



A conceptual model for freshwater mussel (family: Unionidae) remain preservation in zooarchaeological assemblages

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ABSTRACT

Expectations for survival of vertebrate remains have been well developed and intensely studied in the zooarchaeological taphonomic literature. Taphonomic studies of shellfish remains focus on marine species and on variables relevant to remains from paleontological contexts (e.g., fossil marine beds). In this paper we develop a conceptual framework from which to derive expectations concerning the preservation of freshwater mussel remains focusing on two parameters, shell microstructure and shell shape. Shell size does not influence survivorship. Our model is validated through application to late Holocene zooarchaeological mussel assemblages from north Texas. Taphonomically robust species are important regarding zooarchaeological and biogeographic interpretations based on mussel paleofaunas, and fragile species are important indicators of whether or not an assemblage is well preserved.

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1. Introduction

Within zooarchaeology the topic of vertebrate taphonomy focuses on numerous variables that generally relate to natural and cultural transformation processes as summarized by Schiffer (1987). A central concern is bone preservation, which has been explored in reference to factors that cause fragmentation (Marean and Spencer, 1991; Marean et al., 1992; Stiner et al., 1995, 2005) and how those factors relate to a variety of causal agents such as, burning (Stiner et al., 1995, 2005), green fracturing by humans for use of within bone nutrients (Bar-Oz and Munro, 2007; Brink, 1997; Morin, 2007; Munro and Bar-Oz, 2005; Outram, 2001; Wolverton et al., 2008), crushing and pulverization for extraction of grease (Munro, 2004; Munro and Bar-Oz, 2005), trampling (Gifford-Gonzalez et al., 1985; Stiner et al., 1995), among a host of other agents (e.g., Marean and Cleghorn, 2003; Nagaoka et al., 2008; Pickering et al., 2003). A separate but related concern is how identifiable bone fragments are, a factor that relates to fragment size, which is a product of fragmentation intensity (Lyman, 1994a; Marean and Cleghorn, 2003; Marean and Kim, 1998; Marshall and Pilgram, 1993; Stiner, 1991). Bone preservation itself, however, is most often modeled conceptually as a factor of bone density, and this has been accomplished in a variety of ways—qualitatively (Brain, 1969) and quantitatively (e.g., Lyman, 1984, 1994b; Lam et al., 1998). Conclusions

from these models provide the general consensus that bones and portions of bones that are relatively high in density tend to preserve well. All of these studies are at the intraspecific scale because natural and cultural transformations that affect preservation of vertebrate remains have been most often related to answering questions of carcass exploitation for a variety of analytical purposes (Binford, 1978; Broughton, 1999; Nagaoka, 2005, 2006). Only rarely have preservation models relied on variables other than bone density to make predictions about taphonomic survival of carcass parts (see Darwent and Lyman, 2002 for a study of bone shape and diagenesis; see also Stiner et al., 1995, 2005).

Carcasses of vertebrate prey animals are resource patches that were exploited in a variety of ways related to contingencies of search and pursuit time, handling and processing costs, food value of carcass parts (utility), prey availability, and transport distance to occupation sites (Binford, 1978; Cannon, 2003; Munro, 2004; Nagaoka, 2005, 2006; Wolverton, 2002; Wolverton et al., 2008). The same is not the case among many species of mollusks (Bird et al., 2002; Botkin, 1980). For example, the carcass is not a resource patch in freshwater mussels. Instead, *mussel beds* are resources patches (Jones, 1991), foraging returns per individual prey item (but not necessarily per bed) can be expected to be relatively low. As in vertebrate prey animals, the individual carcass can be conceptualized as two portions, edible and inedible (shell). The shell itself, like bone, may have been exploited for a variety of other purposes (e.g., tools and ornamental adornments). But as prey for food, in marked contrast to many vertebrate prey species, mussels are a closed

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exoskeleton with a *small*, edible package inside. Shells would have been most easily opened through either fragmentation, heating, or steaming (Baker, 1942; Muckle, 1985; Parmalee and Klippel, 1974), and foraging returns and preservation in a taphonomic sense are most important at the *interspecific* scale because this is the scale at which body parts and caloric returns vary most (Bird et al., 2002; Randklev et al., 2009).

This paper focuses on factors that influence preservation of freshwater mussel remains. We adopt a few assumptions; first, analysis of the relative abundance of shellfish remains is meaningful (though by no means exclusively meaningful) at the interspecific scale. That is, changes through time in taxonomic abundance reflect either a change in bed exploitation by humans, change in environmental conditions in streams, and/or the effects of taphonomic processes that mediate preservation and potentially archaeological recovery (Bird et al., 2002; Botkin, 1980). Second, in a particular region in a particular mussel community, it should be possible to predict which species are likely to preserve and which ones are less likely to survive effects of fragmentation and diagenesis based on shell morphology much the same as it is possible to predict which skeletal parts are most likely to survive at the intraspecific scale in the vertebrate carcass. Third, even though shellfish remains tend to be fragmented in archaeological faunal assemblages, only some species exhibit morphology that leads to preservation of fragments that are sufficiently large and diagnostic to identify. We provide a conceptual model that predicts which species should preserve well and which should preserve poorly using two parameters—*density* and *shape* of shells—measured as weight per volume and sphericity respectively. We apply that model to several freshwater mussel (family Unionidae) zooarchaeological assemblages from north Texas.

2. Taphonomy of shellfish

Taphonomic studies of shellfish remains are common, especially in paleontology, and these studies often focus on biostratigraphy, paleoenvironmental reconstruction, biological species conservation, among other topics related to zooarchaeology (e.g., Brett and Baird, 1986; Brown et al., 2005; Cintra-Buenrostro, 2007; Claassen, 1998; Edgar and Samson, 2004; Erlandson and Moss, 2001; Helama and Valovirta, 2007; Kidwell, 1986; Lazo, 2004; Morey and Crothers, 1998; Muckle, 1985; Nielsen and Funder, 2003; Parmalee and Bogan, 1986; Parmalee and Hughes, 1993; Parsons et al., 1997; Peacock, 2000; Peacock and Chapman, 2001; Peacock et al., 2005; Peacock and Mistak, 2008; Rick et al., 2006; Warren, 1975, 1991, 1995). A diverse array of agents and processes can influence taphonomic histories in zooarchaeological shellfish faunas including handling and processing for food, the discard process (e.g., height from which shells are dropped by people), orientation of deposition, disparity in burning among shellfish remains of different species, rate of disarticulation of valves, exposure to trampling, chemical weathering in acidic soils, soil formation processes, rates of deposition, sedimentation and erosion, archaeological recovery methods, modification of shells by predators, and shell shape and microstructure. These factors have been studied in experimental and actualistic settings (Best and Kidwell, 2000a, 2000b; Hoffmeister et al., 2004; Kidwell, 1986; Muckle, 1985; Oji et al., 2003; Rick et al., 2006; Robins and Stock, 1990). Many of these studies seek to determine taphonomic patterns that can distinguish one taphofacies from another and provide analogs through experiments and actualistic geospatial studies that cover a variety of ecological, depositional, and burial contexts (most often in marine species) (e.g., Best and Kidwell, 2000b; Parsons et al., 1997). For example, a study by Wani (2004) identifies taphonomic processes that cause particular fragmentation patterns in *Nautilus* shells. Taphonomic experiments with *Nautilus*

are then structured into analogs with which to gauge the taphonomic histories of paleontological cephalopod faunas.

It is critical to note that despite the value of actualistic and experimental studies, particularly those designed for consideration of paleontological contexts, deposition in terrestrial archaeological deposits is much different than accumulation and fossilization in beds. Fossil bed formation is a function of community organization, exposure of shell remains during oscillating episodes of population recruitment, contact with other shells, not to mention a host of sedimentary and water chemistry factors (Best and Kidwell, 2000a,b; Kidwell, 1986). In contrast, as predators humans enhance the probability of shell disarticulation and fragmentation, and remains are potentially buried in shell midden contexts of variable composition (e.g., containing other forms of artifact debris and trash). What can be gleaned from actualistic and experimental studies is a host of parameters that influence shell survival through time whether in marine, freshwater, or terrestrial-archaeological contexts precisely because the starting point of any taphonomic history is an intact shell.

What aspects of shell morphology—at some scale, to some degree—mediate all aspects of shell fragmentation? A study by Zuschin and Stanton (2001) focuses on the properties that affect fragmentation in three marine species; they found that shell thickness at the highest point of the shell (the umbo) is the best predictor of compressive shell strength. Zuschin and Stanton (2001) also link resistance to fragmentation to shell microstructure; some species have less robust lamellar microstructure and fracture more easily than do others (see also Best and Kidwell, 2000b). In addition, the presence of drillholes caused by predators and parasites increases susceptibility to fragmentation during a shell's taphonomic history (e.g., Hoffmeister et al., 2004). Zuschin and Stanton's study also emphasizes shell properties that relate to fragmentation caused by sediment compaction; of particular importance is that number of points of contact among shells in beds increases rates of fragmentation. The primary goal of Zuschin and Stanton's (2001) study is similar to ours, to determine what macroscale properties of shells are most important in fragmentation and preservation. However, their study does not incorporate zooarchaeological data, focuses on only three species, and does not consider freshwater mussels. Our study builds on theirs by also examining shell shape and density as predictors of preservation in paleozoological contexts. In their study and in ours shell preservation does not relate to common measures of shell size, such as length. What is absent from previous studies is a conceptual model that enables close evaluation of shell preservation related to morphology at the interspecific scale analogous to the photon-densitometry and computer tomography models for the vertebrate skeleton at the intraspecific scale (Lam et al., 1998; Lyman, 1994b).

3. A bivalve shell preservation model

Microstructural strength and shape are often cited as physical characteristics of shells that mediate preservation in a variety of settings (see above). Thickness is the single size measure that appears to relate to preservation. It is important to note that our interest is not in whether or not complete shells preserve, however, but that diagnostic features of shells preserve, such as external morphology, pseudocardinal and lateral teeth, and/or the umbo. Related to the anatomy of these features, it is not thickness that matters most, but thickness relative to shell length and height. Together these variables represent shape, and progressively higher thickness relative to length reflects a compression in shell shape toward an increase in sphericity. No shell is perfectly spherical, but because the index of sphericity we use relies on measurements of length, thickness, and height, the higher an average sphericity index value for a species, the more round in areal-shape the shell is

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