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Modifications on the bovid bone assemblage from Dunefield Midden, South Africa: stage one of a multivariate taphonomic analysis

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A three-stage taphonomic analysis was performed on the small, small-medium and large bovid bone assemblages from Dunefield Midden, an open-air Later Stone Age site on South Africa’s west coast. The results of the first stage of the analysis, which focuses on surface and subsurface bone modifications, are presented here. A forthcoming paper will detail the subsequent two stages, in which skeletal element abundance, longbone breakage patterns and overall taphonomic variability are investigated. The Dunefield Midden bovid bone assemblages are amenable to such an indepth study since they were subjected to a comprehensive refitting operation, with particular emphasis on longbone reconstruction. This enabled the systematic incorporation into the analysis of shaft fragments, a crucial yet frequently ignored component of mammalian zooarchaeological assemblages. Including shafts not only improves estimates of skeletal element abundance and thus our understanding of how prehistoric foragers acquired, transported and distributed animal carcasses, but also yields better assessments of the techniques employed for carcass butchery and bone processing. This paper explores the latter two aspects of subsistence at Dunefield Midden by integrating quantitative and configurational data on bovid bone modifications. It shows that the assemblage was principally shaped from within-bone nutrient acquisition by humans. Variation in bone modification patterning is suggested to stem largely from size-related differences in butchery effort and utility-related differences in skeletal element treatment.

Keywords: Dunefield Midden; bone modifications; boids; refitting; multivariate; Later Stone Age
restituent par ailleurs une image plus fidèle des techniques de boucherie et de traitement des os. Cet article explore ces aspects de la subsistance dans le site LSA de Dunefield Midden en privilégiant l’apport des données quantitatives et représentatives des modifications des os de bovidés. Cette étude montre que l’assemblage faunique reflète principalement des activités humaines liées à l’acquisition des nutriments intra-osseux. Les variations observées dans les modifications des os témoigneraient ainsi d’investissements différents accordés aux activités de boucherie et de traitement des carcasses en fonction des apports nutritionnels escomptés.

Introduction

The zooarchaeological study of ungulate bones from hunter-gatherer sites has developed dramatically in the past three decades, largely catalysed by two contemporaneous, watershed studies: Binford’s (1978, 1981) research on the treatment of large mammal bones by Nunamiut hunters and Brain’s (1981) work on depositional processes in African caves. Both raised a number of pressing taphonomic issues, many of which have since been addressed by a wealth of actualistic studies. These studies have, in turn, prompted a major re-evaluation of faunal assemblage formation processes (for reviews see Klein and Cruz-Uribe 1984; Gifford-Gonzalez 1991; Lyman 1994; Fisher 1995; Reitz and Wing 2008). The result is a richer appreciation of the range of, and interplay between, cultural and natural inputs on bone assemblages, along with an attendant strengthening of behavioural inferences.

Perhaps inevitably, however, many taphonomic cautionary tales go unheeded (Munro and Bar-Oz 2004). This is most alarming when actualistic data consistently demonstrate that taphonomic variability can seriously skew interpretations of faunal assemblage patterning. One of the most notorious forms of taphonomic destruction is density-mediated attrition resulting from carnivore ravaging (Binford 1981; Haynes 1983; Marean and Spencer 1991; Blumenschine and Marean 1993; Marean and Bertino 1994; Bartram and Marean 1999; Pickering et al. 2006). Although many actualistic studies show that discarded bones from human meals are often highly attractive to carnivores, particularly those that are greasy and/or contain large amounts of cancellous tissue (Sutcliffe 1970; Binford 1981; Brain 1981; Haynes 1983; Blumenschine 1986, 1988; Potts 1988; Marean et al. 1992; Marean and Spencer 1991; Marean and Bertino 1994; Egelund 2008), researchers continue to neglect the extent to which low-density, spongy bones can consequently be under-represented archaeologically. These bones are also the most susceptible to destruction (Lam et al. 1998, 1999, 2003; Lam and Pearson 2004) by a variety of post-depositional forces such as chemical diagenesis, trampling and soil movement (Lyman 1994; Hedges 2002). They include most of the axial skeleton and low-density portions of longbones (Brain 1981; Lyman 1984, 1994; Grayson 1989; Marean and Spencer 1991; Marean et al. 1992; Lam et al. 1998, 2003).

Longbones have received a particularly large amount of attention in this respect, most vocally from Marean and colleagues (Marean and Spencer 1991; Marean et al. 1992, 2001, 2004; Marean and Bertino 1994; Marean and Frey 1997; Lam et al. 1998; Marean and Kim 1998; Bartram and Marean 1999; Marean and Cleggorn 2003; Pickering et al. 2003; but see also Morlan 1994; Milo 1998; Outram 2001; Costamagno 2002; Barba and Domínguez-Rodrigo 2005; Yravedra and Domínguez-Rodrigo 2009). These researchers argue that neglecting the effects of carnivores
renders conventional zooarchaeological techniques to identify and quantify long-bones inadequate. They use experimental studies involving captive hyenas to verify quantitatively that carnivores preferentially destroy longbone epiphyses, while shafts (particularly middle shaft fragments) are typically left intact because they are denser and less greasy. It follows that since researchers usually rely on longbone epiphyses (or epiphyseal fragments) for quantification because of their diagnostic morphologies, epiphyseal deletion can grossly skew estimates of longbone abundance. This situation can be improved, they argue, by concentrating element abundance enquiries on elements (and element portions) that are least attractive to carnivores and, at the same time, are likely to withstand post-depositional destruction – that is, high density elements such as compact bones, mandibles and, most significantly, shaft fragments (Marean and Spencer 1991; Lam et al. 1998; Marean and Kim 1998; Pickering et al. 2003).

However, instead of becoming research foci, shaft fragments are still often lumped into indeterminate vertebrate or size categories and excluded from further analyses due to the misconception that most shaft fragments are impossible to identify to element, particularly in contexts such as Sub-Saharan Africa with its array of comparably sized and skeletally similar bovids. In fact, the trained eye can routinely identify even heavily splintered shaft fragments to element and portion using element-specific morphological features and shaft thickness (Marean and Spencer 1991; Barba and Dominguez-Rodrigo 2005; Pickering et al. 2006). Excluding shaft fragments not only introduces potential biases into estimates of skeletal element abundance (Marean et al. 2004; Barba and Dominguez-Rodrigo 2005; Pickering et al. 2006; Yravedra and Dominguez-Rodrigo 2009) but may also mask significant cultural and natural processes that conditioned the assemblage. For example, longbone breakage patterns using shaft fragment size and morphology can help determine the method of cooking (Yellen 1991; Oliver 1993), along with whether and to what extent bone fragmentation resulted from green versus dry breakage (Villa and Mahieu 1991). Similarly, confining investigations of bone modifications to those situated on diagnostic longbone ends can mask evidence for butchery practices other than disarticulation (Fisher 1995; Nilssen 2000; Reitz and Wing 2008), deflate frequency counts and, if carnivore activity is implicated, again run the risk of biasing a reliable interpretation due to longbone end deletion (Thompson 2005; Braun et al. 2008). Since marrow is concentrated within the medullary cavities of longbones, shafts alone typically hold evidence for the extraction of this important nutritional resource prized by recent and past forager groups. In short, shaft fragments are very useful for reconstructing taphonomic histories of bone assemblages and essential to any analysis that aims to understand how ungulate carcasses are treated – that is acquired, transported, processed and discarded.

In this and a forthcoming paper I reaffirm the utility of incorporating longbone shaft fragments into zooarchaeological analyses of ungulate bones by presenting an analysis of the bovid bone assemblage from Dunefield Midden, a series of open-air Later Stone Age coastal forager campsites in the Western Cape Province of South Africa (Parkington et al. 1992, 2009; Parkington and Fisher 2006). This analysis forms part of a larger project investigating spatial, social and subsistence organisation at Dunefield Midden that involved an across-the-board refitting operation on several archaeological materials related to subsistence – ceramics, tortoiseshell and
the bones of several differently sized bovid species (Stewart 2005a, 2005b, 2008, in prep.).

For the bovid bones, two types of refitting were employed: mechanical and anatomical (Todd 1983). Mechanical refitting of bone is the best method of ensuring accurate identification of a shaft fragment (Marean et al. 2001; Pickering et al. 2006). When used in conjunction with careful examination of shaft attributes (Marean and Spencer 1991), refitting can greatly enhance the number of identified specimens (NISP) to element (element NISPs) and thus improve the accuracy of assessments of skeletal element frequencies, bone fragmentation (Stewart in prep.) and surface and subsurface modifications (Marean et al. 2001). For sites with a spatial component it may also provide opportunities to investigate processing and consumption areas, disposal sequences and food sharing (Todd 1983; Enloe 1991, 2003; David and Enloe 1992; Enloe and David 1992; Todd and Frison 1992; Enloe et al. 1994; Stewart 2008).

Since exhaustive longbone refitting was employed for the project’s spatial analysis (to facilitate fragment identification to element and produce spatial connections), the Dunefield Midden bovids offer a good opportunity to investigate ungulate bone assemblage formation processes using a shaft-inclusive methodology.

Following Bar-Oz and Munro (2004); see also Yravedra and Domínguez-Rodrigo 2009), I take a multivariate approach to reconstructing the taphonomic history of the Dunefield Midden bovid assemblage by applying a hierarchical sequence of faunal analyses to three bovid size classes (subgroups) – small, small-medium and large. Juxtaposing assemblage subgroups helps eliminate irrelevant or insignificant taphonomic agents at each stage and so isolate those that structured a given assemblage. The process is flexible, simple (see Bar-Oz and Munro 2004, 203) and diminishes equivinality (Bar-Oz and Dayan 2003; Bar-Oz and Munro 2004; Munro and Bar-Oz 2004). The analyses are organised in three stages. In this paper the results of the first stage are presented: an analysis of surface and subsurface modifications on the bones of the three subgroups, with an emphasis on longbones. I show that, despite the diagenetic affects of surface weathering, root etching and density-mediated attrition, Dunefield Midden bovid assemblage formation resulted principally from meat and, most significantly, within-bone nutrient acquisition by humans. Further, configurations of surface and subsurface human induced modifications on refitted small and large bovid longbones are used to explore butchery and bone processing techniques employed at Dunefield Midden; and it is argued that some elements were treated in a standardised fashion that likely reflects butchery preferences similar to those observed among modern Ju/hoansi groups in the Kalahari (Yellen 1991). The second stage of analysis, in which skeletal element abundance and longbone fragmentation patterns are investigated, and the third stage, a comparison of the overall taphonomic variation between the three bovid subgroups, are presented together in a forthcoming paper (Stewart in prep.).

**Dunefield Midden: Site overview**

Dunefield Midden is a set of open-air Later Stone Age campsites located roughly 500m from the shore of Elands Bay, 180 km north of Cape Town on South Africa’s west coast (Figure 1). Situated at the base of a Holocene dune cordon just south of a higher, active dunefield, the site is sandwiched between up to one metre of sterile aeolian dune sands and an underlying coarser sand/pebble matrix (Parkington et al.
The latter was probably deposited by standing seawater during a high sea-level stand when the Atlantic washed over the beach into an adjacent basin (Miller et al. 1993). The southern part of the site appears to have resulted from several overprinted midden deposits and occupations deposited over some 250 years (cal. AD 1200–1450), but the bulk of the northern part of the site represents a single occupational episode dating to cal. AD 1300–1400 (Tonner 2002) (Table 1). Dunefield Midden’s open-air setting, minimal stratigraphy, many in situ features and good organic preservation are ideal for employing a horizontally oriented excavation strategy to explore intra-site spatial patterning of archaeological remains. A total of 859 m² were therefore excavated over the course of 12 years.

The site is composed of 114 features with interspersed and associated shell, bone and artefact distributions. Features are classified into eight types (and graded by levels of confidence): ashy patches, hearths, crusted features, roasting platforms, ash dumps, roasting pits, charcoal-and-ash pits and small carnivore burials (Parkington and Fisher 2006; Parkington et al. 2009). Figure 2 shows the distribution of these
Table 1. All Dunefield Midden uncalibrated and calibrated C14 dates.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Unit</th>
<th>Square</th>
<th>Material</th>
<th>Source</th>
<th>Date, uncalibrate (BP)</th>
<th>Calibrated age (AD)</th>
<th>+1 sd</th>
<th>-1 sd</th>
<th>+2 sd</th>
<th>-2 sd</th>
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<td>1248</td>
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<td>Char. &amp; ash pit</td>
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<td>1393</td>
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<td>1415</td>
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<td>Roasting pit</td>
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<td>1406</td>
<td>1304</td>
<td>1417</td>
<td>1293</td>
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<td>Hearth</td>
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<td>Charcoal</td>
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<td>1491</td>
<td>1426</td>
<td>1537</td>
<td>1392</td>
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</tbody>
</table>

Note: Modified from Tonner 2002, Table 1.
eight feature types. The eastern area of the site is dominated by a series of hearths extending from the site’s far southeast to its northwestern edge. These run effectively parallel and directly adjacent to the Holocene dune cordon. The great majority of the site’s features are associated with a massive heap of shells mixed with bone fragments and ash that spans the western two-thirds of the campsite (Figure 3). This was clearly both a multi-activity work area and a refuse dump. The juxtaposition of this western activity/dump area with the arc of domestic hearths to the east gives the site a degree of north–south linearity and bilateral symmetry (Figure 3). The Dunefield Midden occupants evidently situated their domestic activities between the Holocene dune cordon to the east and the activity/dump area(s) to the west.

Cultural remains include flaked stone artefacts, manuports (utilised and non-utilised), ceramics, ostrich eggshell beads and fragments, bone tools, *Donax serra* shell scrapers, tortoise carapace bowls, ochre fragments and a single marine shell pendant (Parkington et al. 1992; Jakavula 1995; Orton 2002; Stewart 2005a, 2005b, 2008). The flaked stone is heavily quartz-dominated and can be sub-divided into a relatively fresh (‘non-rounded’) component belonging to the main cal. AD 1200–1450 Dunefield Midden occupation(s) and a more weathered (‘rounded’) background component of mid-Holocene age (Orton 2002). Faunal remains at Dunefield Midden are abundant, with over 10,000 skeletal elements identified (R. Klein, pers. comm.). The most numerous taxa are shellfish, seal, tortoise, small bovid, bird, eland, dassie, fish and other microfauna (Parkington et al. 1992; Tonner 2005; Stynder 2008). Thanks to what was likely a rapid burial with dry, alkaline dune sands, organic and inorganic preservation at Dunefield Midden is generally very
Evidence for post-depositional disturbance of the bone assemblages is not enormous, though a number of taphonomic forces were certainly at work (as discussed below).

Methods

Mechanical refitting

The mechanical refitting focused on appendicular, rather than axial, elements, and built on work by Nilssen (1989). To aid identification, comparative skeletal specimens were procured from the Iziko South African Museum mammal osteological collections. Familiarity with the morphological idiosyncrasies of the individual elements of each taxon was gained through habitual observations and handling of the comparative bones (Todd and Frison 1992). This made it possible to sort undiagnostic fragments into their probable bovid size class and anatomical element groupings necessary to refit the assemblage (Marean and Kim 1998). Significant landmarks included characteristic processes, tuberosities, tubercles, fossae, nerve/blood vessel foramina and canals, and general epiphyseal and diaphyseal morphology (and thickness).

All Dunefield Midden bovid bones were first labelled then sorted on workspaces by size class. Within this category they were sorted by element and within this by provenance (the small–medium bovid bones were few enough not to warrant...
partitioning the bones beyond the element category). Based on my familiarity with appendicular bone morphology, I employed two degrees of probability (high and low) that undiagnostic bone fragments could be identified to element. In this way, these specimens were systematically incorporated into the refit sample, allowing for more success in refitting. The procedure was as follows (see Figure 4 for schematic representation):

1. Diagnostic bovid bones separated into size class: small, small–medium and large bovid.
2. Diagnostic bones of each size class further separated by element.
3. Undiagnostic longbone shaft fragments assigned to size class on the basis of comparative morphology and shaft thickness.
4. Undiagnostic longbone shaft fragments assigned to each size class sorted for specimens whose probability of identification to a specific element was high, then separated and added to their diagnostic counterparts to form the working refit sample.

Figure 4. Schematic chart showing the sorting steps used to arrive at the three bovid bone refit samples.
5. Remaining undiagnostic longbone shaft fragments with low probability of identification to element were attempted for inclusion into the working refit sample on the basis of provenance and taphonomic criteria (burnt, chewed, bleached and so forth).

Under this scheme, all bones within each element grouping of each bovid size class were given a chance to fit with all others in that element grouping.

**Bone modification analysis**

Using a 100x binocular microscope with an external and oblique light source, all surface and subsurface bone modifications were recorded on longbones, crania, mandibles, scapulae, phalanges, carpals and tarsals. Pelves, vertebrae and ribs were not examined due to lack of time, but hopefully future research will produce more thorough examinations of the axial elements of these taxa. A broad range of literature was consulted to aid in the accurate identification of modifications (Behrensmeyer 1978; Binford 1981; Bunn 1981; Potts and Shipman 1981; Johnson 1985; Behrensmeyer et al. 1986; Blumenschine and Selvaggio 1988; Fiorillo 1989; Capaldo and Blumenschine 1994; Lyman 1994; Fisher 1995; Blumenschine et al. 1996; Nilssen 2000). Evaluations of modification morphologies were augmented with non-morphological attributes such as the distribution, orientation and frequency of marks on bones, their placement relative to similar marks and other modifications, and the morphology of the bone surface upon which they occur (Binford 1981; Binford and Stone 1986; Olsen and Shipman 1988; Oliver 1989, 1993, 1994; White 1992; Fisher 1995; Nilssen 2000). This configurational approach (Fisher 1995, 16) was integrated with published experimental and ethnographic data to make informed decisions when attributing a given modification to a specific causal agent. Unfortunately, time constraints prevented experimenting with modern control assemblages or performing blind tests of the sort rightly advocated by Blumenschine et al. (1996).

Refitted sets of bone and isolated bones with significant (usually human induced) modifications were illustrated using photo templates taken from Abe and Marean’s (n.d.) BoneEntryGIS and Bone Sorter program. This was done to create a visual record of Dunefield Midden bovid bones integrating provenance information and breakage patterns with the locations and types of modifications. The BoneEntryGIS and Bone Sorter program is designed to calculate minimum number of elements (MNEs) digitally, based on the overlap of bone fragments represented as GIS pixel data (see also Marean et al. 2001). It is also possible to enter bone modification data into this digital recording system (Abe et al. 2002). However, the relatively small sample size and refitting effort made use of this system impractical. Instead, modification, skeletal element abundance and fragmentation data were recorded on the photo templates using the manual overlap approach (Marean et al. 2001). Longbones were divided into configurational zones for recording modifications. These zones consist of five longbone portions (lengthwise one to five) and four sides (anterior, posterior, medial and lateral). The lengthwise portions correspond to the following (see Figure 5):

1. Proximal end (proximal articular area).
2. Proximal shaft (33.3% of the shaft below the proximal end).
The Dunefield Midden bovids in dietary context

The Dunefield Midden bovids are first placed in context by briefly assessing their overall contribution to the Dunefield Midden dietary range. Numerically, the most common faunal remains at Dunefield Midden are shellfish, with a total shellfish weight exceeding 2,500 kg (Tonner 2002, 2005). This discussion, however, excludes shellfish, as well as the as yet unanalysed fish and microfaunal remains. My database is inappropriate for making inter-taxa comparisons since the refitting process resulted in the identification of many more bovid fragments relative to those of other taxa, leading to substantially inflated NISPs. Thus Klein’s (pers. comm.) identification data are used here.

NISPs and minimum number of individuals (MNIs) for all macrofaunal species and size classes are listed by Dunefield Midden excavation unit in Table 2. These were derived by Klein using the methodology outlined in Klein and Cruz-Uribe (1984, 24–34 and 107–128). Total NISPs and MNIs for all macrofaunal species are shown in Figure 6. It is clear from this that Cape fur seals (*Arctocephalus pusillus*) are by far the most abundant macrofauna at Dunefield Midden, comprising 85% of the...

Figure 5. Five longbone portions that, together with four sides (anterior, posterior, medial and lateral), comprise 20 configurational zones for recording bone modifications.

3. Middle shaft (33.3% of the shaft between the proximal and distal shafts).
4. Distal shaft (33.3% of the shaft above the distal end).
5. Distal end (the distal articular area).
Table 2. All Dune Midden macrofauna NISPs and MNIs by 10 m² excavation unit.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>ANN NISP</th>
<th>BER NISP</th>
<th>ELA NISP</th>
<th>FRA NISP</th>
<th>JAC NISP</th>
<th>JED NISP</th>
<th>KIR NISP</th>
<th>MIT NISP</th>
<th>NIC NISP</th>
<th>PET NISP</th>
<th>SHA NISP</th>
<th>SYL NISP</th>
<th>TOM NISP</th>
<th>ZUK NISP</th>
<th>ALL NISP</th>
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<td>6</td>
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<td>379</td>
<td>6</td>
<td>660</td>
<td>14</td>
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<td><em>Aëthiops pusillus</em> (h藁tra)</td>
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<td>8</td>
<td>66</td>
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<td>75</td>
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<td>Small-medium bovid(s)</td>
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<td>0</td>
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<td>0</td>
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<td>1</td>
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<td>Large-medium bovid(s)</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Large bovid(s)</td>
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<td>6</td>
<td>1</td>
<td>3</td>
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<td>14</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>1</td>
<td>13</td>
</tr>
</tbody>
</table>

Notes: NISPs = number of identified specimens; MNIs = minimum number of individuals.
8097 bones identified by Klein. Restricting the focus for the moment to NISPs at the species level of identification, the next five most abundant taxa are, from most to least: grey mongoose (*Herpestes pulverulentus*), grysbok/steenbok (*Raphicerus* sp(p.), striped polecat (*Ictonyx striatus*), eland (*Tragelaphus oryx*) and sheep (*Ovis aries*). If we increase this to include bovid specimens identifiable only to size class, bovids become a more significant component. The five most abundant taxa after seals are now: small bovid, grey mongoose, large bovid, grysbok/steenbok and small/medium bovid.

Turning to MNIs, the five most abundant species after seals are: grysbok/steenbok, grey mongoose, Cape dune molerat (*Bathyergus suillus*), eland and rock hyrax or dassie (*Procavia capensis*). Bovids are still among the best-represented animals, with the combined grysbok/steenbok category second only to seals,
although some smaller animals again enter into the picture. However, the relatively high occurrences of grey mongoose are probably not related to food procurement since they were recovered as fully articulated, defleshed skeletons that were intentionally (ritualistically?) buried (Parkington and Fisher 2006). The importance of bovids as food sources at Dunefield Midden increases further when we group all bovid size class MNIs and compare them as a family to other mammalian categories (Figure 7). Taken as a family, there are nearly half as many bovids (MNI = 37) as there are seals (MNI = 83). However, the fact that highly robust bovid shaft fragments were omitted from Klein’s database makes it probable that the proportion of bovids relative to seals is considerably higher than this (Stewart in prep.). The next largest group is small carnivores (MNI = 21), some of which were probably not food. The combined evidence thus shows that bovids comprise the most significant food resource at Dunefield Midden besides shellfish and seals.

**Bone modifications**

Modifications are present on bones of all Dunefield Midden bovid size classes. While it is recognised that optimally all bones in a faunal assemblage should be examined for modifications (Fisher 1995, 49), time constraints and alternative analytical goals (the spatial analysis) made the evaluation of every bovid bone in each size class unfeasible. Rather, the focus here is on longbones since these elements are well suited to elucidating taphonomic histories and human behaviours and are thus central to the fragmentation, skeletal element abundance and spatial analyses presented elsewhere (Stewart 2008, in prep.). Longbones also commonly retain numerous, well preserved modifications from not only meat processing, but also marrow extraction. Moreover, a number of axial (crania, mandibles, scapulae) and non-longbone appendicular (carpals, tarsals, phalanges) elements were checked for human-induced modifications and very few were noted (Table 3). Those on longbones, by contrast, are plentiful.

In response to the call for analytical and terminological standardisation, I follow the conventions set out by Gifford-Gonzalez (1991) as expanded by Fisher (1995), who groups bone modifications into two main categories: non-human and human induced. The Dunefield Midden bovids have modifications belonging to both. Non-human induced modifications include weathering (abrasion, polish, bleaching and

![Figure 7](image-url)
exfoliation), trampling, carnivore and rodent tooth marks, and acid and root etching. This category may also include excavation and/or preparation damage, but this was slight and easy to control for. Human induced modifications include cut marks (which can be further subdivided into cut, slice, scrape, shave and gouge marks) hammerstone-induced conchoidal flake scars or ‘percussion notches’ (and resulting bone flakes), percussion marks (pits, grooves, patches of stria tions), incipient fracture cracks, crushing, polish and burning. This category may also include human tooth marks, but currently no methodology exists to distinguish these from striated tooth marks made by carnivores (Binford 1981; Fisher 1995; but see Landt 2007).

Non-human induced modifications

Non-human induced modifications are present on over half the longbone assemblage of each size class (small bovid = 64.7%; small–medium bovid = 69.4%; large bovid = 52.5%) (Figure 8a). The extent to which each taphonomic process impacted bovid longbones varies tremendously. The most ubiquitous by far are root etching and weathering which affected 35.4% and 19.9% of all bovid longbones, respectively. Frequencies of the other non-human modifications are negligible. Visible carnivore damage (tooth marks, scoring and furrowing) occurs on only 4% of longbones, although the element MNIs and longbone fragmentation analyses presented elsewhere strongly suggest these agents were more destructive than this (Stewart 2008, in prep.). Trampling striations (Behrensmeyer et al. 1986; Fiorillo 1989; Oliver 1989) occur on 2.2% of longbones, although this may be an underestimation since trampling on abrasive substrates such as sand dunes can leave striations on bone surfaces similar to (albeit more randomly oriented than) human induced cut, scrape and percussion marks; trampling is thus difficult to isolate with confidence (Shipman and Rose 1984; Olsen and Shipman 1988). Finally, rodent gnawing occurs on 1% and acid etching on 0.4% of bovid longbones.

Breaking down non-human induced modifications by bovid size class (Figure 8b) reveals two interesting patterns. First, an inverse relationship between root etching and weathering emerges when comparing the two smaller bovid size classes with the large bovids. Small and small-medium bovids appear more susceptible to root etching than large bovids, while the latter show a higher degree of weathering than the other two. This contradicts experiments of weathering rates on bone of different sized mammals undertaken in the Amboseli Basin, Kenya, in which larger carcasses degraded less rapidly than small (<100 kg) ones (Behrensmeyer 1978; see also Yeshurun et al. 2007). However, none of the habitats in that

Table 3. Human induced modifications on bovid non-longbone elements checked.

<table>
<thead>
<tr>
<th>Non-longbone element</th>
<th>Small bovid (NISP)</th>
<th>Small-medium bovid (NISP)</th>
<th>Large bovid (NISP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mandible</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Scapulae</td>
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</tr>
<tr>
<td>Carpals</td>
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</tr>
<tr>
<td>Tarsals</td>
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</tr>
<tr>
<td>Phalanges</td>
<td>0</td>
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</tr>
</tbody>
</table>
study included similarly sandy substrates, and the low rates of small and small–medium bovid weathering at Dunefield Midden may simply indicate the ease with which these much smaller bones can be quickly buried in unconsolidated dune substrates by aeolian processes and/or trampling. Second, the frequencies with which longbones of each size class are carnivore damaged are consistent (small bovid = 3.6%; small-medium bovid = 4.7%; large bovids = 4.9%), despite the fact that the longbone fragmentation patterning suggests they experienced differences in carnivore induced attrition (Stewart 2008, in prep.). This underscores the taphonomic necessity of undertaking rigorous, shaft-inclusive faunal analyses.

Figure 8. Dunefield Midden: nonhuman induced bovid bone modifications.

**Human induced modifications**

Human induced modifications can be split into three broad categories: (1) surface (cortical) damage from tissue severing; (2) surface (cortical) damage from percussion; and (3) subsurface (medullary) damage from percussion. Other human induced modifications on the Dunefield Midden bovid bones include burning, working bones into tools and trampling, but these are all very rare and thus are excluded from the
analysis. Due to the small sample size of the small–medium bovid assemblage, it could not be subjected to the same analysis as the small and large bovids, although isolated modifications on these bones are periodically brought into the discussion when relevant. I begin by discussing bone surface damage resulting from severing tissue.

**Damage from tissue severing**

Evidence on Dunefield Midden bovid bones for tissue severing consists of cut marks resulting from various forms of cutting, slicing, scraping and shaving. Nilssen (2000), 37–38 provides detailed descriptions of the various permutations and combinations that these and other tissue severing marks can take. He differentiates incisions produced by cutting (cut marks) and slicing (slice marks) as those made perpendicularly or at an angle to the bone surface, respectively. Both actions create ‘elongate, relatively narrow, linear striation[s] . . . imparted to bone by a sharp-edged implement, generally in the process of cutting through or removing attached soft tissue’ (Fisher 1995, 12). Cut/slice marks are typically V-shaped in cross-section and imparted to bone surfaces during carcass dismemberment, filleting or skinning (Bunn 1981, 1983; Shipman 1983; Shipman and Rose 1983; Nilssen 2000), On longbones they are often –

![Figure 9. Transverse-oriented cut mark with V-shaped cross-section on a small bovid distal tibia epiphysis.](image-url)
but by no means always (Nilssen 2000) — on or very near epiphyses (Figure 9) and oriented transversely or obliquely to the long axis of the bone. Scrape marks and shave marks result from a stone tool cutting edge moving across a bone surface at roughly a right angle to the direction that produces cut marks — that is, perpendicular, rather than parallel, to the long axis of the cutting edge. This creates ‘...a set of multiple, closely spaced, and parallel or nearly parallel striations that are elongate, linear, and relatively narrow’ (Fisher 1995, 18). Nilssen (2000, 38) notes that with shave marks these striations occur within (and perpendicular to the long axis of) a shallow shaved area, whereas with scrape marks ‘no part of the cortical surface has been shaved away.’ Scrape/shave marks have received far less attention in the literature than cut/slice marks, but those observed on ethnographic assemblages result almost exclusively from removing tissue — either meat or periosteum — from bone. The latter is commonly removed as a preparatory measure to facilitate bone cracking for marrow extraction (Binford 1981). Scrape/shave marks are generally more variable in orientation (transverse, oblique and longitudinal) than cut/slice marks (transverse, oblique) and occur most frequently on diaphyses (Wheat 1979; Binford 1981; Nilssen 2000).

Although ethnographic observations show that cut/slice and scrape/shave marks often grade into one another morphologically, at Dunefield Midden there is a marked morphological difference between transverse/oblique marks, which are mostly V-shaped, and those that are oriented longitudinally, which are mostly U-shaped. To maximise objectivity, I classify marks as either transverse/oblique or longitudinal rather than designating them cut, slice, scrape, shave marks and so forth (Leslie and Fisher 1990; Fisher 1995; Nilssen 2000).

Figure 10 shows the number of occurrences of transverse/oblique and longitudinal marks on the small and large bovid assemblages when all longbones in each assemblage are combined. Occurrences are not counts of individual marks, but rather the number of times a particular mark occurs in a given configurational zone (for example, anterior longbone end). Looking first at the transverse/oblique marks, a major difference can be seen in their distribution between the two bovid size classes. These marks occur more often on large bovid longbone ends than on these element portions of the small bovid assemblage, where they are found mostly on shafts. This discrepancy may point to size-related differences in butchery difficulty. Larger animals have more robust connective tissues that require greater effort to penetrate when disarticulating bones at joints, resulting in higher frequencies of cut marks in these areas (Marshall 1986; Cruz-Uribe and Klein 1994; Nilssen 2000). Perhaps also relevant is Binford’s (1981) observation that frequencies of cut marks near articular surfaces should be generally lower in stone tool-using societies than in ethnographically documented groups that use more intrusive metal tools (see Nilssen 2000, 227). Stone-tool users probably more often employed a technique combining leverage and strategically placed cuts (a so-called ‘dislocation strategy’) similar to that used by Nunamiut to dismember caribou. If this were the case with the Dunefield Midden bovids, it is unsurprising to see the fewest transverse and oblique marks on the smallest, most manageable species.

Of the relatively few transverse and oblique marks that occur on bovid longbone ends, the majority in both size classes are located on the medial and anterior surfaces of the distal humerus. Although Binford (1981) argued that this placement results from efforts to sever the tight humeral-radio-cubitus joint, Nilssen (2000, 246–247) has shown that most distal humerus mark placements equivocally result from
disarticulation and/or filleting. Other epiphyseal transverse/oblique marks, however, are more unambiguously consistent with dismemberment. By contrast, evidence for skinning, usually in the form of transverse and/or oblique marks on crania, mandibles, foot bones and lower limbs (Frison 1971; Binford 1981; Noe-Nygaard 1989; Reitz and Wing 2008), is extremely limited. Only three bone fragments exhibit marks that convincingly resulted from skinning: two small bovid metatarsals (one with transverse marks located on the proximal shaft and the other oblique marks on the middle shaft) and a small–medium bovid metacarpal (with transverse marks on the proximal shaft). Metapodial shafts in ethnographic assemblages frequently exhibit transverse marks created by skinning (Frison 1971; Binford 1981; but see Nilssen 2000), and the possibility that these marks result from filleting can obviously be discounted since metapodials are not important meat-bearing bones. That they were produced during periosteum removal is also unlikely since none of the marks are associated with percussion damage (see below).

In both size classes, most transverse and oblique marks are situated on meat-bearing longbone shafts. Since shafts are inappropriate as places to deliver cuts for anatomical dismemberment, their placement on these portions indicates that the majority of transverse and oblique marks on bovid bones result from tissue removal. Tissue removal marks (whether cut/slice or scrape/shave marks) concentrate more

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**Figure 10.** Occurrences of transverse/oblique and longitudinal marks on small and large bovid longbones.
heavily on diaphyses than epiphyses because the former are where most longbone meat is found and filleted, and these areas are targeted for marrow cracking and thus preparatory ‘cleaning’ (Binford 1981; Fisher 1995). Transverse/oblique marks on diaphyses are one of two forms of tissue removal marks observed on the Dunefield Midden bovids – the other form is longitudinal. Longitudinal marks are sinuous, U-shaped, internally striated marks running parallel to the long axis of longbones and commonly have a series of obliquely oriented striations emanating from the main mark (or so-called ‘feathering’) (Lewis 2008) (Figure 11). The latter look similar to marks that Eickhoff and Herrmann (1985, 267–269) observed on Neolithic skeletons from Saxony, what they refer to as ‘splitting’. Only one longitudinal mark occurs on a (small) bovid longbone end (Figure 10), and this occurrence is the terminus on a distal tibia epiphysis of a longer mark that originates mid-shaft. All others are exclusive to shafts, implying that these too are products of tissue removal.

From Figure 10, however, it is clear that the frequency and distributions of the two tissue removal mark types – transverse/oblique and longitudinal – differ greatly both between and within the two bovid size classes. Longitudinal marks are much more frequent and occur in far more configurational zones on small bovid longbones (NISP = 37; number of occurrences = 51) than those of large bovids (NISP = 3; number of occurrences = 6). Within the small bovid assemblage, longitudinal marks not only occur more frequently than transverse/oblique marks, but are also more tightly clustered. The majority occur on posterio-lateral shaft fragments (58.8%), whereas transverse/oblique marks are more evenly spread across the zones. Further, when mark frequencies on small bovid longbones are examined by element, longitudinal marks cluster much more dramatically: the vast bulk occur on small bovid tibiae and femora (94.6%) (Figure 12). In fact, longitudinal marks on small bovid tibiae and femora comprise the majority (50.7%) of all tissue severing marks on longbones of this size class and nearly a third (26.0%) of all tissue severing marks on small and large bovid longbones combined.

Surface and subsurface percussion damage
Blumenschine and Selvaggio (1988) have shown that diagnostic evidence for hammerstone percussion can occur on the longbone cortical surface or medullary subsurface (see also Domínguez-Rodrigo 2002; Domínguez-Rodrigo and Barba 2006). At Dunefield Midden, surface percussion damage takes two forms: cortical flaking and percussion marks. Cortical flaking typically occurs on the opposite side of the bone from percussion notches (see below) and thus represents damage sustained where the bone was in contact with a stone anvil. Percussion marks consist of superficial patches of striations, and pits and grooves with or without associated striations (Blumenschine and Selvaggio 1988). These are created at impact points on bone cortical surfaces by natural protrusions in the hammerstone, hammerstone slippage during percussion or slippage of the bone against an anvil during percussion (Blumenschine and Selvaggio 1988; Fisher 1995). Subsurface hammerstone percussion damage, or ‘percussion notches’, consists of conchoidal flake scars on bone medullary surfaces that occur when a hammerstone blow breaks the cortical surface (Blumenschine and Selvaggio 1988). These usually result from hammerstone blows on green bone. On longbones they fan out along the medullary cavity from the impact point on the cortical surface where they leave a characteristically crescentic or
arcuate fracture edge. The resulting bone flakes sometimes remain partially attached to the scar. These incipient percussion notches are common at Dunefield Midden.

Percussion marks and/or cortical flaking are present on 11.8% (NISP = 69) of small bovid marrow-yielding longbone fragments and 18.9% (NISP = 30) of those of large bovid. Percussion notches are more abundant on small bovid longbones at 17.0% (NISP = 100) and slightly less so on large bovids at 15.7% (NISP = 25). The surface and subsurface percussion damage on these two taxa are now compared. I proceed element-by-element beginning with the meat-bearing longbones before turning to the metapodials.

Small bovid humeri exhibit most surface and subsurface percussion damage on the medial and lateral shafts (Figure 13). Percussion notches are most frequent on the medial side, while percussion marks and cortical flaking occurs on the opposite lateral surface. The high degree of visible damage to converse sides of humeri makes it clear that these elements were broken using the hammer-and-anvil technique. Large bovid humeri show a consistent pattern of percussion that differs from their smaller counterparts: notching occurs on the distal shaft (very near the epiphysis) on the
anterior and posterior sides with what appears to be converse percussion damage on the anterior surface (Figure 14). Again, the hammer-and-anvil technique is implicated (on at least two specimens) but blows were clearly dealt to different surfaces than those of small bovid humeri.

Percussion notches on small bovid radii are highest on the posterio-lateral near-end shafts, whereas surface percussion damage concentrates overwhelmingly on anterior near-end shafts (Figure 13). Again, this implies that hammerstone blows were delivered to the posterio-lateral near-end surfaces of these elements while resting on an anvil. Upon impact, the sedimentary particles of the anvil stones abraded their broad, flat anterior surfaces resulting in very high frequencies of percussion marks. The only small–medium bovid radius with percussion damage exhibits this same pattern. Evidence of percussion on large bovid radii is remarkably rare given the relatively high number of these longbone fragments: only four percussion notches are present and surface percussion damage is absent entirely. On this very small sample medial near-end shafts were targeted for blows (Figure 14), a more directly side-on approach than that taken on small bovid radii which resulted in a different pattern of percussion damage (no marks as compared to the heavily

![Diagram of longbone fragments with marked percentage of total fragments marked for transverse & oblique and longitudinal marks.](image-url)

Figure 12. Dunefield Midden: Proportions of transverse/oblique and longitudinal marks on small bovid longbones.
Figure 13. Dunefield Midden: Percussion damage frequencies on small bovid longbones.
Figure 14. Dunefield Midden: Percussion damage frequencies on large bovid longbones.
striated small bovid anterior shafts). However, hammer-and-anvil percussion on these elements cannot be demonstrated.

Turning to the hindlimbs, small bovid femora are notched with equal frequency on their medial and lateral sides (Figure 13), but surface percussion damage is highest on lateral surfaces. Visual observation suggests that the latter is mostly in the form of cortical flaking from converse percussion damage. Femora too, therefore, seem to have been cracked for marrow using a hammer and anvil, with blows being dealt mostly to the medial surface. Large bovid femoral fragments are very few, but the pattern is largely consistent with these small bovid femora—blows are delivered side-on with the bones resting on an anvil, although with lateral rather than medial surfaces perhaps favoured (the very small sample size makes this difficult to assess) (Figure 14).

Small bovid tibiae exhibit more complex patterns than other longbones (perhaps because of their larger sample size?). Percussion notches are most frequently situated on lateral sides, followed by posterior, then anterior and finally medial (Figure 13). Surface percussion damage occurs mostly on anterior and lateral surfaces. Part of the ambiguity likely stems from bone morphology—tibiae are, at the same time, angular and rounded and thus modifications in this configurational scheme often overlapped multiple surfaces. The overall visual impression is that the posterio-lateral shafts were dealt blows, with the bone resting on an anvil anterior-medial face down. Variations do exist, however, with percussion notches also occurring on anterior and medial sides, sometimes very close to distal epiphyses. The size of the large bovid tibia sample, like that of femora, is very small but these elements seem to have been cracked consistently. Blows were dealt exclusively to lateral and medial near-proximal end shafts using the hammer-and-anvil technique, leaving often severe cortical flaking and percussion marking on the side opposite (Figure 14). Percussion of large bovid tibiae thus exhibits less variation than those of small bovid, but in both cases most blows were dealt to the lateral surfaces. Unfortunately, the hugely different sample sizes make further comparisons tenuous.

Metacarpals and metatarsals are grouped together to take account of modifications on fragments of these elements that could not be assigned with confidence to either one. Both small and large bovid metapodial bone cracking appears standardised. However, as with the forelimbs, the configurations diverge. Surface and subsurface percussion damage on small bovid metapodials centres on the medial and lateral sides (Figure 13). Lateral sides are perhaps preferred striking platforms, as they possess more notches and medial sides more surface damage. The breakage technique is certainly hammer-and-anvil, as converse percussion damage exists in almost every case. Evidence for marrow cracking is scant on large bovid metapodials and percussion patterns are more difficult to interpret for two reasons. First, evidence is confined mostly to metacarpals (perhaps because these are more numerous than metatarsals?). Second, several metapodial epiphyses exhibit evidence of carnivore chewing, and some or all of the many pits found on diaphyses (all without striae) may result from this rather than percussion. Nevertheless, the few examples available suggest that the Dunefield Midden inhabitants preferred delivering blows to the broad, flat posterior surface of large bovid metacarpals (Figure 14), rather than lateral or medial surfaces as with the small bovids. This could reflect either a functional adaptation or a culturally specific ‘stylistic’ choice.
(Yellen 1991). Hammer-and-anvil percussion is suggested, but the ambiguous pits on anterior surfaces make this difficult to demonstrate. Most metapodials of all size classes were split longitudinally through the (particularly proximal) epiphyses. Finally, one large bovid metacarpal and one metatarsal (both rights) have substantial cortical flakes removed from their proximal epiphyses. In both cases, the proximal articular surface was used as a striking platform, resulting in several fairly thick flakes being removed from the anterior-medial epiphyseal surface of the metacarpal and from the anterior epiphyseal surface of the metatarsal. What the flakes were used for is unknown, but several of the handful of Dunefield Midden bone awls/points appear to have been fashioned from large bovid proximal metapodials.

**Discussion and conclusion**

One potential hindrance to drawing robust behavioural inferences from the data presented above is that high incidences of root etching and weathering may have impacted human induced modification frequencies. However, the vast bulk of root etching is very slight, and the sinuous shapes of root etches, along with the staining within their grooves, make them easily distinguishable from cut or percussion marks (Lyman 1994, 377), even in more severe cases (Figure 15). Similarly, most evidence of weathering is restricted to bleaching or polishing from aeolian sand abrasion, rather than serious exfoliation of cortical surfaces. Although this issue cannot be firmly resolved until the remainder of the Dunefield Midden bovid bone fragments are inspected, the remarkable freshness of (particularly the small) bovid bone surfaces means that cut, scrape and percussion mark frequencies are probably not seriously biased by obliteration resulting from diagenesis.

The potential impact of carnivores on surface modifications should not, however, be underestimated. Although carnivore-induced modifications on Dunefield Midden bovid bones are relatively rare (4.0%), the copious longbone-end deletion evidenced by the fragmentation analysis (Stewart in prep.) suggests that these taphonomic agents may be partially or largely responsible for the low frequencies of epiphyseal

![Figure 15](image-url)  
**Figure 15.** Percussion or perhaps trampling damage clearly visible on a small bovid radius shaft despite considerable root etching.
marks characteristic of carcass dismemberment. Carnivore chewing, along with trampling, can also mimic percussion marks (Binford 1981; Shipman and Rose 1983; Blumenschine 1988; Potts 1988; Fiorillo 1989; Oliver 1989). Percussion notches and cortical flaking are thus considerably better indicators of marrow cracking patterns, particularly since percussion notches more commonly result from direct hammerstone impact and cortical flaking from converse damage on an anvil, whereas percussion marks are more easily produced by either.

Notwithstanding these taphonomic hazards, the configurational analysis presented above reveals some interesting patterns in how the inhabitants of Dunefield Midden processed bovid carcasses. Differential transverse/oblique mark frequencies on small and large bovid longbone ends likely point to differences in butchery strategies related to animal size (Nilssen 2000, 213). Dismembering an eland into appropriately sized packages for consumption requires much more effort than that needed for a steenbok; the higher proportion of large bovid epiphyseal fragments with V-shaped transverse/oblique marks likely attests to this. Dewar et al. (2006) also found very low frequencies of dismemberment marks on the many small-medium bovid (springbok) bones at the Namaqualand mass kill site, SK400. An alternative possibility is that the Dunefield Midden inhabitants employed bludgeoning as a technique to dislocate small bovid joints, similar to that occasionally used by the Alyawara and Nunamiut when they process smaller mammals (as observed by Binford 1981). If so, carnivores may be getting the short end of the bone, as it were, as the prime culprits of longbone end deletion (Stewart in prep.). However, Binford reports the use of this technique as rare, and in any case it is difficult to see how this could be realistically differentiated from density-mediated attritional processes. As far as I am aware, moreover, this technique has not been documented in African ethnographic contexts.

The lack of more evidence for skinning beyond two small bovid metatarsals and a small-medium bovid metacarpal is puzzling, particularly considering the frequency with which bovid skins (especially steenbok) are processed in the Kalahari (Lee 1979; Silberbauer 1981; Yellen 1991). Although small and large bovid cranial, mandible and phalanx fragments were not examined as thoroughly as longbones, carpals and tarsals, they were checked. However, Nilssen (2000) observed in his actualistic butchery study that skinning almost never left marks on small and large bovid longbones (as opposed to carpals, tarsals, mandibles and crania). The several that did occur were restricted to distal tibiae and radii and could not be unambiguously distinguished from marks resulting from dismemberment or filleting; Dunefield Midden may present an analogous situation. Failing this, the lack of marks either reflects extreme skill in hide removal, or that Dunefield Midden’s inhabitants were simply interested in other bovid products. Indeed, the very high MNI (87) of Cape fur seals may indicate that the skins of these animals were more sought after, a scenario consistent with eighteenth century accounts of coastal foragers wearing and trading seal skins in southern Namibia (Smith and Pheiffer 1992, 1993).

The vast majority of cut marks on longbones of both size classes occur on diaphyses and are clearly related to tissue removal. These come in two forms – transverse/oblique and longitudinal. The differences between these two tissue removal mark types in morphology and the frequency with which they occur on certain elements provoke the question of whether they originate from different tasks – namely, filleting versus longbone cleaning for marrow extraction. Confounding the
issue is Binford's (1981) observation that each task involves making incisions that have the potential to create both types of mark. Filleting, for example, entails

... generally two types of cuts: (a) initial long, longitudinally oriented, bone exposing cuts, and (b) shorter, more oblique cuts made to the underside of the exposed bone to free it from the mass of meat and/or sever muscle insertions. Given such a strategy, it is not surprising to see longitudinally oriented cut marks and shorter, more obliquely oriented marks along the posterior and anterior surfaces of long-bone diaphyses. (Binford 1981, 129)

Similarly, cleaning longbones of remaining meat and tendon produces 'short, parallel cut marks essentially indistinguishable from ... filleting marks', while removing the sheath of periosteum leaves ‘longitudinal scratches and striations’ along longbone diaphyses (Binford 1981, 134). Nilssen (2000), moreover, observed tremendous variability in placements and orientations of marks derived from filleting, many of which resemble periosteum cleaning marks documented by Binford (1981). This morphological overlap makes distinguishing between these two tasks problematic. Leslie and Fisher (1990) also struggle with this issue in their analysis of pronghorn antelope remains from Lost Terrace (north-central Montana). They note the presence of cut marks on pronghorn longbone diaphyses similar to both types of tissue removal marks observed on the Dunefield Midden bovids, and speculate that transverse/oblique marks result from filleting and the longitudinal, sinuous variety from cleaning prior to marrow cracking.

Close inspection of longitudinal mark placement on the small bovid femora and tibiae (on which over 95% of these marks occur) reveals that they are often closely associated with percussion notches, percussion marks and cortical flake scars. On some bone fragments, they occur on the cortical surfaces that directly overlay percussion notches (Figure 16). On others, they are directly truncated by cortical flake scars (Figure 17). The only longitudinal marks that occur on the cortical surface of a small bovid radius cut across a gap formed by an incipient flake (Figure 18). Similarly, on one of the only two large bovid longbones (both tibiae) with longitudinal marks they directly overlap and are truncated by a prominent percussion notch (Figure 19). Finally, a longitudinal mark was found on the medullary, rather than the cortical, surface of a small bovid radius (Figure 20), providing a direct association of this type of mark with the act of marrow removal itself. Observing Nunamiut marrow cracking techniques, Binford (1981, 135) notes that: "The secret to controlled breakage of marrow bones is the removal of the periosteum in the area to be impacted" [my emphasis]. The consistent association of longitudinal marks and percussion damage strongly suggests that these marks result from periosteum removal in preparation for marrow cracking to avoid the intrusion into the marrow of diaphyseal splinters.

Strengthening this inference is Binford's (1981) observation that longitudinal filleting marks on Nunamiut assemblages are principally found on the scapula and pelvis (a pattern also evident in Hadza assemblages – O’Connell et al. 1992), whereas short, oblique or transverse marks result when filleting longbones (see also Nilssen 2000, 190–193, 200–204). On numerous Dunefield Midden bovid longbone diaphyses, the placement of transverse/oblique marks is highly consistent with those created by the Nunamiut or Nilssen’s (2000) butchers during filleting. On longbones
Figure 16. Longitudinal marks overlapping a percussion notch on a small bovid femur fragment.

Figure 17. Longitudinal marks truncated by cortical surface damage on mechanically refitted small bovid tibia fragments.
Figure 18. Longitudinal marks overlapping a percussion notch with an incipient flake on mechanically refitted small bovid radius fragments.

Figure 19. Longitudinal marks truncated by a percussion notch on mechanically refitted large bovid tibia fragments.
processed by the Nunamiut, these typically ‘...cluster where the shape of the bone is irregular and where there are numerous muscle insertions’ (Binford 1981, 130). Examples at Dunefield Midden include transverse/oblique marks on the prominent ridge that forms the proximal lateral margin of two small bovid tibiae, on the convex surface that forms the opposite (medial) side of the tibial crest and on a large bovid anterior tibial crest. Two small bovid and one large bovid ulnae exhibit oblique marks along their posterior ridge. Series of oblique marks occur on large bovid proximal and distal femora, and on several distal humerus shaft fragments. These are all areas identified by Binford (1981; see also Nilssen 2000) as hotspots for filleting marks.

The configuration of tissue removal marks on Dunefield Midden bovid bones and their association with percussion damage both appear to lend support to the correlations posited by Leslie and Fisher (1990) at Lost Terrace: transverse/oblique marks on longbone diaphyses result from filleting and longitudinal marks from diaphyseal cleaning. Yet the Dunefield Midden data also present several problems. First, and most inscrutably, there is a complete absence of longitudinal marks on the metapodials of each bovid size class, the only longbones that yield solely marrow. Binford (1981), by contrast, notes particularly high frequencies of these marks on metapodials from Nunamiut assemblages. Second, longitudinal marks are extremely rare or absent on all bovid longbones besides small bovid femora and tibiae, despite the fact that all appear to have been cracked for marrow. Third, although longitudinal marks often occur in association with percussion damage, this is by no means always the case. In fact, in some cases they occur in areas exactly where Binford (1981) and Nilssen (2000) suggest we should expect to find filleting marks.

These problems can be addressed by integrating the longitudinal mark distributions with the configurational patterning of percussion damage. The latter show a distinction between small and large bovids in the consistency of methods used to crack forelimbs versus hindlimbs. Small bovid humeri, radii and metacarpals were targeted for percussion on different surfaces than large bovids. By contrast, broadly the same surfaces of large and small bovid femora and tibiae were struck (none of the few large bovid metatarsals exhibit percussion damage). Taken alongside the

Figure 20. Longitudinal marks with striae on the medullary, rather than cortical, surface of the bone.
Note: This strengthens their association with marrow retrieval.
conspicuous concentration of longitudinal (periosteum removal?) marks on small bovid femora and tibiae, and large bovid tibiae, it may suggest that the highest utility longbones were processed in a more standardised way than those of lower utility. This fits well with Yellen’s observations of the consistency with which the Ju/'hoansi treat different bovid longbones:

…species elements at each end of the continuum, those with the most marrow [femora and tibiae] and those with the least [ulnae], tend to be treated in the most consistent fashion. High standardisation results from the fact that most individuals when confronted by such species elements make the same decision. It appears that a general consensus exists on what species elements have the highest and lowest utility and standardised methods for marrow extraction – or lack thereof – have been developed. Yellen (1991, 21)

If the Dunefield Midden inhabitants were preferentially standardising the processing of certain bovid longbones, several scenarios can be put forward as to why. It is possible, for example, that hindlimb meat was commonly processed with an eye to storage, perhaps in the form of biltong (Yellen 1977), although Nilssen (2000, 140, 142) notes that the butchers he observed considered both small and large bovid tibiae meat too sinuous for drying or roasting. Alternatively, specific elements may have been consistently processed by specific individuals with idiosyncratic butchery techniques. One condition under which we may expect the latter to occur is the consistent distribution of specific elements to certain individuals through food sharing (Stewart 2008). Another activity that encourages standardisation is mass processing. Binford (1981, 158–163) documents a high degree of standardisation in longbone treatment when Nunamiut men and women perform ‘gang processing’ of many longbones at once for both meat and marrow. Testing these scenarios requires a full treatment of the bovid bone spatial patterning, which is beyond the scope of this paper (see Stewart 2008). Although many bovid bone modifications at Dunefield Midden surely result from culturally specific, ‘stylistic’ choices (Yellen 1991, 24; see also Seetah 2008), the consistency with which marrow-rich (particularly small bovid) bones were treated seems to support Yellen’s (1991, 21) contention that some aspects of carcass processing have a functional logic that ‘may extend across both ethnographic context and time.’

To conclude, the Dunefield Midden bovid size classes show marked differences in both non-human and human induced modifications, including damage from attritional processes, tissue severing and hammerstone percussion. Higher incidences of root etching on the smaller bovid taxa at Dunefield Midden contradict recent research by Yeshurun et al. (2007), who posit a positive relationship between degree of root etching and bone fragment surface area. The higher proportion of weathered large bovid bones relative to those of their smaller counterparts also runs counter to Behrensmeyer’s (1978) data on ungulate bone weathering rates, but is consistent with the findings of Yeshurun et al. (2007, 143). The higher frequency of damage from carcass dismemberment on the bones of larger animals probably reflects increased effort expenditure (Nilssen 2000), but taphonomic factors such as density-mediated attrition of longbone ends cannot be discounted (Stewart in prep.). Most tissue severing marks on both small and large bovid longbones occur on diaphyses and were almost certainly produced by removing tissue rather than dismemberment. Also, the close association of longitudinal marks with surface and subsurface

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percussion damage on bones of both size classes suggests they result from preparatory cleaning prior to marrow cracking. However, there are major differences in how longitudinal marks are distributed on different longbones both within and across Dunefield Midden bovid size classes, with the vast majority occurring on small bovid tibiae and femora. The uneven distribution of these marks, taken alongside differences in forelimb versus hindlimbs percussion patterns, may indicate that the most marrow-rich longbones were treated with a higher degree of standardisation, as observed in the Kalahari when Ju/'hoansi process small mammals (Yellen 1991). The hammer-and-anvil technique was clearly the predominant, if not exclusive, one used for marrow cracking as evidenced by the high degree of converse damage to longbones of all size classes, a finding consistent with the many stone anvils found at Dunefield Midden (Jakavula 1995).

Most importantly, this paper has shown that investigating types, frequencies and configurations of surface and subsurface modifications on refitted ungulate longbones permits a detailed, accurate reconstruction of butchery and bone processing techniques. Longbone refitting dramatically increases the number of identifiable fragments, providing accurate longbone sample sizes and the ability to attribute bone modifications on undiagnostic shaft fragments to specific skeletal elements. The result is a more realistic understanding of modification frequencies and configurations on animal carcasses. The main drawback to refitting is its tendency to be time-consuming (Klein and Cruz-Uribe 1998; Stiner 1998; Klein et al. 1999) and many research agendas, project budgets and zooarchaeological assemblage types preclude it. Further, shafts can now be more rapidly incorporated into estimates of minimum number of skeletal elements (MNE) using GIS (Marean et al. 2001; Abe et al. 2002). But for developing a detailed picture of the behavioural factors shaping the composition of an ungulate bone assemblage there are few substitutes. The strength of this position will be tested in a forthcoming paper that investigates Dunefield Midden bovid skeletal element abundance and longbone fragmentation and integrates these analyses with the modification data presented here using a multivariate, shaft-inclusive approach.

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