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Improving mortality profile analysis in zooarchaeology: a revised zoning for ternary diagrams

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ABSTRACT

Mortality profiles have figured prominently among tools used by zooarchaeologists to investigate relationships between hominids and prey species. Their analysis and interpretation have been considerably influenced by M.C. Stiner's approach based on ternary diagrams. Part of this method included the demarcation of “zones” in ternary diagrams identifying specific mortality patterns (e.g. attritional, catastrophic, prime-dominated, etc.). Since its introduction some twenty-five years ago, this zoning has, however, received little critical attention. Mathematical modelling as well as a reassessment of the ecological data used to define these zones reveal several problems that may bias interpretations of mortality profiles on ternary diagrams.

Here we propose new, mathematically supported definitions for the zoning of ternary diagrams combined with species-specific age class boundaries based on ethological and ontological data for seven of the most common hominid prey (bison, red deer, reindeer, horse, zebras, African buffalo and common eland). We advocate for the use of new areas (JPO, JOP, O and P zones) that produce more valid interpretations of the relative abundance of juveniles, prime and old adults in an assemblage. These results contribute to the improvement of the commonly used method of mortality profile analysis first advanced by M.C. Stiner.

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1. Introduction

1.1. Mortality profiles in zooarchaeology

Mortality profiles are widely used in zooarchaeology, serving as a key line of evidence for exploring relationships between past societies and the animal species they exploited (e.g. Frison, 1978; Stiner, 1991b; Brugal and David, 1993; Stiner, 1994; Morel and Müller, 1997; Turner et al., 2002; Steele, 2004; Fernandez et al., 2006; Bignon, 2008; Hill et al., 2008; Bunn and Pickering, 2010b; Street and Turner, 2013). Age-frequency distributions are commonly used to document choices made by human populations in terms of prey acquisition strategies (e.g. Reher, 1973; Klein, 1982; Stiner, 1990; Brugal and David, 1993; Fernandez et al., 2006; Driver and Maxwell, 2013) or herd management (e.g. Payne, 1973; Halstead, 1998; Greenfield, 2005; Vigne and Helmer, 2007; Marom and Bar-Oz, 2009).

Based on data from contemporary wild populations, two theoretical models have been proposed to describe the demography of stable large mammal cohorts (Deevey, 1947; Caughley, 1966, 1977). The first corresponds to the age profile of a typical stable living population, often referred to as a “catastrophic” or “living structure” pattern. The second basic mortality type is characterized by an under-representation of prime adults alongside larger numbers of young and old individuals, which corresponds to “attritional” mortality factors implicating elevated mortality rates for juvenile and old individuals. In the fossil record, these basic mortality types were first used by palaeontologists to shed light on the mortality factors underlying the formation of faunal assemblages (e.g. Kurtén, 1953; Voorhies, 1969), and later by zooarchaeologists in order to considerably enrich discussions concerning past hunting strategies (e.g. Reher, 1970, 1973; Klein, 1982; Stiner, 1990):

- “Catastrophic” profiles are generally considered illustrative of mortality events related to natural disasters (Voorhies, 1969;

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Lyman, 1987), mass kills (e.g. Reher, 1970; Levine, 1983; Costamagno et al., 2006; Hill et al., 2008; Kuntz and Costamagno, 2011; Rendu et al., 2012) or non-selective hunting episodes (e.g. Klein, 1978, 1981; Stiner, 1990; Costamagno, 2003). Solitary ambush predators do not track their prey but generally capture them during chance encounters, meaning that these predators are more likely to generate mortality profiles resembling the expected age structure of a living population, i.e. catastrophic profiles (Stiner, 1990).

- "Attritional" mortality profiles can have several causes, including disease, malnutrition, accidents and predation (Clutton-Brock et al., 1982; White et al., 1987; Stiner, 1991b; Delgiudice et al., 2006). Social cursorial carnivores (e.g. wolves, wild dogs and spotted hyenas), which engage in long chases of their quarry, are also more prone to produce attritional mortality profiles (Stiner, 1990). While Klein (1978) interpreted attritional profiles in Palaeolithic sites as reflecting the inability of hominids to hunt prime-age adults, Stiner (1991a) interpreted them as the product of scavenging.

Additional mortality types have also been recognized in archaeological assemblages. For instance, old-dominated mortality profiles have been considered typical signatures of scavenging (Klein, 1982; Klein and Cruz-Uribe, 1991; Stiner, 1991a, 1994), as primary predators often leave behind very little of the fragile skeletons of young individuals. Stiner (1990, 1991a) also showed that several archaeological sites exhibit a strong bias towards prime adults, with the selection of the most profitable prey considered evidence for the emergence of specific hunting strategies (selective ambush techniques) during the Late Mousterian. Prime-mortality profiles have since been recognized in older archaeological assemblages (e.g. Wallertheim cf. Gaudzinski, 1995; Le Lazaret cf. Valensi and Psathi, 2004; Bocksteinschmiede cf. Krönneck et al., 2004; see also Steele, 2004) as well as in natural accumulations (e.g. Wolverton, 2001, 2006; Kahlke and Gaudzinski, 2005).

1.2. Methods used to identify mortality patterns

While the analysis of mortality profiles is not limited to the identification of a specific mortality pattern (e.g. catastrophic or attritional mortality), these broad categories often guide behavioural interpretation. Because of their significant interpretative power, it has long been considered important to both elaborate and improve the tools available to zooarchaeologists for identifying different theoretical mortality patterns (e.g. Klein, 1982; Lyman, 1987; Stiner, 1990; Steele and Weaver, 2002). Zooarchaeologists working with Palaeolithic assemblages have favoured two types of graphical representations to identify these patterns, histograms and ternary plots. Although other graphical solutions can be used to represent age distributions (e.g. survivorship curves cf. Deevey, 1947; Caughley, 1966; Spinage, 1972; Millard and Zammuto, 1983), they have rarely been applied to mortality analyses in zooarchaeology (although see Lyman, 1987; Fernandez and Legendre, 2003; Fernandez et al., 2006). For instance, survivorship curves, commonly used in Neolithic contexts (e.g. Payne, 1973; Vigne and Helmer, 2007; Marom and Bar-Oz, 2009), feature far less often in Palaeolithic studies (e.g. Klein, 1978). Similarly, the alternative advanced by Klein et al. (1981), which relies on boxplots of crown heights representing age distribution of adults, is still rarely employed (Klein and Cruz-Uribe, 1996; Steele, 2005; Klein et al., 2007).

Histograms are commonly used to represent the relative or absolute frequency of individuals in a series of age classes. Generally, age classes are defined either as a given duration in years or months (e.g. Voorhies, 1969; Lyman, 1987; Turner, 2002) or as a proportion of total life expectancy (Klein, 1982). In a histogram where age classes are of similar duration, the shape of the age profile provides an initial assessment of the corresponding mortality pattern. The curve of a catastrophic profile is typically "L-shaped" (i.e. half-pyramidal), characterized by a progressive decrease in the number of individuals in each subsequent age class (Fig. 1a). Conversely, the curve of attritional profiles is most often "U-shaped" (Fig. 1b), with juvenile and old individuals being best represented and prime adults rare. It is important to note that the "L" or "U" shape of an age profile can only be recognized on histograms where age classes are of similar duration. However, depending on the ageing method used, the precision in age estimates is not always sufficient for individuals to be ascribed to classes of equal duration. In such cases, "corrected" age profiles are sometimes produced by dividing raw class frequencies by the percentage of lifespan represented by a given class in order to render them comparable with theoretical profiles (Bignon, 2006a; Vigne and Helmer, 2007, Fig. 5).

While H.C. Greenfield (1988), in his study of Neolithic domestic animal production strategies, was the first to rely on a three-age system where assemblages are plotted on ternary diagrams, it was M.C. Stiner (1990, 1991a, 1994) who popularized the method. In promoting its clear advantages for the comparison of mortality profiles from small samples, she proposed three age groups (juveniles, prime adults and old adults), which "*correspond to major life history phases in artiodactyls and equids*" (Stiner, 1990: 311). Individuals with deciduous teeth were considered as juveniles, those with the full complement of permanent teeth as prime adults and individuals with more than half of their crown worn away as old adults. These broad age classes are interesting as they correspond to nutritional trade-offs faced by hunters as well as non-human predators. Juveniles and old adults have lower fat levels than prime adults, and juveniles have a lower body weight, while prime adults provide the most calories, yet are less vulnerable to predation. By comparing a large number of age profiles from both archaeological sites and modern wildlife datasets on ternary diagrams, Stiner (1990) was able to discuss niche separation in prey age selection between different predators. While this was not the main objective of her analyses, Stiner (1990) also identified various zones on ternary diagrams that were correlated with basic mortality patterns (Fig. 1c). In addition to areas delimiting profiles reflecting a bias towards one of the three main age groups (juvenile, prime and old dominated), she demarcated the expected range of variation for both U- and L-shaped profiles: "*The U-shaped mortality model and the natural cases of mortality […] occur in the lower left-central region of the graph […] The living-structure model, live census data, and cases of mass (catastrophic) death are distributed in the lower right-central region of the graph*" (Stiner, 1990: 319). Since 1990, Stiner's zoned ternary diagrams have been widely used in zooarchaeological studies, especially in Palaeolithic research (e.g. Lyman, 1994; Marean, 1997; Speth and Tchernov, 1998; Díez et al., 1999; Lubinski, 2000; Munro, 2001; Steele and Weaver, 2002; Kahlke and Gaudzinski, 2005; Adler et al., 2006; Wolverton, 2006; Hill et al., 2008; Byers and Hill, 2009; Steele and Klein, 2009; Rendu, 2010; Driver and Maxwell, 2013). When used in mortality profile analyses, ternary diagrams almost systematically employ Stiner's zonation. While the position of an age profile according to Stiner's zones is seldom the only line of evidence mobilised for interpreting mortality profiles, it has been used to identify an age profile as L-shaped, U-shaped, prime dominated, old dominated or juvenile dominated. This age profile can then subsequently be evoked as further evidence of a particular prey acquisition strategy. For example, when profiles from archaeological sites fall in the "L-shaped zone" on ternary plots, they could be interpreted as evidence for non-selective hunting episodes,

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