be expected if depositional histories had been the same across spits.

This phase is interpreted as an occupation layer, the reduced weathering and gnawing in spit 13, suggests relatively rapidly accumulation through small-scale deposits whilst the prevalence of tramping suggest the area was openly accessible to livestock at this time. The increase in weathering seen in spit 12 is consistent with a hiatus in deposition, with remains exposed to the elements for a longer period, rather than being protected by subsequent deposits. The limited trampling and gnawing evidence suggests little settlement or other activity (and therefore few active taphonomic agents) during the hiatus.

4.2.2. Phase 2 (spits 11–10)

Spits 11 and 10 had a greater density of bone, signalling an intensification of deposition. This material was more modified than preceding levels and exhibited relatively homogeneous modification patterns. Level 11 was heavily weathered despite only moderate susceptibility to modification and exhibited the greatest degree of trampling overall, higher than seven other spits (4–9, 12); differences with only three spits could be explained by composition. Level 10 also exhibited high levels of trampling and weathering, and whilst compositional susceptibility was also high, this could again not explain all significant differences. There was significantly more weathering than four levels including abutting spit 9, significantly more trampling than in six spits (4–6, 7, 9, 12) with composition only accounting for three of these differences. Therefore spits 10 and 11 exhibit more modification than would be expected if all levels were exposed to the same degree.

The very similar modification patterns in these spits indicate widespread modification and disturbance. These patterns suggest gradual, piece-meal deposition with extensive disturbance and turbation, causing both increased sub-aerial exposure and a homogenisation of modification signatures as spits are mixed. It is also plausible that the phase results from a single or very short episode of deposition, followed by substantial disturbance. However, continuous deposition of small deposits combined with disturbance is considered more likely due to the level of weathering. Gradual accumulation would be more likely to promote extensive weathering throughout the layers, as all remains would be exposed for a time at the point of deposition. The small scale dumping events would not fully protect previous deposits and would in themselves cause disturbance. In addition the mixing of different layers and high levels of trampling suggests livestock activity, a key process of disturbance.

The intensification of deposition may indicate the initiation of the midden accumulation sequence (resulting from feasting events). This primary stage is then followed by an interval with little consistent deposition resulting in disturbance and modification associated with sub-aerial exposure. This phase lasted for a period of at least months, but more likely years prior to the next depositional phase. Therefore this period is best described as an occupation phase, which perhaps intensified into a disturbed middening phase. A separate phase of accumulation in the deepest spits of the midden was recognised by Lawson (2000: 25), principally based on artefact density. This analysis provides greater resolution to the character and extent of this initial phase.

4.2.3. Phase 3 (spits 9–8)

This phase has been assigned two spits (9 and 8), which have markedly different modification patterns. Spit 9 signals a new period of deposition with the first clear evidence for large-scale, rapid dumping and also had significantly less weathering than five levels including abutting 8 and 10, in spite of having high susceptibility. No gnawing tests produced significant results, as the spit had the highest compositional susceptibility to this modification, overall this suggests a dearth of gnawing in real terms. Level 9 had significantly more trampling than three spits (4–6) but also had significantly less than four levels, including two that abut (8, 10, 11, 13). As this spit had the highest susceptibility to weathering it exhibits far less modification than would be expected if depositional histories were identical across spits.

Spit 8 had significantly more weathering than four levels (5, 6, 7, 9); this can largely be explained by composition but the significantly greater weathering than overlying spit 7 could not be accounted for. Spit 8 also comprised the highest proportion of gnawed fragments (18%), significantly more than three spits (4–6), but these can all be explained by compositional tests. Significantly more trampling was evident than in six spits (4–6, 7, 9, 12). Only three of these results (4–6) can be explained through composition and therefore overall trampling is very common and clear differences are apparent with abutting levels.

The minimal modification in spit 9 is interpreted as evidence for very rapid accumulation with material regularly deposited in large quantities over a period unlikely to be longer than weeks, allowing little opportunity for weathering to occur. Spit 8 accumulated at a similar rate and protected the underlying layer from modification but also exhibited extensive evidence of sub-aerial exposure, indicating a subsequent lengthy interruption in deposition. Such a clear difference in modification between levels, in contrast to phase 2, indicates reduced disturbance and turbation, perhaps due to less animal movement in the area. This is not in accordance with trampling prevalence (partially explained by composition) and may indicate more a difference in the size of the trampling agents, possibly with medium sized-rather than large mammals present (roaming, foraging or penning). This would cause trampling, but as lower energy agents, would not cause the same degree of disturbance. Such detailed interpretation is however speculative and taphonomic patterns alone cannot provide this level of resolution.

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4.2.4. Phase 4 (spits 7–4)

Phase 4 represents a further intensification of deposition in four spits. The significant difference in weathering between spits 7 and 8 indicates a substantial hiatus in activity between these levels. Overall spit 7 exhibited little modification; weathering evidence was scarce with the sample exhibiting significantly less than five spits (4, 8, 10–12) in spite of having high compositional susceptibility. Three significant results showing a dearth of trampling in spit 7 could not be explained by composition. Spit 6 exhibited even less modification, with fourteen significant results in pair-wise comparisons showing less modification in this spit, but all except two (more weathering in 4 and 12) were coupled with differences in composition. When considering composition spit 6 exhibited similarly low levels of modification to spit 7.

Level 5 was of very similar character to level 6. Significant results were produced in 17 pair-wise tests, with spit 5 always having less modification, but all but one of these (the greater weathering in spit 4) were matched with differences in composition. Taxonomic composition differed greatly in spits 5 and 6 compared to all preceding layers, meaning much lower susceptibility to modification. Whilst this complicates interpretation, in absolute terms the spits exhibit very little modification and not all differences can be explained in terms of composition. Although composition must have had a substantial impact in mediating reduced modification, there can be little doubt that few bones from this layer underwent prolonged exposure.

Level 4 exhibited a very different signature from the three preceding spits. Weathering was significantly more common than in four spits (5–7, 9). This is surprising, as the sample had the lowest susceptibility of all spits with nine negative results in taxon and element tests. Therefore if all levels were subject to the same degree of exposure, spit 4 should exhibit the least weathering. Little gnawing was observed and patterns adhered to compositional susceptibility. Absolute evidence of trampling was scarcer than in any spit, with only 2% of specimens affected, significantly less than spits 7–13. However, all trampling patterns could be explained through differences in composition, although such low levels must indicate that little trampling occurred. The exceptionally severe weathering indicates prolonged exposure but results from other modifications are not in accordance. Gnawing and trampling require active human/animal interference. In spite of bones being sub-aerially exposed for prolonged periods, results indicate that relatively little disturbance occurred. It is unlikely that patterns result from percolation of taphonomically re-elaborated material from overlying plough-affected layers, or that remains represent laterally displaced material from the truncated 'on-terrace' area (see Lawson et al., 2000: 254), as trampling and gnawing would also be prevalent in both instances.

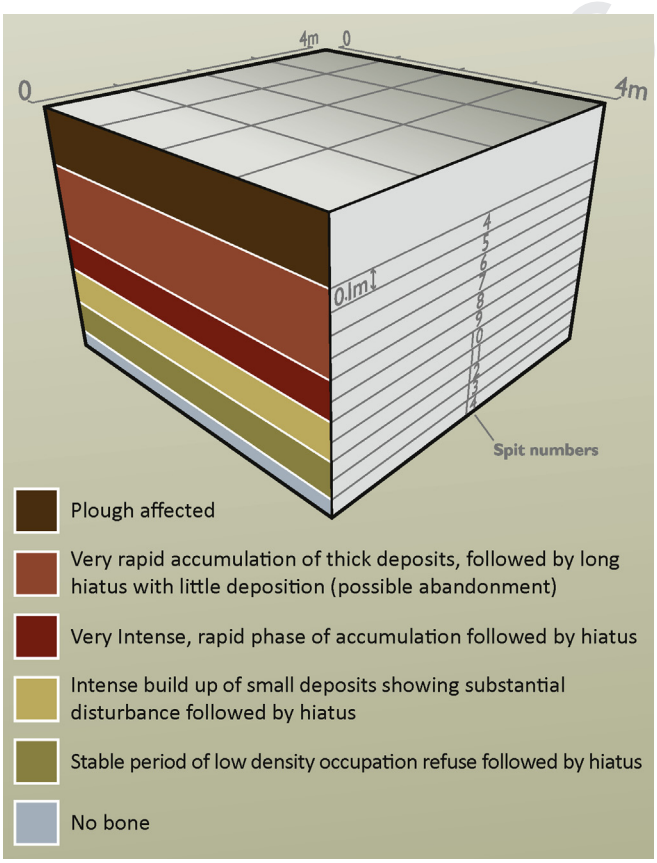

Fig. 4. Schematic diagram with reconstructed phases of deposition. Image by J. Vallender (©English Heritage) and modified by I. Dennis, redrawn from Madgwick (2011).

Taphonomic patterns in this phase provide a signature of rapid accumulation through large deposits, with all but the uppermost layer (representing a hiatus) showing little modification. Spit 4 is interpreted as an exposed horizon at the end of a period of rapid accumulation of substantial quantities of material that created approximately 40 cm thick deposits. The contrast between abundant weathering and a lack of trampling and gnawing indicates that an abandonment phase, during which agents of gnawing and trampling are largely absent, fits the data best. Another possibility is that this area may have been fenced off allowing weathering to occur but preventing modifications requiring active agents. This fits with the cycles of activity posited by Lawson et al. (2000: 258–60), with areas demarcated for certain activities cyclically. To identify abandonment confidence further testing on different areas of the midden is required, as the 16 m^2 sample area cannot be considered representative. This does not necessarily represent the final use of the midden, as it is likely to have been followed by later phases of activity that have been obscured by ploughing (Lawson et al., 2000: 253).

4.3. Summary

The nature of activity in the study area can be summarised as follows (also see Fig. 4). Phases 1 (spit 13–12) and 2 (11–10) show homogeneous modification patterns, suggesting stable periods of accumulation, separated by a hiatus during which little deposition occurred. This is probably indicative of a small permanent human population in phase 1, which grows larger in phase 2 and includes substantial numbers of livestock. Phase 3 (9–8) signals a change in practice with the likely periodic influx of a substantial temporary population engaged in large feasting events, with a small permanent population remaining in residence, as evidenced by the trampling and gnawing in spit 8. In phase 4 (7–4), the low level modification in spits 7–5 suggests that accumulation of vast quantities of material (30–40 cm thick) occurred quite rapidly, with little disturbance. It seems unlikely that such a quantity of material could result from a single vast feasting event but this possibility cannot be excluded and it may be that deposition simply focussed on the study area at a certain point in time. Alternatively periodic feasting events may have intensified in scale and frequency. This was followed by the abandonment of the permanent population and the cessation of feasting practices, although later events may be obscured in the plough-affected layers.

Whilst this analysis has reconstructed the depositional history for one zone of the site, it is highly unlikely that the Potterne midden, covering an area of 3.5 ha, would accumulate in a uniform manner across its area. Therefore phases described here cannot be

considered representative of the whole site. The aim of this research was to test the application of the approach, rather than reconstruct phases of deposition for the whole site. Results from testing unequivocally demonstrate the value of taphonomic modification for reconstructing depositional histories and methods signify a substantial advancement in the use of taphonomic data. Although large numbers of tests are required, these analyses are simple and can be undertaken very rapidly with multiple results obtained in a single analysis using SPSS.

Many factors that cannot be traced archaeologically mediate the rate, severity and prevalence of modification (e.g. sub-aerial micro-environment and taphonomic re-elaboration) and therefore it is impossible to identify exposure duration with precision. In addition patterns of deposition will undoubtedly be blurred, as more than one activity phase may be represented in a single spit and therefore each spit will have a weaker signature than if the exact activity phase could be defined stratigraphically. However, by taking account of composition, the prevalence and severity of modification can indicate the degree of exposure at an ordinal level and significant differences signal shifts in depositional practice.

5. Conclusion

Stratigraphy should always be the principal criterion on which to base interpretation of formation processes and therefore this method is best suited to sites where stratigraphic relationships are uncertain or unobservable. However, taphonomic analysis represents a useful supplement to stratigraphy in providing greater information on processes affecting material and agents responsible for deposit formation, even if samples are prohibitively small for statistical analysis. For example, taphonomic comparisons would be useful for achieving improved resolution into processes of pit infilling. Results from programmes of testing in this chapter have successfully disentangled the different phases of deposition and to some degree the practices involved in midden accumulation. Results demonstrate that it is crucial to temper interpretation with compositional comparisons, but raw patterns of modification should not be disregarded. Composition may account for significant differences between spits but this does not preclude interpretation of raw taphonomic data, as modifications provide direct evidence for processes that affect bones.

Findings further demonstrate the degree to which animal bone taphonomy represents an under-exploited resource in archaeology. By providing information far beyond that which is useful for reconstructing human–animal relations, a greater focus on taphonomy has the potential to extend the applications of zooarchaeological data, allowing us to achieve a more nuanced understanding of site formation processes.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2014.10.015.

References

Andrews, P., Cook, J., 1985. Natural modifications to bone in a temperate setting. Man 20, 675–691.
Atici, A.L., 2006. Who let the dogs out? Bone destruction and its broader implications in interpreting the Bronze Age pastoral economies at Kaman-Kalehöyük. Anatol. Archaeol. Stud. 15, 121–132.
Bar-Oz, G., Adler, D.S., 2005. Taphonomic history of the middle and upper Palaeolithic faunal assemblage from Ortvale Klde, Georgian Republic. J. Taphon. 3, 185–211.
Bar-Oz, G., Munro, N.D., 2004. Beyond cautionary tales: a multivariate taphonomic approach for resolving equifinality in zooarchaeological studies. J. Taphon. 2, 201–220.
Bar-Oz, G., Weinstein-Evron, M., Livne, P., Zeidner, Y., 2005. Fragments of information: preliminary taphonomic results from the Middle Palaeolithic breccia layers of Misliya Cave, Mount Carmel, Israel. In: O'Connor, T. (Ed.), Biosphere to Lithosphere: New Studies in Vertebrate Taphonomy. 9th ICAZ Conference, Durham 2002. Oxbow, Oxford, pp. 126–134.
Bartosiewicz, L., 2008. Taphonomy and palaeopathology in archaeozoology. Geobios 41, 69–77.
Behrensmeyer, A.K., 1978. Taphonomic and ecological information from bone weathering. Paleobiology 4, 150–162.
Behrensmeyer, A.K., 1993. Discussion: noncultural processes. In: Hudson, J. (Ed.), From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains. Occasional Paper, vol. 21. Centre for Archaeological Investigations, Southern Illinois University, Carbondale, pp. 342–348.
Bland, J.M., Altman, D.G., 2[illegible] Multiple significance tests: the Bonferroni method. Br. Med. J. 310, 170.
Buikstra, J., Ubelaker, D., 1994. Standards for Data Collection from Human Skeletal Remains. Arkansas Archaeological Survey, Fayetteville.
Conard, N.J., Walker, S.J., Kandel, A.W., 2008. How heating and cooling and wetting and drying can destroy dense faunal elements and lead to differential preservation. Palaeogeogr. Palaeoclimatol. Palaeoecol. 266, 236–245.
Devos, Y., Fechner, K., Vrydaghs, L., Degraeve, A., Deligne, F., 2007. Contribution of archaeopedology to the palaeoenvironmental reconstruction of (pre-)urban sites at Brussels (Belgium). The example of the Treurenbergsite. Atti Soc. Tosc. Sci. Nat. Mem. Ser. A 112, 145–151.
Devos, Y., Vrydaghs, L., Degraeve, A., Modrie, S., 2011. Unravelling urban stratigraphy. The study of Brussels' (Belgium) dark earth. An archaeopedalogical approach. Mediev. Mod. Matters 2, 51–76.
Dirrigl, F.J., 2001. Bone mineral density of wild turkey (*Meleagris gallopavo*) skeletal elements and its effect on differential survivorship. J. Archaeol. Sci. 28, 817–832.
Elkin, D.C., 1995. Volume density of South American camelid skeletal parts. Int. J. Osteoarchaeol. 5, 29–37.
Fisher, J.W., 1995. Bone surface modifications in zooarchaeology. J. Archaeol. Method Theory 2, 7–68.
Gàl, E., 2008. Faunal and taphonomic analyses of a Late Pleistocene bird-bone assemblage from a cave deposit in north-west Hungary. Geobios 41, 79–90.
Haynes, G., 1980. Evidence of carnivore gnawing on Pleistocene and recent mammalian bones. Paleobiology 6, 341–351.
Haynes, G., 1983. A guide for differentiating mammalian carnivore taxa responsible for gnaw damage to herbivore limb bones. Paleobiology 9, 164–172.
Henderson, J., 1987. Factors determining the state of preservation of human remains. In: Boddington, A., Garland, A.N., Janaway, R.C. (Eds.), Death Decay and Reconstruction: Approaches to Archaeology and Forensic Science. University of Manchester Press, Manchester, pp. 43–54.
Hill, J.D., 1995. Ritual and Rubbish in the Iron Age of Wessex. In: BAR British Series 242. Tempus Reperatum, Oxford.
Ioannidou, E., 2003. Taphonomy of animal bones: species, sex, age and breed: variability of sheep, cattle and pig bone density. J. Archaeol. Sci. 30, 355–365.
Kooyman, B., 2001. The roles of bone density and cultural behaviour in Head-Smashed-In bone bed taphonomy. In: Gerlach, S.C., Murray, M.S. (Eds.), People and Wildlife in Northern North America: Essays in Honour of R. Dale Guthrie, BAR International Series 944. Archaeopress, Oxford, pp. 285–293.
Kreutzer, A., 1992. Bison and deer bone mineral densities: comparisons and implications for the interpretation of archaeological faunas. J. Archaeol. Sci. 19, 271–294.
Lam, Y.M., Pearson, O.M., 2004. The fallibility of bone density values and their use in archaeological analyses. J. Taphon. 2, 99–115.
Lam, Y.M., Chen, X., Marean, C.W., Frey, C.J., 1998. Bone density and long bone representation in archaeological faunas: comparing results from CT and photon densitometry. J. Archaeol. Sci. 25, 559–570.
Lawson, A.J., 2000. Potterne 1982-5: Animal Husbandry in Later Prehistoric Wiltshire. Wessex Archaeology Report No. 17. The Trust for Wessex Archaeology, Salisbury.
Lawson, A.J., Powell, A., Thomas, R., 2000. Discussion. In: Lawson, A.J. (Ed.), Potterne 1982-5: Animal Husbandry in Later Prehistoric Wiltshire. Wessex Archaeology Report No. 17. The Trust for Wessex Archaeology, Salisbury, pp. 250–272.
Locker, A., 2000. Animal bone. In: Lawson, A.J. (Ed.), Potterne 1982-5: Animal Husbandry in Later Prehistoric Wiltshire. Wessex Archaeology Report No. 17. The Trust for Wessex Archaeology, Salisbury, pp. 101–119.

Lodwick, M., Gwilt, A., 2005. Continuing excavation at Llanmaes, Vale of Glamorgan. Archaeol. Wales 45, 91–92.
Lyman, R.L., 2008. Quantitative Palaeozoology. Cambridge University Press, Cambridge.
Macphail, R., 2000. Soils and microstratigraphy: a soil micromorphological and microchemical approach. In: Lawson, A.J. (Ed.), Potterne 1982-5: Animal Husbandry in Later Prehistoric Wiltshire. Wessex Archaeology Report No. 17. The Trust for Wessex Archaeology, Salisbury, pp. 47–70.
Madgwick, R., 2008. Patterns in the modification of human and animal bones in Iron Age Wessex: revisiting the excarnation debate. In: Davis, O., Sharples, N., Waddington, K. (Eds.), Changing Perspectives on the First Millennium BC. Oxbow, Oxford, pp. 99–118.
Madgwick, R., 2010. Bone modification and the conceptual relationship between humans and animals in Iron Age Wessex. In: Morris, J., Maltby, M. (Eds.), Integrating Social and Environmental Archaeologies: Reconsidering Deposition, BAR International Series 2077. Archaeopress, Oxford, pp. 66–82.
Madgwick, R., 2011. Investigating the Potential of Holistic Taphonomic Analysis in Zooarchaeological Research (Unpublished PhD thesis). Cardiff University.
Madgwick, R., Mulville, J., 2012. Investigating variation in the prevalence of weathering in faunal assemblages in the United Kingdom: a multivariate statistical approach. Int. J. Osteoarchaeol. 22, 509–522.
Madgwick, R., Mulville, J., 2014. Feasting on fore-limbs: conspicuous consumption and identity in later prehistoric Britain. Antiquity (in press).
Marciniak, A., 2005a. Social changes in the early European Neolithic. A taphonomy perspective. In: O'Connor, T. (Ed.), Biosphere to Litosphere: New Studies in Vertebrate Taphonomy. Oxbow Books, Oxford, pp. 146–154.
Marciniak, A., 2005b. Placing Animals in the Neolithic. Social Zooarchaeology of Prehistoric Farmingcommunities. UCL Press, London.
Marean, C.W., Cleghorn, N., 2003. Large mammal skeletal element transport: applying foraging theory in a complex taphonomic system. J. Taphon. 1, 15–42.
Montalvo, C.I., Melchor, R.N., Visconti, G., Cerdeño, E., 2008. Vertebrate taphonomy in loess-palaeosoil deposits: a case study from the Late Miocene of central Argentina. Geobios 41, 133–143.
Moran, M.D., 2003. Arguments for rejecting the sequential Bonferroni in ecological studies. Oikos 100, 403–405.
Orton, D., 2012. Taphonomy and interpretation: an analytical framework for social zooarchaeology. Int. J. Osteoarchaeol. 22, 320–337.
Outram, A.K., 2001. A new approach to identifying bone marrow and grease exploitation: why the 'Indeterminate' fragments should not be ignored. J. Archaeol. Sci. 28, 401–410.
Outram, A.K., 2004. Applied models and indices versus high resolution observed data: detailed fracture and fragmentation analyses for the investigations of skeletal part abundance patterns. J. Taphon. 2, 167–184.
O'Connor, T.P., 2000. The Archaeology of Animal Bones. Stroud, Sutton.
Parker Pearson, M., Allen, M., French, C., Pollard, J., Richards, C., Robinson, D., Thomas, J., Tilley, C., Welham, K., n.d. The Stonehenge Riverside Project 2007: Full Interim Report. Unpublished interim report. University of Sheffield.
Pavao, B., Stahl, P.W., 1999. Structural density assays of leporid skeletal elements with implications for taphonomic, actualistic and archaeological research. J. Archaeol. Sci. 26, 53–66.
Randall, C., 2010. More ritual rubbish? exploring the taphonomic history, context formation processes and 'specialness' of deposits including human and animal bone in Iron Age pits. In: Morris, J., Maltby, M. (Eds.), Integrating Social and Environmental Archaeologies: Reconsidering Deposition, BAR International Series 2077. Archaeopress, Oxford, pp. 83–102.
Reilly, P., Locker, A.M., Shennan, S.J., 1988. Pattern recognition in sub-surface artifact distributions; expanding the role of computer graphics in the analysis of buried data. In: Rahtz, S.P.Q. (Ed.), Computer and Quantitative Methods in Archaeology 1988, BAR International Series 446 (I). Archaeopress, Oxford, pp. 265–294.
Rice, W.R., 1989. Analyzing tables of statistical tests. Evolution 43, 223–225.
Russell, A., 2010. Structured deposition or casual disposal of human remains? A case study of four Iron Age sites from southern England. In: Morris, J., Maltby, M. (Eds.), Integrating Social and Environmental Archaeologies: Reconsidering Deposition, BAR International Series 2077. Archaeopress, Oxford, pp. 45–65.
Simes, R.J., 1986. An improved Bonferroni procedure for multiple tests of significance. Biometrika 73, 751–754.
Stiner, M.C., 2004. A comparison of photon densitometry and computed tomography parameters of bone density in ungulate body part profiles. J. Taphon. 2, 117–145.
Symmons, R., 2005a. Taphonomy and Çatalhöyük: how animal bone taphonomy can enhance our interpretative powers. In: Buitenhuis, H., Choyke, A.M., Martin, L., Bartosiewicz, L., Mashkour, M. (Eds.), Archaeozoology of the Near East VI. ARC-Publicaties, Groningen, pp. 103–111.
Symmons, R., 2005b. New density data for unfused and fused sheep bones, and a preliminary discussion on the modelling of taphonomic bias in archaeofaunal age profiles. J. Archaeol. Sci. 32, 1691–1698.
Symmons, R., 2005c. Bone density variation between similar animals and density variation in early life: implications for future taphonomic analysis. In: O'Connor, T. (Ed.), Biosphere to Lithosphere: New Studies in Vertebrate Taphonomy. 9th ICAZ Conference, Durham 2002. Oxbow, Oxford, pp. 87–93.
Thompson, J.C., 2005. The impact of post-depositional processes on bone surface modification frequencies: a corrective strategy and its application to the Loigongalani Site, Serengeti Plain, Tanzania. J. Taphon. 3, 67–89.
Uerpmann, H.-P., 1973. Animal bone finds and economic archaeology: a critical study of 'osteo-archaeological' method. World Archaeol. 4, 307–322.
Vannieuwenhuyze, B., Charruadas, P., Devos, Y., Vrydaghs, Luc, 2012. The medieval territory of Brussels: a dynamic landscape of urbanisation. In: Kluiving, S.J., Guttmann-Bond, E.B. (Eds.), Landscape Archaeology Between Art and Science. From a Multi- to an Interdisciplinary Approach. Amsterdam University Press, Amsterdam, pp. 223–238.
Verzi, D.H., Montalvo, C.I., Deschamps, C.M., 2008. Biostratigraphy and biochronology of the Late Miocene of central Argentina: evidence from rodents and taphonomy. Geobios 41, 145–155.
Villagran, X.S., Giannini, P., DeBlasis, P., 2009. Archaeofacies analysis: using depositional attributes to identify anthropic processes of deposition in a monumental shell mound of Santa Catarina State, southern Brazil. Geoarchaeology 24, 311–335.

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