THE TAPHONOMY OF ARCHAEOLOGICAL FISH REMAINS: EXPERIMENTAL APPROACHES TO UNDERSTANDING THE EFFECTS OF NATURAL AND CULTURAL PROCESSES ON THE PRESENCE AND IDENTIFICATION OF CUT MARKS

by

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A DISSERTATION

Presented to the Department of Anthropology
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

June 2014

DISSERTATION APPROVAL PAGE

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Title: The Taphonomy of Archaeological Fish Remains: Experimental Approaches to Understanding the Effects of Natural and Cultural Processes on the Presence and Identification of Cut Marks

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Degree awarded June 2014

DISSERTATION ABSTRACT

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Doctor of Philosophy

Department of Anthropology

June 2014

Title: The Taphonomy of Archaeological Fish Remains: Experimental Approaches to Understanding the Effects of Natural and Cultural Processes on the Presence and Identification of Cut Marks

Despite the fact that fish are a common component of coastal and other aquatic archaeological sites, fish bone taphonomy—including bone surface modifications and the effects of burial—remains woefully understudied. Various ethnographic accounts describe fish butchering techniques for immediate consumption and drying, yet cut marks are rarely reported on archaeological fish remains. To address a significant gap in our understanding of fish taphonomy, I devised an experimental research program aimed at assessing whether butchering fish produces cut marks on fish bones and, if so, what factors might account for the discrepancy between the experimental results and the archaeological record.

Chapter I provides an introduction to experimental archaeology, including the criticisms and benefits of this approach. Chapter II presents the results of my initial butchery experiment, which establishes that butchering fish can produce abundant cut marks. Chapter III evaluates the effect of the butcher's skill level on the number and distribution of cut marks produced on fish bone during butchery. The results indicate that professional butchers produce nearly 50 percent fewer cut marks than novice- and intermediate-level butchers. Chapter IV addresses the effect of post-depositional

taphonomic processes on the long-term visibility of cut marks. Despite a relatively short burial period (27 months), visible cut marks decreased by up to 75 percent, depending on the species. Chapter V is a re-analysis of the fish bone from column E6 at Daisy Cave (CA-SMI-261). Appling the referential framework I acquired through the experiments, I identified 62 cut marks on bones dating from the Early to Late Holocene.

A comprehensive understanding of aquatic resource use has implications for a broad range of archaeological topics, including our understanding of hominid diet and resource use; identifying butchery and processing practices among fishing peoples; distinguishing between human and natural agency in the accumulation of fish remains; and assessing questions of behavioral modernity and social complexity. As we continue to recognize the primacy of coastal adaptations throughout human history, it is increasingly critical to expand the breadth of our knowledge regarding the taphonomy of fish remains at archaeological sites.

This dissertation includes previously published and unpublished co-authored material.

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Willis, L. M., M. I. Eren, and T. C. Rick
2008 Does Butchering Fish Leave Cut Marks? *Journal of Archaeological Science* 35:1438-1444.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Jon Erlandson, and the rest of my committee for their assistance in the preparation of this manuscript. I would also like to thank Torrey Rick, now at the Smithsonian Institution, for encouraging my career and being a catalyst for this research.

Numerous people helped in the procurement of the fish specimens used for these studies. Thanks to Bob McMichael, Sean Fisk, and the Florida Fish and Wildlife Research Institute; to Gary Nelson and the Massachusetts Division of Marine Fisheries; to John Kerwin, Larona Lavallie, and the Washington Department of Fish and Wildlife Cowlitz Hatchery; and to Curt Kramers and the McKenzie Fish Hatchery for donating the fish.

Many thanks to my butchers: Dwight Collins, Chris Avila, and Shu Kaisi of Newman’s Fish Company in Eugene, Oregon; Andrew Boehm; Metin Eren; Ali McQueen; Carol Stafford; and Fraser Stuart. It was a smelly job, and I couldn't have done it without you. Thanks to Jamie Benning for advice regarding the pH testing, Leslie Reeder-Myers, and Rory Walsh.

Thanks to my parents, Scott and Joanne Willis, for not scoffing (too much) when I announced I wanted to become an archaeologist and for all their love and support. Finally, thanks to Andrew Boehm for being my sounding board and my teammate.

Support for this research came from University of Oregon’s Museum of Natural and Cultural History and the Department of Anthropology, and from Southern Methodist University's Institute for the Study of Earth and Man.

I dedicate this to my dad, Scott Willis. He taught me an appreciation of nature and the outdoors, and always encouraged me to question everything.

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CHAPTER I

INTRODUCTION

Experimental archaeology is deeply rooted in the history of American archaeology. Examples of experimental research in North American archaeology can be traced back to the 19th century. During the late 19th and early 20th century, North American archaeology was developing into a formalized discipline. According to Schiffer (2009), archaeologists during this period integrated experimental archaeology into their research to better understand the 'primitive' technologies that informed their evolutionary sequences. However, the emphasis on actualistic research faded in the early 20th century with the rise of culture history, when archaeologists became interested in building cultural chronologies, and less interested in asking 'how' or 'why' questions about the artifacts themselves.

By the mid-20th century, North American archaeologists again began using experiments to answer questions about the archaeological record. As in the 19th century, these experiments were confined primarily to issues of subsistence and technology (Ascher 1961; Coles 1973:13, 18). According to Ascher (1961:793), although such experiments covered "a relatively narrow range in the total cultural spectrum, [it] does not diminish their utility, for the bulk of archaeological data consists of evidence relevant to these areas." Similarly, Coles (1973:13) described subsistence and technology as "those ancient features that form the backbone of archaeology as a study, the surviving aspects of material culture." Yet, archaeologists needed to ask more complex questions "if experimentation [was] to develop and reach its potential as an important analytical tool" (Saraydar and Shimada 1973:349). Experimental archaeology now encompasses an extremely broad range of cultural materials, including perishable and non-perishable artifacts, faunal remains, as well as natural and cultural site formation processes.

More recently, some researchers began to apply experimental archaeology to phenomenological studies—that is, “the replication of people sensing, perceiving, or feeling certain things” (Mathieu 2002a:4). Although there are some detractors regarding the relevance of experimental archaeology for interpreting “human motive or emotion in the recent or remote past” (Reynolds 1999:158), researchers are, for example, using 3-D reconstructions to test or replicate perceptions of architectural spaces in the past (e.g., Gifford and Acuto 2002; Mathieu 2002a; Vranich 2002). The bulk of experimental studies, however, continue to focus on lithic technologies, ceramics, and faunal remains.

In this chapter, I outline my own experimental research program (cf. Schiffer et al. 1994) aimed at improving our understanding of fish bone taphonomy in archaeology, including the effects of pre- and post-depositional processes on cut mark production and survivorship. I begin by defining experimental archaeology and summarizing its theoretical foundations. I address the criticisms, limitations, and benefits of experimental archaeology as a whole. I then highlight the ways that experimental archaeology can contribute to our interpretations of the archaeological record, using examples relating to faunal remains and taphonomy. I conclude with a summary of my research and its broader implications.

After demonstrating that butchering fish can produce an abundance of cut marks on fish bone (Willis et al. 2008; Chapter II), the goal of my later studies was to explain the discrepancy between the original experimental results and the dearth of cut marks reported on archaeological fish bone. Possible explanations included human variability, cut mark survivorship, and modern analytic techniques. Two additional experiments were designed to understand the effects of the butcher's experience on the number and locations of cut marks on fish bone (Chapter III) and the impact of post-depositional taphonomic processes on the visibility of cut marks on fish bone (Chapter IV). Lastly, the results of the experimental research was applied to an assemblage of fish bones recovered from Daisy Cave (CA-SMI-261) on San Miguel Island, California, to see whether the current, standard analytic techniques are causing archaeologists to overlook cut marks on fish bone from archaeological assemblages (Chapter V). The results provide zooarchaeologists with an improved protocol for analyzing fish bone assemblages, leading to a better understanding of past human behavior and site formation processes in coastal, riverine, and other aquatic settings.

Defining Experimental Archaeology

What is experimental archaeology? Skibo (1992a:18) defined experimental archaeology as "the fabrication of materials, behaviors, or both in order to observe one or more processes involved in the production, use, discard, deterioration, or recovery of material culture." Shimada (2005:615) defined it as "a structured method for empirically testing our beliefs about and discovering the past material world and human activities through experiments." Mathieu (2002a:1) defined experimental archaeology as "a sub-field of archaeological research which employs a number of different methods, techniques, analyses, and approaches within the context of a *controllable* imitative experiment to *replicate past phenomena* (from objects to systems) in order to *generate and test hypotheses* to provide or enhance *analogies for archaeological interpretation*" (emphasis in original). According to Mathieu, this definition improved upon previous definitions by including the ultimate goal of experimental research—to provide or improve the analogies that help archaeologists interpret the archaeological record. Alternatively, Outram (2008) did not provide any one definition for what experimental archaeology is, but he clearly stated what experimental archaeology is not—it is *not* "re-enactment groups, outdoor education and public presentation centres, and other demonstrations of past life and technology" (Outram 2008:3; also see Reynolds 1999).

Given the diversity of the field, it is no wonder that definitions abound. It seems that with each new literature review or edited volume, the author takes the opportunity to 'redefine' experimental archaeology. In essence, experimental archaeology tests hypotheses about the cultural and natural processes that create and modify archaeological assemblages through controlled experiments to improve our understanding and interpretation of the archaeological record.

Many recent reviews of experimental archaeology make a clear distinction between laboratory experiments, where variables are carefully controlled, and actualistic or field experiments, where experiments occur in a natural setting with less control of the variables (e.g., Cruz 2007; Lubinski and Shaffer 2010; Mathieu 2002a; Outram 2008; Shimada 2005; Skibo 1992b). Each approach has its own benefits and drawbacks. For example, the control of variables in laboratory experiments means that results are repeatable, and provides more confidence in the relationship between that which is being tested and the results. However, "the results of controlled laboratory experiments are often abstract and seemingly far removed from an archaeological inference of the past" (Skibo 1992b:29). On the other hand, field experiments more closely replicate real-life conditions, but the lack of control over variables makes it difficult, if not impossible, to determine which variable(s) caused the result. Ideally, laboratory and field experiments are part of a two-step process where the effects of independent variables are individually determined before multiple variables are tested in a more natural setting.

Theoretical Foundations and Contributions of Experimental Archaeology

Experiments, regardless of discipline, are based upon the hypothetico-deductive model. Using a positivist approach, the experimenter formulates a hypothesis and tests to see whether this hypothesis can be falsified. If the hypothesis is falsified, the researcher must formulate a new hypothesis. If the hypothesis repeatedly holds up during the tests, the hypothesis is considered valid (Popper 2002:10). According to Outram (2008:1), "'valid', in this sense, does not mean 'true', but merely that the principles behind the hypothesis can continue to be used until falsified and replaced by a better set of principles." Although there are critiques to positivism (e.g., Cleland 2001; Feyerabend 1975; Kuhn 1962), it remains "the underlying philosophy of modern science" (Outram 2008:1).

Uniformitarianism and Analogy

How can archaeologists use experimental results to interpret the past? Two concepts—uniformitarianism and analogy—are implicit in the execution and interpretation of archaeological experiments. Uniformitarianism (specifically, methodological uniformitarianism [cf. S. J. Gould 1965]) asserts that natural laws are invariable in time and space. According to Gould (1965), this condition is necessary to use processes observable in the present to explain changes in the past, and is an accepted principle of all modern science (also see Gifford-Gonzalez 1991:219; Domínguez-Rodrigo 2008:69). Gould and Watson (1982:365) argued that uniformitarianism is essential to the scientific reasoning that underlies ethnoarchaeology (and, by extension, experimental archaeology), as it is what allows archaeologists to bridge the present to the past.

> [Uniformitarianism] furnishes assumptions about those relationships in nature which hold true in both the past and present, and it permits us to test these assumptions in cases of human behavior to see how much of the behavior we observe in human societies today must also have occurred in past human societies living under similar conditions (Gould and Watson 1982:369).

Similarly, archaeologists depend on analogies to infer details about the past (Crawford 1982; Gifford-Gonzalez 1991:220; Hodder 1982). The use of analogy in archaeology has often been criticized for being unreliable or unscientific (e.g., Freeman 1968; Wobst 1978). Some archaeologists (e.g., Gifford-Gonzalez 1991; Hodder 1982; Wylie 1985) argue that this criticism is due to the use of formal analogy in archaeology, wherein an archaeologist assumes similarities in a few aspects or characteristics indicate similarities across all aspects, or where similarities are based on physical characteristics only. According to Hodder (1982:16), formal “analogies are weak in that the observed association of characteristics of the objects or situations may be fortuitous or accidental.” An example of the problem of formal analogy can be found in the Ginsberg experiment, where Stanford et al. (1981) attempted to replicate possible bone tools from three suspected pre-Clovis sites dating back to 50,000 years ago. Based merely on the perceived similarities between the experimentally-produced bone tools and the ‘modified’ bone from the sites, the authors argued that their results provided evidence for early human activity, as well as provided a useful analogy for interpreting the Pleistocene-aged assemblages. The sites had no other evidence of Pleistocene-aged human presence, however, and are no longer accepted as pre-Clovis archaeological sites (e.g., Meltzer 1999; Nelson et al. 1986).

In contrast, relational analogies “involve a demonstration that there are similarities between source and subject with respect to the causal mechanisms, processes, or factors that determine the presence and interrelationships of (at least some of) their manifest properties” (Wylie 1985:95; also see Gidna et al. 2013; Gifford-Gonzalez 1991:224; Hodder 1982; Wylie 1989). For example, an experiment by Gidna et al. (2013) demonstrated that captive and wild lions produced different patterns of bone modification. The authors argued that experiments using captive carnivores create weak or misleading analogs, as a result of the different environmental context of captive (artificial) and wild (natural) animals. This study highlighted the importance of context when using analogies. Finally, the results of experimental studies contribute to a growing body of reference data that can be utilized to construct relational analogies (Gifford-Gonzalez 1991:224; Pobiner and Braun 2005).

Contributions to Theory

The modern manifestation of experimental archaeology in North American archaeology is closely tied to two theoretical approaches born of the New Archaeology: middle-range theory (Binford 1977, 1981) and behavioral archaeology (i.e., Schiffer 1976). For Binford (1981), the goal of middle-range theory was to define the law-like principles that translate the archaeological record into statements about past cultures; in other words, “to transform evidence into inference” (Schiffer 1988:462). Behavioral archaeology “is the study of material objects regardless of time or space in order to describe and explain human behavior” (Reid et al. 1975:864).

In regard to middle-range theory, Binford emphasized that actualistic studies, including experimentation, are the central methodologies for bridging the “dynamic properties of the past about which one seeks knowledge and the static material properties common to the past and the present” (Binford 1981:29). Domínguez-Rodrigo (2008) identified experimental archaeology as an integral component of both middle-range theory and modern scientific archaeology. According to Karr and Outram (2012a), the influx of experimental studies over the last 30 years on bone modification is a direct result of Binford’s “call for middle range research and the use of actualistic studies as a means of understanding the archaeological past.”

Similarly, experimental archaeology and ethnoarchaeology are key components in behavioral archaeology (Reid et al. 1975; Schiffer et al. 1994). Schiffer (1988) divided behavioral archaeology into three realms: social theory, reconstruction theory, and methodological theory. Of concern here is reconstruction theory, which includes “material culture dynamics (correlates), cultural formation processes of the archaeological record (c-transforms), and noncultural processes contributing to the formation of the archaeological and environmental records (n-transforms)" (Schiffer 1988:464). According to Schiffer (1988), experimental archaeology can be used to develop correlates (i.e. those principles that relate human behavior to material culture) and improve our understanding of natural and cultural formation processes.

Even as one of the primary tools utilized by archaeologists to address the questions asked by middle range research and behavioral archaeology, experimental archaeology is not immune to criticisms about its limitations, perceived or real. I will address these criticisms in the following section.

Limitations and Criticisms of Experimental Archaeology

The limitations or criticisms of experimental archaeology generally fall into two broad categories: problems relating to a lack of clearly stated methodologies or theories and incongruity in the relationship of experimental results to the interpretation of the archaeological record. Archaeologists have acknowledged these potential pitfalls since the resurgence of experimental archaeology in North America (i.e., Ascher 1961; Saraydar and Shimada 1973; Tringham 1978). Although significant strides have been made in how archaeologists formulate, interpret, and apply experiments, some of these criticisms are still applicable today.

Methodological and Theoretical Ambiguity

Ambiguous methodologies and theoretical biases have plagued experimental archaeology for over a century. According to Schiffer (2009:9), information about an author's methods or theoretical approaches "tends to be elusive" in publications dating to the "American School" of the late 19th and early 20th century. However, as experimental archaeology fell out of vogue during the culture-history period, the discipline did not attain "consciousness" (let alone "self-consciousness" or "critical self-consciousness"; Clarke 1973), and practitioners did not learn from these early shortcomings. In the early stages of the re-emergence of experiments in North American archaeology, Ascher (1961:794) acknowledged that, "the imitative experiment has failed to receive general acceptance because the evaluation of the procedures and results of such experiments are ambiguous." Similarly, Tringham (1978:171) argued that experiments in archaeology had been "justifiably ignored because of (1) their lack of a strong theoretical base and a resulting lack of general applicability in testing archaeological hypotheses … and (2) their lack of rigor and of attention to scientific experimental procedure in design, execution, recording, and analysis." Unfortunately, many of these issues are still pertinent today. Denys (2002:480) lamented that "the samples used for experiments are in most cases too small to be statistically significant, and the protocols are not always detailed in published papers."

A related issue concerns the potential for circularity. Using an example from flintknapping experiments, Teltser (1991:366) warned that:

> When a reduction model based on modern knapping experiments is used to categorize archaeological assemblages, an assumption is made that the reduction process is known. To the extent that the analytic goal is to elucidate the technological process, the logic becomes circular.

Circular logic remains a problem today, and not just for flintknapping experiments. In regard to butchery experiments, for example, Bement (2010) argued that general butchery studies, such as those examining the relationship between the number of strokes and cut marks, are of little use for reconstructing archaeological butchery sequences. According to Bement, butchery experiments must be site-specific, and the experimental design should be based on the butchery sequence previously inferred from the archaeological faunal remains. Essentially, he suggested that the experimenter should attempt to replicate a preconceived butchery sequence to validate the preconception. The design and logic of such an experiment are clearly circular.

Applicability of Experimental Correlates to Archaeological Interpretation

Another area of criticism centers on the applicability of experimental results to our understanding and interpretation of the archaeological record. These criticisms boil down to one argument—experimenters have failed to demonstrate that experiments provide strong correlates for archaeological interpretation. This criticism is likely derived from a number of factors. First, experiments are often too particularistic, so that the results cannot be used to develop inferences beyond the specific site or set of circumstances in which the experiment was conducted (Denys 2002; also see Nagaoka 2005). Second, site formation is undoubtedly complex, and "few experiments combine different agents to fit more closely to the complexity of most [archaeological assemblages]" (Denys 2002:469). Similarly, many archaeological sites are palimpsests; that is, "more than two processes occur[ed] on the same materials or overlap[ed] on the same spot" (Domínguez-Rodrigo et al. 2011:3). At this time, few archaeological experiments even attempt to address the sequence of site formation processes (Denys 2002). For example, in a statistical analysis of cut mark frequency at archaeological sites, Domínguez-Rodrigo and Yravedra (2009) purposefully excluded sites identified as palimpsests from their analysis to avoid variables for which they could not account. As a result of these factors, critics argue that experimental results commonly do not “provide an explicit means of establishing the more complex relationships and interactions represented in archaeological assemblages” (Teltser 1991:366).

Other critics caution that experiments are unable to tell us anything about the thought processes of prehistoric peoples. Although an advocate for experimental research, Skibo (1992b) argued that simply because an experiment demonstrates that a particular technological characteristic improves performance, this does not mean that the improvement was apparent to users in the past. Skibo (1992b:36) referred to this as a problem of behavioral significance:

> But applying these results in archaeological inference requires that one deal with the question of behavioral significance. That is, would improvements in thermal shock resistance as a result of changes in surface treatment observed in an archaeological assemblage be perceptible to the pottery users? Moreover, when do people actually act upon perceived differences, because not all such differences are behaviorally significant.

This caution is echoed by Reynolds (1999:158), who argued that, “no experiment can be designed to enhance our understanding of human motive or emotion in the recent or remote past.”

Finally, critics point to potential issues of equifinality—“the fact that different causes can produce identical outcomes” (Rogers 2000:709; see Simek 1994). Most archaeologists have expanded the concept of equifinality to include outcomes that are similar, not merely identical (e.g., Domínguez-Rodrigo 2008; Lyman 2004). As the number of uncontrolled variables increases, the possibility for equifinality also increases (Lubinski and Shaffer 2010). The issue of equifinality is best combated with multiple lines of evidence and multiple methods of analysis to identify possible convergence and “to justify arguing for one or the other behavioral context and actor” (Gifford-Gonzalez 1991:232; also see Carr and Bradbury 2010:73-74). It is worth noting that a number of researchers have argued that issues of equifinality are better understood through experimental archaeology. For example, Lyman (2004:15) argued that the improvement in our current knowledge and understanding of the variation in skeletal part frequencies “has resulted from use of the equifinality concept because that concept demands innovative analyses of previously unimagined variables.” Similarly, Marsh and Ferguson (2010:4) advocated the use of experimental archaeology to test for equifinality, which remains a “persistent issue in interpretations of archaeological data.”

Validity vs. Fact

Before moving on from the limitations of experimental archaeology, it is important to return, momentarily, to the positivist foundations of experimental archaeology, and the difference between validity and fact. It is not possible, using experimental data, to prove that the experimental results are tantamount to the reality of the past. According to Ingersoll et al. (1977:xiv), “the strength of imitative experimentation lies not in proving a final and single magical proof of a hypothesis, but rather in the elimination of improbable hypotheses and narrowing and sharpening the definition of the ‘information’” (see also Ascher 1961; Coles 1973:15, 18, 168; Mathieu 2002a; Reynolds 1999; Shimada 2005:618). Multiple experimental trials, combined with corroborating archaeological evidence, strengthen experimental results and the archaeological correlates developed from those results.

Experimental Archaeology and Archaeological Interpretation

Although there are valid criticisms of experimental archaeology of which archaeologists need to be aware, the benefits of experimental archaeology outweigh the limitations. Independent of the field of study, the experimental process entails a testable hypothesis, the isolation and control of variables, repeatability, and objectivity. The strength of experimental archaeology lies in these very characteristics. Archaeological excavations are—generally—undermined by their small sample sizes, their non-repeatability, and the complexities of site formation processes and time averaging. In contrast, experiments allow an archaeologist to control variables and isolate the factors that influence the formation of the archaeological record (Capaldo 1998; Denys 2002; Marsh and Ferguson 2010), improving our understanding of the specific traces left by cultural and natural processes (Pobiner and Braun 2005). Experiments also allow archaeologists to “corroborate conclusions through multiple trials of repeatable experiments" (Marsh and Ferguson 2010:3). The ability to replicate, and thereby strengthen, experimental results is what distinguishes experimental archaeology from exploration and experience (cf. Reynolds 1999; Jolie and McBrinn 2010).

As emphasized by critics of experimental archaeology, the results of any given experiment are only relevant to the particular set of circumstances in which it was carried out (cf. Harry 2010:14). Schiffer et al. (1994) argued for a tradition of experimental archaeology where experiments are not "one-shot affairs," but rather part of a continuous research program. This allows "the findings of one experiment [to be] nested within families of related principles (correlates) that, together, furnish a foundation for explaining technological variation and change" (Schiffer et al. 1994:198). Although Schiffer and colleagues addressed ceramic technologies, the concept holds true for any facet of archaeological inquiry. Similarly, Jolie and McBrinn (2010:168-169) favor linking a series of tightly focused experiments that manipulate one independent variable at a time. In this sense, each experimental result is a piece of the larger puzzle. These stepwise experiments are particularly relevant to the series of successive taphonomic processes that affect archaeological material before and after deposition.

Taphonomic processes include *both* the cultural and natural processes and agents that act on and form the archaeological record. Whether the concept of taphonomy is limited to the biotic record (e.g., Lyman 2010), or, more generally, to any remains produced by humans (e.g., Domínguez-Rodrigo et al. 2011), the taphonomic processes that affect archaeological remains are complex. I doubt any archaeologists would dispute the fact that we still have a great deal to learn about pre- and post-depositional taphonomic process. According to Gifford (1981:424), "in the face of ambiguous evidence, the logical recourse is actualistic research." There is a general consensus that experimental archaeology is one of the best tools archaeologists have to unravel the complexities of site formation and taphonomic processes (e.g., Behrensmeyer et al. 2000:133-4; Binford 1981; Capaldo 1998; Clarke 1973; Denys 2002; Faith and Behrensmeyer 2006; Gifford-Gonzalez 1991; Ingersoll et al. 1977; Lubinski and Shaffer 2010; Roberts et al. 2002). Capaldo (1998:313) summarized the benefits of an experimental approach to improving our understanding of taphonomic processes:

> Experimental methods are used because the original composition and condition of each experiment are known and because relevant aspects of site formation can be controlled and observed. Therefore, traces can be unambiguously connected to the causal processes, effectors and actors which produced them, as well as to the behavioural and ecological contexts in which they were produced.

Over the past half-century, a myriad of experimental studies have investigated the wide range of the taphonomic processes that commonly affect archaeological bone. These include, but are not limited to, studies of butchery and cut marks (e.g., Blumenschine et al. 1996; Egeland 2003; Potter 2005), cooking (e.g., Church and Lyman 2003; Medina et al. 2012; Roberts et al. 2002; Ugan 2010), digestion (e.g., Butler and Schroeder 1998; Crandall and Stahl 1995; Hockett 1996), trampling (e.g., Andrews and Cook 1985; Behrensmeyer et al. 1986; Fiorillo 1989), carnivore and scavenger modification (e.g., Blumenschine 1988; Capaldo 1998; Gidna et al. 2013; Marean et al. 1992; Ugan 2010), soil pH (e.g., Fernández-Jalvo et al. 2002:358; Nicholson 1996a; White and Hannus

1983), and fluvial transport (e.g., Boaz and Behrensmeyer 1976; Coard and Dennell 1995; Kaufmann et al. 2011; Pante and Blumenschine 2010). Collectively, experimental research allows archaeologists to confidently make inferences about an archaeological record steeped in complexities. Each successive experiment improves and builds on the former, strengthening the causal ties between various agents and the measurable traces of those actions, and ultimately improving our interpretation and understanding of the past.

Cut Marks on Archaeological Fish Bones

In the following chapters, I present my findings from a series of experiments investigating cut marks on fish bone. Cut marks are rarely reported on fish bone from archaeological sites as compared to bird and, especially, mammal bones (Colley 1990:216-217; deFrance 2005; Domínguez-Rodrigo and Yravedra 2009; Lyman 1987, 1994:439; Steadman et al. 2002). The rarity of cut marks on fish bone could be due to a variety of factors, including prehistoric butchery practices, post-depositional taphonomic processes, and flawed analytic techniques. Although each of my experiments can stand alone, they are part of a continuous research program aimed at improving our understanding of the effects of butchery and burial on the production, location, and long-term visibility of cut marks on archaeological fish bone. Chapter III also has implications for the methodology of butchery experiments for other classes of animals (i.e., mammals, birds, and reptiles).

Chapters II and III examine the number and locations of cut marks caused by butchering fish. Specifically, Chapter II—co-authored with M. I. Eren and T. C. Rick—addresses a simple question: does butchering fish result in cut marks? To test this question, my co-authors and I butchered 30 fish, including 10 specimens each of hardhead catfish (*Ariopsis felis*), summer flounder (*Paralichthys dentatus*), and Coho salmon (*Oncorhynchus kisutch*) (Willis et al. 2008). These species are found in diverse geographical regions, making the results applicable to a wider range of archaeological sites. Butchery methods followed those used by Rousseau (2004) in a salmon butchery experiment, but are based upon ethnohistoric and ethnographic accounts of salmon butchery in the Pacific Northwest and Alaska (e.g., Albright 1984; Emmons 1991; Gideon 1989; Hoffman et al. 2000; Kennedy and Bouchard 1992; Romanoff 1985).

Chapter III—co-authored with A. R. Boehm—examines whether the experience level of the butcher affects the production of cut marks on fish bone. Although it may seem obvious that someone with more experience would inflict fewer cut marks (Lyman 2012), archaeological inferences should be developed from tested hypotheses, not preconceived notions. I am unaware of any other study that systematically evaluates the influence of experience level on cut mark production. Following methods similar to the initial experiment (i.e., Chapter II), two novices, two individuals with moderate experience, and two professional fishmongers each butchered five Chinook salmon (*Oncorhynchus tshawytscha*). Together, the results from Chapters II and III suggest that, if prehistoric peoples were butchering fish with methods similar to my experimental method, cut marks on archaeological fish bone should be reported in much greater frequencies. The discrepancies between the experimental results and archaeological reports may be due to a variety of factors, including different butchery/cooking methods, post-depositional taphonomic processes, and the tendency among archaeologists to not examine fish bones carefully for cut marks. The final two chapters address the latter possibilities.

Chapter IV—co-authored with A. R. Boehm—examines whether post-depositional taphonomic processes affect the visibility of cut marks on fish bone. To test this, we buried 13 butchered fish for 27 months. After 27 months, the skeletons were recovered and water-screened over 1/32-inch mesh. Interestingly, after this (relatively) short time span, the number of visible cut marks decreased, particularly on those species with smaller, more fragile bones (i.e., spotted weakfish, *Cynoscion nebulosus*, and summer flounder, *Paralichthys dentatus*). Although this experiment demonstrates that post-depositional processes can affect the visibility of cut marks on archaeological fish bone, I still expect to see more cut marks than are reported.

Another explanation for the discrepancy between the experimental results from Chapters II and III and what we see archaeologically may be due to how archaeologists identify and quantify fish remains. Commonly, bones and bone fragments that cannot be identified to family, genus, or species are not carefully inspected. The results of my experiments demonstrate that cut marks commonly occur on ribs, vertebral processes, and pterigiophores—bones that are unlikely to be identified taxonomically (Willis and Boehm 2014; Willis et al. 2008).

Chapter V—co-authored with J. M. Erlandson and T. C. Rick—applies the results of my experiments to a previously analyzed fish bone assemblage from Daisy Cave (CA-SMI-261) on San Miguel Island (see Rick et al. 2001), to test whether current analytic methods inhibit our understanding of prehistoric fish processing. Daisy Cave is a multi-component shell midden with discrete occupations dated to the Terminal Pleistocene, Early Holocene, Middle Holocene, and Late Holocene (Erlandson et al. 1996). Over

27,000 fish bones were recovered from Early Holocene midden deposits dated between about 10,200 and 8,500 years ago (Rick et al. 2001). The excellent preservation of faunal remains from Daisy Cave makes it an ideal assemblage with which to test the results of my experimental results on a sizable collection of archaeological fish remains.

Finally, in Chapter VI, I conclude with a summary of my experimental program and the broader applications and implications of my results. Although previous experimental research has been conducted on fish remains (e.g., Butler and Schroeder 1998; Colley 1990; Nagaoka 2005; Nicholson 1996a), it remains an important area for further research. My experimental research contributes to our understanding of a range of pre- and post-depositional taphonomic effects on fish bone, including where cut marks are likely to occur, how human variability affects the frequency and location of cut marks, and how post-depositional processes affect the survivability of cut marks. My research also evaluates whether standard analytic methods cause cut marks on fish bone to be systematically overlooked, skewing our understanding of prehistoric butchery practices.

CHAPTER II

DOES BUTCHERING FISH LEAVE CUT MARKS?

This work was published in volume 35 of the *Journal of Archaeological Science* in 2008. Torben C. Rick and I initially identified the problem, and I developed the experimental methods. Metin I. Eren and I butchered and processed the specimens; I identified all cut marks. I was the primary author; Eren and Rick provided editorial assistance.

Introduction

Fish and other aquatic resources played an important role in human social, biological, and cultural evolution. Fundamental to understanding the significance of fish in ancient human economies, however, is documenting the ways that fish were procured, processed, and consumed by people. Evidence for processing manifests itself archaeologically in the form of burning, cut marks, body-part frequency, and other patterns. Despite being fairly common on archaeological mammal and bird bones (deFrance 2005; Domínguez-Rodrigo 2002; Lyman 1987; Steadman et al. 2002), cut marks are rare on archaeological fish bones (e.g., Colley 1990:216-217; Lyman 1994:439). In an analysis of thousands of fish bones from natural and cultural deposits from the Northwest Coast, for example, Butler (1990, 1993) did not identify a single cut mark. While the frequency of cut marks on mammal remains varies and is also sometimes limited (Lyman 2005), the frequency of such marks on fish bones is consistently low. This lack of identified cut marks or other signs of butchering on fish bones limits the interpretation of prehistoric and historic fish processing when ethnographic evidence is unavailable.

The dearth of cut marks on fish bone may be attributed to a number of factors (e.g., butchering practices, post-depositional taphonomic processes, fish anatomy, rushed inspection/analysis), but without experimental studies many of these factors remain speculative. Given the importance of fish and other aquatic remains in the human past (see Bailey and Milner 2002; Erlandson,2001; McBrearty and Brooks 2000), we performed a set of butchering experiments designed to evaluate whether or not such practices leave cut marks or other signatures on fish bones. Here we present the first in a series of experiments dealing exclusively with fish bone modification and taphonomy. We address whether butchering fish results in cut marks and where these cut marks occur on the skeleton.

Materials and Methods

Fifteen lithic blanks and a metal knife were used for butchering. The lithic blanks were knapped by Eren from a gray/blue chert from an unknown source using soft hammer direct percussion. The stone tools ranged in length (mm) from 52.66 to 90.49 (average=68.12), in maximum width (mm) from 57.07 to 94.60 (average=75.60), and in thickness (mm) from 2.81 to 24.32 (average=8.20). The metal knife is a standard non-serrated kitchen knife, with a length of 25 cm from handle to blade tip (13 cm blade, 12 cm handle), and a blade width of 2 cm.

We used spotted weakfish (*Cynoscion nebulosus*, n=4) and red drum (*Sciaenops ocellatus*, n=3) as trial specimens for the experimental methods described below. The trial specimens ranged in weight (g) from 190 to 1710 with an average of 653 and in standard length (cm) from 23 to 49 with an average of 32. These fish provided the opportunity to become familiar with the butchering process before proceeding with the catfish, flounder, and salmon. Although these were practice specimens, similar cut mark frequencies and distributions were noted. Some of these test specimens were slightly damaged (i.e., cranium sawed for otolith removal) during previous fisheries data collection; consequently, they have been omitted from our analysis.

For the experiment, we butchered 10 hardhead catfish (*Ariopsis felis*), 10 summer flounder (*Paralichthys dentatus*), and 10 Coho salmon (*Oncorhynchus kisutch*; Table 1). These fish were captured using nets (hardhead catfish), an otter trawl (summer flounder), or were diverted into a hatchery during spawning runs (Coho salmon). These species also have distinct body sizes and morphologies, diverse geographic distributions, and represent taxonomic families frequently encountered in archaeological assemblages. Hardhead catfish are found in both prehistoric and historic faunal assemblages from the Florida Gulf coast (e.g., Quitmyer and Massaro 1999; Walker 1992) and the Atlantic coast of the southeastern United States (e.g., Crook 1984; Reitz 1982, 2004). Summer flounder are infrequent or absent in archaeological assemblages (Tveskov 1997), but winter flounder (*Pseudopleuronectes americanus*) are commonly identified in northeastern US Atlantic coast sites (e.g., Spiess and Lewis 2001) and share similar size ranges, habitats, and geographic distributions with summer flounders (Murdy et al. 1997; Robins and Ray 1986). Coho salmon and other species of the genus *Oncorhynchus* are common in archaeological sites in the Pacific Northwest and the Canadian Plateau, playing a fundamental role in Northwest Coast subsistence for millennia (e.g., Butler 1990, 1993; Butler and Campbell 2004).

Weight and standard length measurements were recorded for each fish (Table 1). All fish were kept frozen and were thawed just prior to being butchered, with measurements taken after the fish had thawed. Our fish skeletal element terminology follows Cannon (1987, flounder and salmon), Mundell (1975, catfish), and Wheeler and Jones (1989:122-124, general).

A total of 37 fish (n=7 trial and n=30 experimental) were butchered following two methods (A and B). Method A was used to butcher the trial species (i.e., spotted weakfish and red drum), hardhead catfish, and Coho salmon and is based on Rousseau's (2004:18-22) experimental method, which incorporates butchering strategies documented in a number of ethnohistoric and ethnographic accounts of salmon butchery in the Pacific Northwest and Alaska (Emmons 1991; Gideon 1989; Hoffman et al. 2000; Kennedy and Bouchard 1992). For Method A, a fish is placed on its side and an incision is made from the anus to the pectoral fins. Next, the head and viscera are removed. The initial ventral incision is extended from the anus to the caudal fin and the fish is laid open and flat with the vertebral column exposed. Cuts are then made laterally on both sides of the vertebral column, severing rib attachments. Finally, the vertebral column and caudal fin are cut off of the remaining fillets.

Method B, as demonstrated by a local fish market employee, was used to butcher the morphologically distinct summer flounder. After placing the flounder on its blind side, the initial incision is made along the length of the dorsal fin, from the pectoral girdle to the caudal fin. Following the initial incision, long strokes are used to separate away the

Table 1. Measurements of experimental specimens.

Specimen	Weight	SL
AF-01	373.5	26
AF-02	414.2	26
AF-03	411.8	31
AF-04	399.0	30
AF-05	677.7	33
AF-06*	569.7	30
AF-07*	503.5	30
AF-08*	517.8	30
AF-09*	541.5	28
AF-10*	374.6	27
OK-01	4083.9	64
OK-02	4867.0	67
OK-03	4911.6	68
OK-04	3133.6	57
OK-05	4306.0	65
OK-06*	1979.0	48
OK-07*	4127.3	63
OK-08*	3008.9	56
OK-09*	2951.4	59
OK-10*	6193.7	67
PD-01	1106.6	39
PD-02	625.0	32
PD-03	880.9	35
PD-04	780.0	36
PD-05	236.6	23
PD-06*	852.6	33
PD-07*	887.7	34
PD-08*	750.1	36
PD-09*	865.8	34
PD-10*	940.3	35

AF = *Ariopsis felis*, OK = *Oncorhynchus kisutch*, PD = *Paralichthys dentatus*, SL = Standard Length. The * indicates those specimens butchered with the metal knife; all others butchered with stone tools. All weights in grams and SL in centimeters.

fillets. The same incision is made along the anal fin, and long strokes are used to remove the ventral portion of the fillet. A cut is made posterior to the pectoral girdle to completely remove the fillet. The head and viscera are removed. Lastly, placing the flounder on its ocular side, the same process is used to remove the blind-side fillet. The vertebral column, ribs, and dorsal, anal, and caudal fins remain articulated.

After butchering, the skeletons were cold-water macerated (Reitz and Wing 1999:363-364). After nearly three months, a light detergent-based enzyme was added to a majority of the flounder specimens to help speed the maceration process. Once the skeletons were cleaned, the bones of each specimen were carefully inspected twice for cut marks. Both individual cut marks and cut mark clusters (groups of cut marks < 3mm apart) were recorded. Occasional hacks through vertebrae resulting from the severing of the head or tail were noted. All skeletons used in this experiment are housed in the Department of Anthropology, Southern Methodist University.

Like all archaeological experiments, this one possesses limitations, the most obvious being the butchering method. In the event that prehistoric/historic populations were not butchering fish, but rather roasting/smoking them whole (e.g., Robbins et al. 1994: 260; Stewart and Gifford-Gonzalez 1994), cut marks would not appear on the bone. Alternatively, a different butchering strategy might produce a different number or patterning of cut marks. However, our method incorporates observed butchering accounts from the Pacific Northwest and is a fairly common approach used to butcher fish.

Experience is another factor potentially influencing the results of this study. Although Eren has experience butchering mammals with stone tools, this experiment represents the first time either Willis or Eren butchered fish. To minimize the effects of experience, seven trial specimens were butchered, as described above. Nevertheless, it is also likely that archaeological faunal assemblages were in part produced from the actions of novice or less experienced participants (e.g., in a learning context; see Shea 2006), as well as people who regularly butchered fish and other animals. These potential concerns aside, the following results have important implications for evaluating how ancient peoples processed fish.

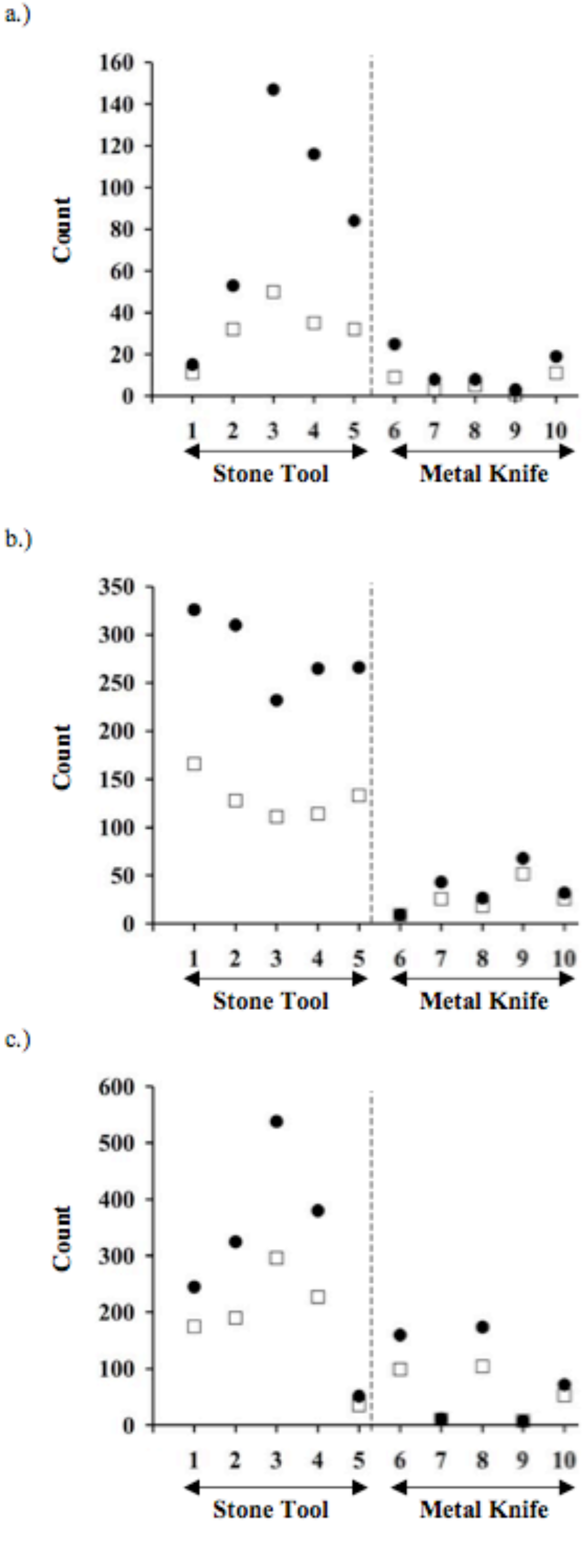
Various studies of cut mark frequencies have also suggested that the frequency of bones with cut marks is positively correlated with butchering intensity, as measured by counting the number of strokes when cutting (Abe et al. 2002; Lyman 1992, 1994:301-303). However, an experimental test of this assumption shows that there is no statistically significant relationship between the number of tool strokes and the number of observable cut marks (Egeland 2003). For this study, we did not count the number of tool strokes, leaving this as an avenue for future research.

Results

Does Butchering Fish Produce Cut Marks?

Our research suggests that cut marks resulting from butchering fish are common. For hardhead catfish, the total cut mark count for butchering with stone tools ranges from 15 to 147 cut marks per fish, while the total for the metal knife ranges from 3 to 25 per fish (Figure 1a). For Coho salmon, the total cut mark count using stone tools resulted in a range of 232 to 326 cut marks per fish, while the total with the metal knife ranges from 9 to 68 per fish (Figure 1b). For summer flounder, the total cut mark count using stone tools ranges from 51 to 538 per fish, while the total with the metal knife ranges from 7 to

Figure 1. Individual cut marks (circles) and cluster (squares) counts for (a.) hardhead catfish (*Ariopsis felis*), (b.) Coho salmon (*Oncorhynchus kisutch*), and (c.) summer flounder (*Paralichthys dentatus*). Values on the x-axis represent the specimen numbers.



174 per fish (Figure 1c). These data indicate that butchering with hand-held stone tools generally results in more cut marks than butchering with a metal knife, a pattern that is statistically significant (hardhead catfish: $t = 3.0754$, $p = 0.0342$; Coho salmon: $t = 12.7621$, $p < 0.0001$; summer flounder: $t = 2.5441$, $p = 0.0472$).

Where Do Cut Marks Appear?

Due to the relative dearth of bone diversity in the axial skeletons of fish, cut marks are distributed on a limited number of elements (Figures 2–6). Table 2 shows where cut marks appear on the fishes. Cut marks on catfish vertebrae make up 59 percent and 35 percent of the total number of cut marks produced by stone and metal tools, respectively. Over 90 percent of the cut marks on catfish vertebrae are on the vertebral processes, rather than on the centra. Cut marks on ribs, fin rays, and unidentifiable bone fragments contribute another 27 percent of the total cut marks for the catfish butchered with the stone tools, and 59 percent for the metal knife. The remaining cut marks for catfish were located on the ventral surface of the Weberian complex vertebrae (resulting from butchering mistakes made when removing the head), the pectoral and second dorsal spines, and the cleithrum.

Cut marks on Coho salmon vertebrae provide 41 percent and 17 percent of the total number of cut marks produced by stone and metal tools, respectively. Similar to the catfish, over 90 percent of the cut marks located on Coho salmon vertebrae occur on the vertebral processes. For the stone-tool butchered salmon, cut marks on ribs account for 46 percent of the total, pterygiophores 12 percent, and the lower postcleithrum and

Figure 2. Two views of cut marks on a caudal vertebra from fish specimen PD-03 (summer flounder): (A.) Side view of cut marks and (B.) Overhead view showing bone shavings. Photographs by M. I. Eren.

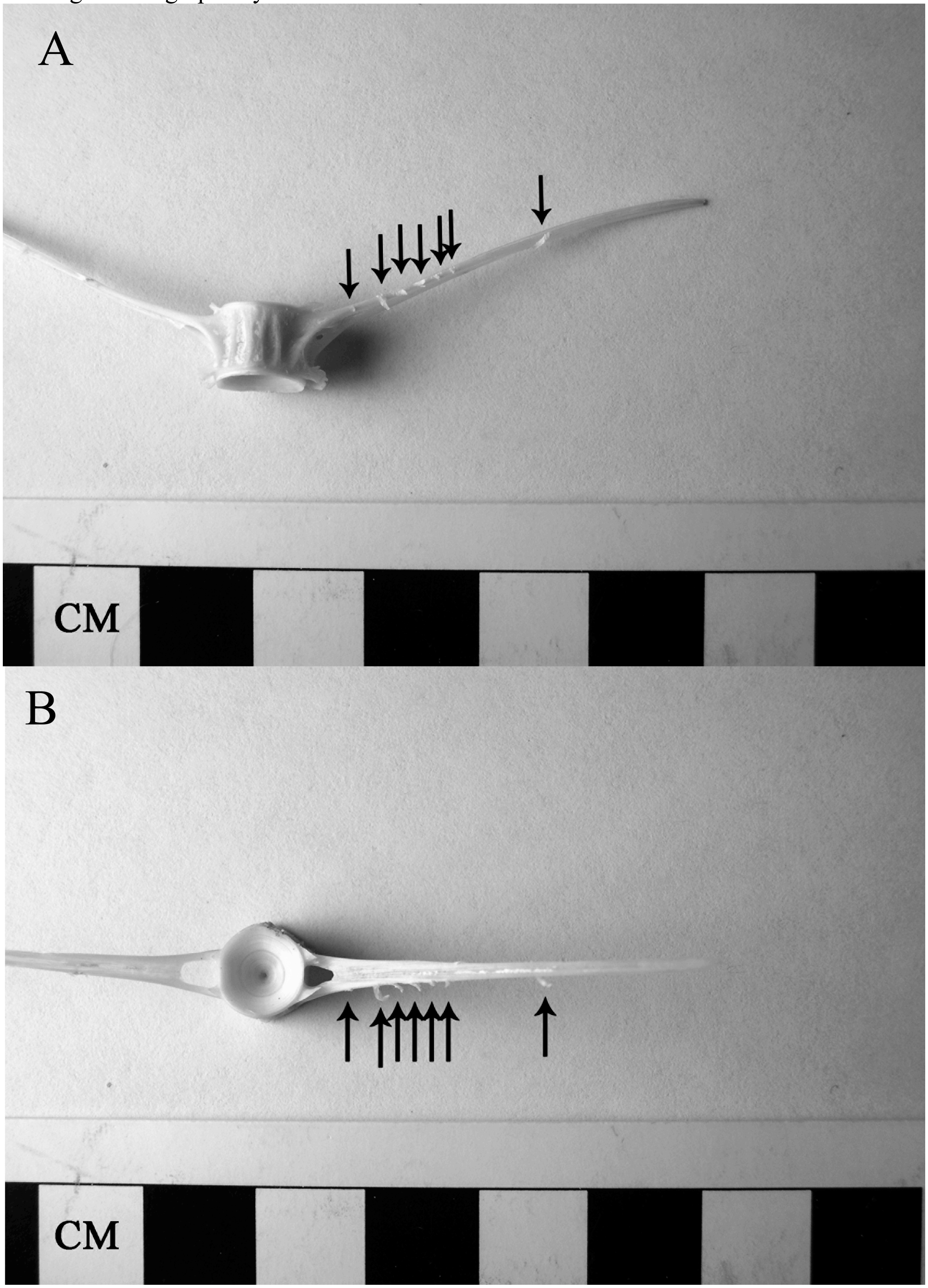


Figure 3. Cut marks on a cleithrum from fish specimen AF-03 (hardhead catfish). Photograph by M. I. Eren.

Figure 4. Sheared precaudal vertebra from fish specimen PD-06 (summer flounder). Photograph by M. I. Eren.

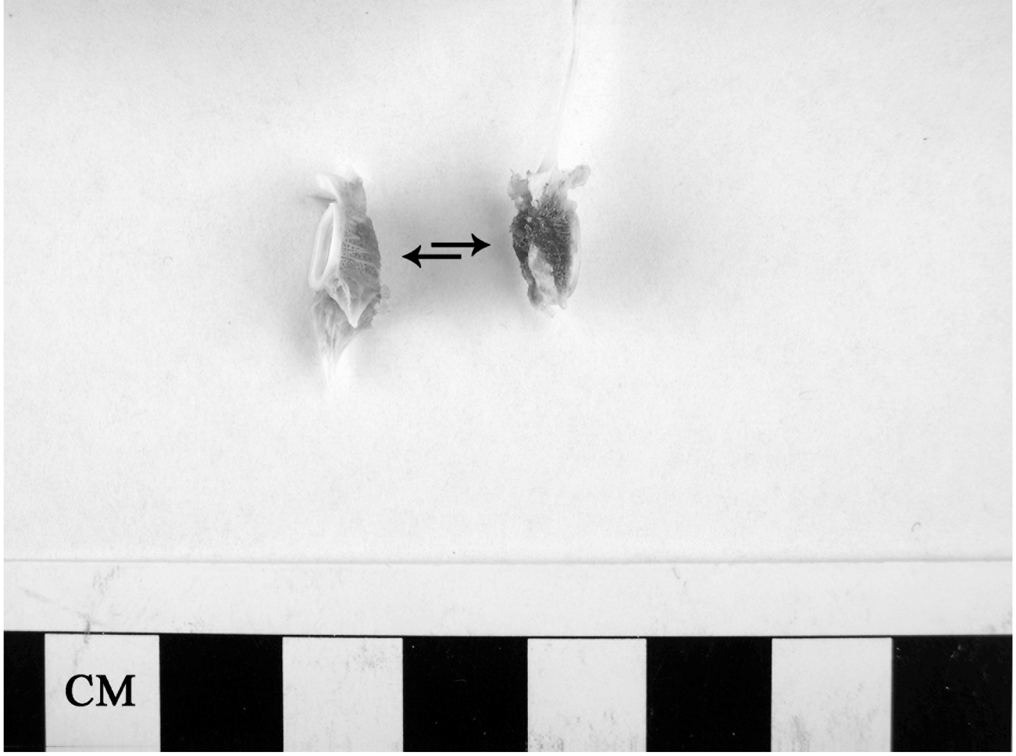


Figure 5. Cut marks on a rib from fish specimen AF-05 (hardhead catfish). Photograph by M. I. Eren.

Figure 6. A series of cut marks from a single butchering stroke on fish specimen OK-05 (Coho salmon). Photograph by M. I. Eren.

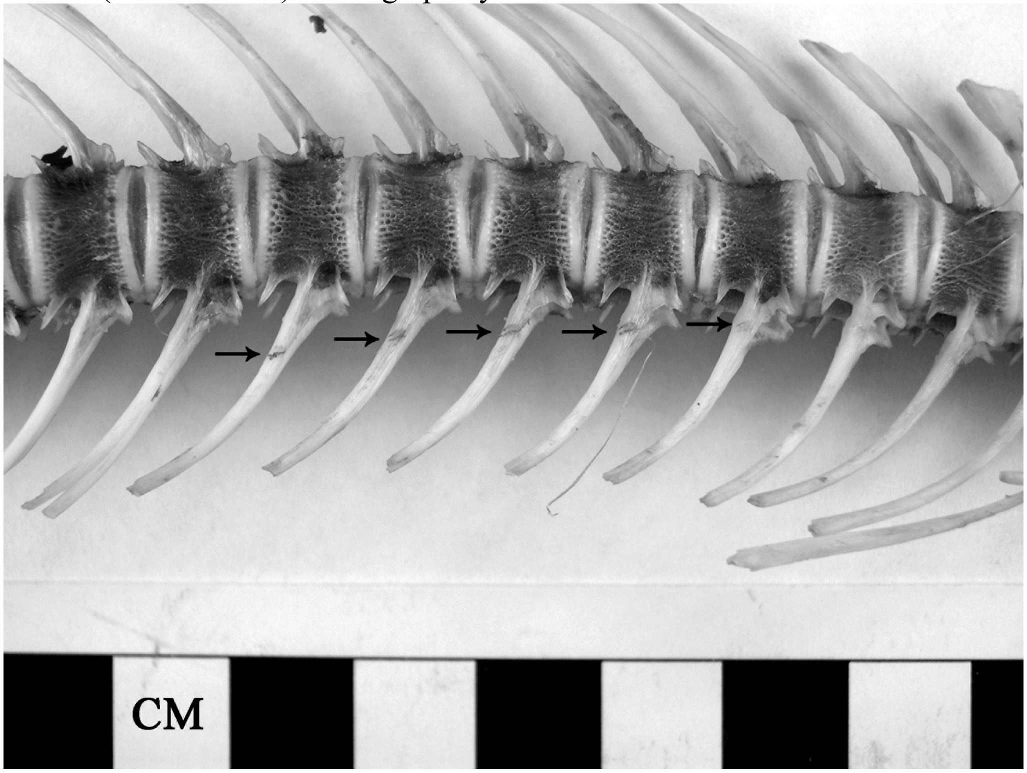


Table 2. Cut mark distribution percentages.

Element	Count	Percent
Hardhead Catfish: Stone Tool		
Thoracic Vertebrae	39	9
Precaudal Vertebrae	96	23
Caudal Vertebrae	79	19
Rib	105	25
Unidentified Bones, Fragments	5	1
Pectoral Spine	26	6
Second Dorsal Spine	10	2
Fin Ray	4	1
Cleithrum	24	6
Weberian Complex Vertebrae	35	8
Hardhead Catfish: Metal Knife		
Thoracic Vertebrae	8	5
Precaudal Vertebrae	24	16
Caudal Vertebrae	21	14
Rib	84	58
Unidentified Bone Fragments	1	1
Pectoral Spine	9	6
Coho Salmon: Stone Tool		
Thoracic Vertebrae	90	6
Precaudal Vertebrae	152	11
Caudal Vertebrae	327	24
Rib	642	46
Fin Ray	1	<1
Pterygiophore	170	12
Lower Postcleithrum	3	<1
Unidentified Bone Fragments	5	<1
Coho Salmon: Metal Knife		
Thoracic Vertebrae	15	8
Precaudal Vertebrae	4	2
Caudal Vertebrae	11	6
Rib	142	82
Pterygiophore	6	3
Expanded Neural Spine	1	<1

Table 2 Continued. Cut mark distribution percentages.

Element	**Count**	**Percent**
Summer Flounder: Stone Tool		
Thoracic Vertebrae	5	<1
Precaudal Vertebrae	119	8
Caudal Vertebrae	560	36
Interhaemal Spine	29	2
Postcleithrum	2	<1
Rib	19	1
Fin Ray	10	<1
Pterygiophore	676	44
Unidentified Bone Fragments	119	8
Summer Flounder: Metal Knife		
Thoracic Vertebrae	14	3
Precaudal Vertebrae	19	4
Caudal Vertebrae	19	4
Interhaemal Spine	14	3
Postcleithrum	1	<1
Rib	3	<1
Fin Ray	1	<1
Pterygiophore	317	75
Unidentified Bone Fragments	36	8

Bone terminology follows Cannon (1987, flounder and salmon), Mundell (1975, catfish), and Wheeler and Jones (1989:122-124, general).

unidentifiable bone fragments each less than one percent of the total cut marks. For the salmon butchered with the metal knife, 82 percent of the total cut marks occurred on ribs, with 3 percent of the cut marks on pterygiophores and less than one percent on the expanded neural spine.

For the summer flounder, cut marks on vertebrae make up 44 percent and 11 percent of the total number of cut marks produced by stone and metal tools, respectively. Approximately 90 percent and 75 percent of these cut marks occur on the vertebral processes for stone-tool butchered flounder and metal knife butchered flounder, respectively. The majority of the cut marks for both the stone-tool and metal knife butchered flounder are distributed on pterygiophores (44% and 75%, respectively). Less than 10 percent of cut marks were located on ribs, fin rays, the postcleithrum, interhaemal spine, and unidentified bone fragments.

Discussion

The presence and abundance of cut marks on fish skeletons in our study is surprising given their apparent absence in most archaeological fish analyses. We believe this discrepancy can be attributed to a variety of factors (e.g., cut mark distribution, the small size of cut marks, fish body morphology, and taphonomic processes), though future experiments will help to determine which factors have the most influence on a given assemblage.

The vast majority of experimental cut marks were distributed on vertebral processes, ribs, and pterygiophores. It is not uncommon for the vertebral processes to break off of centra post-depositionally as a result of trampling or other taphonomic agents (Wheeler and Jones 1989:108). Once separated from the centrum, vertebral spines and processes, along with ribs and other undiagnostic fish bones, are not useful for precise taxonomic identification. Thus, the evidence for fish butchering may be present in faunal assemblages, but is overlooked due to the distribution of cut marks on elements that are not carefully examined beyond a weight and/or a count of osteichthyan bone. The results presented here suggest that researchers should examine undifferentiated fish bone for evidence of butchering.

Another compounding factor that may be leading to the discrepancy between the experimental results and faunal analyses is the quality of the cut marks themselves. The majority of the cut marks tend to be small and shallow; even on fresh, clean bone, a magnifying glass was occasionally needed to identify the cut marks. Given that fish bone is often less likely to preserve as well as more robust mammal bones (Butler and Chatters 1994; Colley 1990; Lyman 1984, 1994; Wheeler and Jones 1989), it is possible that taphonomic processes (e.g., trampling, root etching, and human or other animal digestion) may remove or obscure the signatures of fish butchering. Chapter IV addresses the influence of post-depositional processes on the preservation of fish bone cut marks.

Although the primary goal of the current experiment was not to compare stone and metal tools, but rather whether fish butchering produces observable cut marks, we note that butchering with stone tools generally resulted in a higher number of total cut marks than butchering with the metal knife. Further research is needed to test this hypothesis.

An Archaeological Correlate

To provide an archaeological test of the experimental data, we analyzed an assemblage of 9391 fish bones previously reported by Rick (2007:110-111) from Unit 2 at CA-SMI-163, a Protohistoric and Historic period village site on San Miguel Island, California. The assemblage is well preserved and contains roughly 17 different marine fishes, including rockfish (*Sebastes* spp.), surfperch (Embiotocidae), cabezon (*Scorpaenichthys marmoratus*), California sheephead (*Semicossyphus pulcher*), and other common kelp bed and rocky shore fishes. Of the 9391 bones, 8182 were spines, rays, ribs, or small, fragmented bones not identifiable to low taxonomic categories. During the previous analysis, no cut marks or definitive evidence of processing other than burning were noted. The assemblage of bird (n=422) and mammal (n=65) remains from the site was considerably smaller than the fish assemblage, but cut marks were noted on six of the marine mammal bones and one bird bone. All of the identified and undiagnostic fish bones were reanalyzed for this study to determine if any of the bones had cut marks that were previously unrecognized.

Only a single utilized flake was identified as a cutting tool in the assemblage. No metal or glass tools were identified at this site, although some shell beads were drilled with iron needles (Rick 2007:34). We suspect people were primarily using expedient stone tools to butcher fish and other animals, but it remains possible that metal and possibly shell tools were at least occasionally used as well.

Thirty-three cut marks were identified on 16 bones, with only two of these bones (rockfish vertebrae) identified beyond undifferentiated bony fish. The remaining bones consisted of unidentified ribs, spines, and small bone fragments. Several other specimens had ambiguous marks that could either be root etching or cut marks that were too small to differentiate. Because only 0.17 percent of the total assemblage contained cut marks, in this case evidence for butchering appears to be quite limited. This could be a result of several factors. The fish may have been consumed with limited or no formal filleting or other cutting. Alternatively, the cut marks could be obscured or erased by post-depositional processes, especially root etching. In this case, we suspect that a combination of the butchering strategy and post-depositional processes may account for the dearth of cut marks. Without the experimental data, however, no signs of butchering would have been identified.

Conclusions

Our conclusions have important implications, especially for distinguishing natural from cultural fish assemblages and for understanding food-processing techniques. With the dramatic increase of taphonomic studies over the past few decades, numerous researchers have worked to delineate the characteristics separating natural from cultural assemblages in coastal and other aquatic regions (Butler 1990, 1993; deFrance 2005; Erlandson and Moss 2001; Erlandson et al. 2007; Gifford-Gonzalez et al. 1999; Stewart 1991; Van Neer and Muñiz 1992). Due to the low frequency of cut marks observed on fish bone, several studies have focused on fish body-part frequency and skeletal completeness (Butler 1990, 1993; Hoffman et al. 2000). Our data illustrate the need for researchers working with fish assemblages to consider the potential presence of cut marks on undifferentiated fish bones within these assemblages. Through the examination of (often overlooked) bony fish fragments, researchers may discover another line of evidence to support the argument for a cultural assemblage when a site lacks other cultural markers. This research also adds to a growing number of studies that demonstrate the utility of experimental analyses for better understanding the archaeological patterning of fish and other faunal remains (e.g., Butler and Schroeder 1998; Nagaoka 2005). We hope this study will prompt other researchers to conduct butchering experiments on fish and other animals to help test and refine the data and interpretations presented here.

Bridge

In this chapter, we established that butchering bony fish does produce cut marks on the bones. The results of this initial experiment were surprising, given the dearth of cut marks reported on archaeological fish bone. In our discussion and conclusion, we proposed a number of factors that may have contributed to the discrepancy between the experimental results and the archaeological record, including the quality and location of the cut marks, the species of fish used, and post-depositional taphonomic processes. Although it was discounted as a variable in this chapter, it is possible that our lack of familiarity with butchering affected the results. In the following chapter, I evaluate the effect of skill level on the number and distribution of cut marks produced on fish bone during butchery.

CHAPTER III

EVALUATING THE ROLE OF SKILL LEVEL IN FISH BUTCHERY

This work was co-authored with Andrew R. Boehm, and was accepted for publication in the *Journal of Taphonomy*. Boehm contributed substantially to this work by participating in the butchery and specimen processing. I was the primary author; Boehm provided editorial support and created Figures 10 and 13.

Introduction

Experimental archaeology—including both controlled experiments and actualistic studies—is one of the best tools available to archaeologists for unraveling the complexities of site formation processes and taphonomy (e.g., Binford 1981; Denys 2002; Gifford-Gonzalez 1991; Ingersoll et al. 1977; Lubinski and Shaffer 2010; Mathieu 2002b; Reynolds 1999; Skibo 1992b). As a result, experimental programs seeking to replicate aspects of the prehistoric record such as tool making, hunting, and butchery are commonplace in archaeology. In many cases, the researchers or their students served as the subject(s) (i.e., hunter, flintknapper, butcher, craftsman) attempting to replicate or gain insight into past human activities (e.g., Backwell and d'Errico 2004; Eren et al. 2008; Jeffra 2008; Karr and Outram 2012b; Lombard and Pargeter 2008; Pickering and Egeland 2006; Schiffer et al. 1994; Yaroshevich et al. 2010). Looking specifically at butchery studies, it is not uncommon for archaeologists to butcher the experimental specimens themselves, to recruit untrained butchers, or to fail to report on the experience level of the butchers (e.g., de Juana et al. 2010; Domínguez-Rodrigo 1997; Egeland 2003;

Jones 1980; Machin et al. 2007; Selvaggio 1994a; Walker and Long 1977; West and Louys 2007; Willis et al. 2008).

Recognizing experience as a potential source of error, researchers are increasingly emphasizing the importance of understanding the skill and expertise of the human subjects conducting the experiment (Aubry et al. 2008; Darmark and Apel 2008; Domínguez-Rodrigo 2012; Machin et al. 2005:24-25; Nonaka et al. 2010; Outram 2008; Seetah 2008). This is a positive methodological adjustment for most research questions, but we do not yet have a firm understanding of the degree to which a person's skill level influences experimental results, especially in regard to animal butchery. Before the numerous studies conducted by non-professionals are disregarded, an examination of the influence of skill level is required.

Motivation

Despite being a common component of coastal and other aquatic archaeological sites, cut marks are rarely reported on archaeological fish remains. To assess whether butchering practices would produce cut marks on fish bones, Willis et al. (2008) examined the number of cut marks produced on fish bones when butchering salmon, catfish, and flounder. These species were chosen because they were morphologically and geographically distinct, and represented taxonomic families frequently encountered in archaeological assemblages. Based on the relative dearth of cut marks on fish bones in the archaeological record, the authors expected to find few cut marks, but this was not the case. Surprisingly, the hardhead catfish, summer flounder, and Coho salmon specimens averaged 84.6, 307.8, and 278 total cut marks, respectively (Willis et al. 2008). The authors hypothesized that the discrepancy between the experimental results and the archaeological record might be due to the ‘erasing’ of cut marks by post-depositional taphonomic processes, given the ephemeral nature of many of the cut marks produced. The novice experience level of the butchers was acknowledged, but it was discounted as an influential variable.

This paper evaluates whether a butcher’s experience level affects experimental results—an issue of importance to all butchery studies, not just those focused on fish. Although researchers have acknowledged the potential influence of butchery experience on cut mark totals (e.g., Dewbury and Russell 2007; Domínguez-Rodrigo 2008; Domínguez-Rodrigo and Yravedra 2009; Fairnell 2008; Galán and Domínguez-Rodrigo 2013; Haynes and Krasinski 2010; Machin et al. 2007), we are unaware of any published studies that systematically evaluate the influence of experience level on cut mark production (however, see Haynes and Krasinski 2010:185-186).

Experimental Design

Butchers

To test the effects of experience on cut mark frequency and location, we employed butchers with varying levels of skill. The skill of a butcher can be thought of as the product of two factors: knowledge and know-how (cf. Pelegrin 1990). Knowledge is declarative and explicit; it is the information needed to complete a particular task, and can be communicated to the learner (Apel 2008; Harlacker 2006; Pelegrin 1990). In contrast, know-how cannot be taught or learned—it is experiential. Know-how includes the unconscious decisions and movements one can only obtain through prolonged, practical experience (Apel 2008; Harlacker 2006; Olausson 2008). Although these concepts are most commonly applied to studies of lithic technology (e.g., Apel 2006, 2008; Bamforth and Finlay 2008; Bleed 2008; Eren et al. 2011; Harlacker 2006; Olausson 2008), they are relevant to our understanding of butchery skill. For the purposes of this study, knowledge includes an understanding of and familiarity with how to butcher a fish, while know-how includes those subtleties that can only come through repetition and experience—how to hold and manipulate the tool and the fish; the pressure required to pierce the skin; how often to clean the tool; the location of the bones; and other skills.

The butchers used in this study fall into three categories: novice, intermediate, and professional. We used two butchers per category, for a total of six butchers. The two novice butchers had neither knowledge nor know-how; that is, they had no experience butchering fish (or any other animals) and were unfamiliar with the anatomy of a salmon. The intermediate-level butchers had knowledge, but lacked know-how; each had occasional experience gutting and filleting fish as recreational fishermen, so they were familiar with the process, but did not have the unconscious muscle memory obtained through prolonged repetition. Finally, the professional butchers—fishmongers with 12 and 16 years of experience—had both knowledge and know-how.

It is important to note that two of the butchers, including one of the intermediate-level butchers and the professional fishmonger with 16 years of experience, had prior experience butchering animals with stone tools. However, because their prior experience was limited, the differences in the number of cut marks produced by the participants can be attributed to their overall experience (or lack thereof) in filleting fish.

Methods

Each of the six participants butchered five Chinook salmon (*Oncorhynchus tshawytscha*), for a total sample of 30 specimens. We utilized salmon because they could be easily obtained in large numbers, and processing techniques for drying are well documented in ethnographic literature (Albright 1984; Romanoff 1985). The salmon were donated from the McKenzie River hatchery, located outside of Eugene, Oregon. The fish were wild salmon that returned upriver to spawn, at which time they were harvested by the hatchery and frozen. Although some of the fish at the hatchery had been subjected to varying degrees of processing after collection, we ensured that all the specimens used for the experiment were undamaged (i.e., no visible cut marks or punctures). Prior to butchery, each specimen was defrosted for approximately 24 hours at room temperature.

The butchers each gutted and filleted five salmon using expedient obsidian flakes. The butchers self-selected their tools from an assortment of expedient flakes, and were instructed to replace their tool whenever they desired. The entire butchery process was recorded with a video camera (cf. Nilssen 2000), and the time needed to butcher each specimen was determined from the video. The butchery steps, described below, were kept as consistent as possible across the participants. A short discussion with the professional butchers revealed that their normal butchery methods aligned with ethnographic accounts of salmon butchery from British Columbia (e.g., Albright 1984; Romanoff 1985). Similarly, the intermediate-level butchers only required a short description of the experimental butchery steps to ensure consistency. In contrast, the novices were given a detailed description of the butchery steps, and they watched a video recording of one of the professional butchers.

Butchery of the salmon began with a slice along the length of the belly to remove the viscera (Figure 7a). Cuts were made just behind the gills up toward the vertebral column to separate the fillet from the head (Figure 7b). On a few occasions, the butcher severed the head from the vertebral column, but it was usually left attached. Next, the fish was laid open and cuts were made along each side of the vertebral column, separating the caudal fin, vertebral column, and head from the remaining fillets (Figure 7c). Lastly, the pectoral and pelvic fins were removed. This butchery method is similar to ethnographic accounts of processing salmon for drying in the Pacific Northwest. For example, the Tahltan (Albright 1984:63) and Lillooet (Romanoff 1985) of British Columbia removed the head and made two cuts along the backbone, separating the backbone and tail from the meat; the head, fillets, and backbone and tail were dried as three separate pieces. Fins were cut off and given to dogs (Albright 1984:63).

The specimens were individually sealed in 5-gallon buckets and left to cold-water macerate for just over three months. Because the buckets were stored outside, the cold temperatures slowed the maceration process. After three months, we simmered the specimens to remove the remaining flesh from the bones. After simmering, the specimens were rinsed over 1-mm screen and air-dried.

Figure 7. Stages of salmon butchery. Photographs by A. R. Boehm.

a. Cut was made along the length of the belly.

b. Cuts were made posterior to the gills.

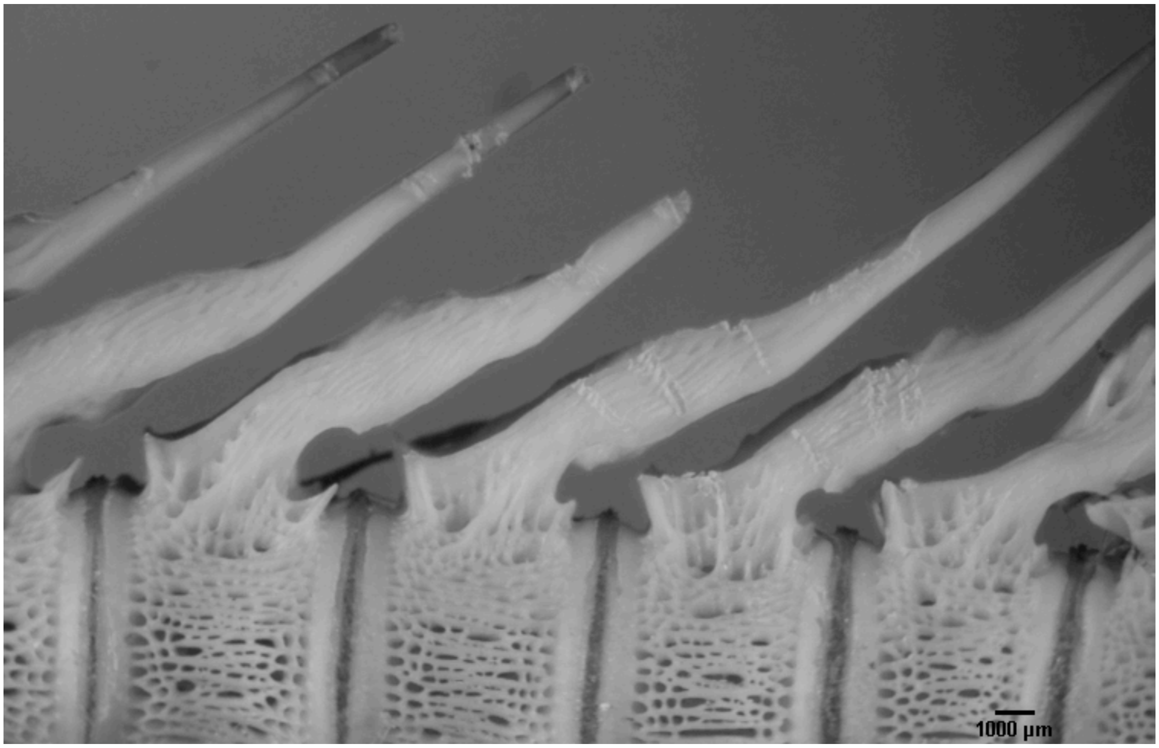
Figure 7 Continued. Stages of salmon butchery. Photographs by A. R. Boehm.

c. Cuts were made along both sides of the vertebral column, separating the tail, backbone, and head from the fillets.

Willis inspected every bone from each specimen for cut marks using a 5x lens under strong light. Only clear, unambiguous cut marks were recorded. Cut marks included typical V-shaped grooves (Fisher 1995; Walker and Long 1977) (Figure 8a) as well as asymmetrical incisions accompanied by curled bone shavings (Figure 8b). Elements that were clearly damaged or altered as a result of the butchery process were noted (e.g., vertebral processes sheared off of vertebra; vertebra cut in half; Figure 9), but were not recorded as cut marks.

Figure 8. Cut marks on caudal vertebrae (a, b). Photographs by L. M. Willis.

a.



b.

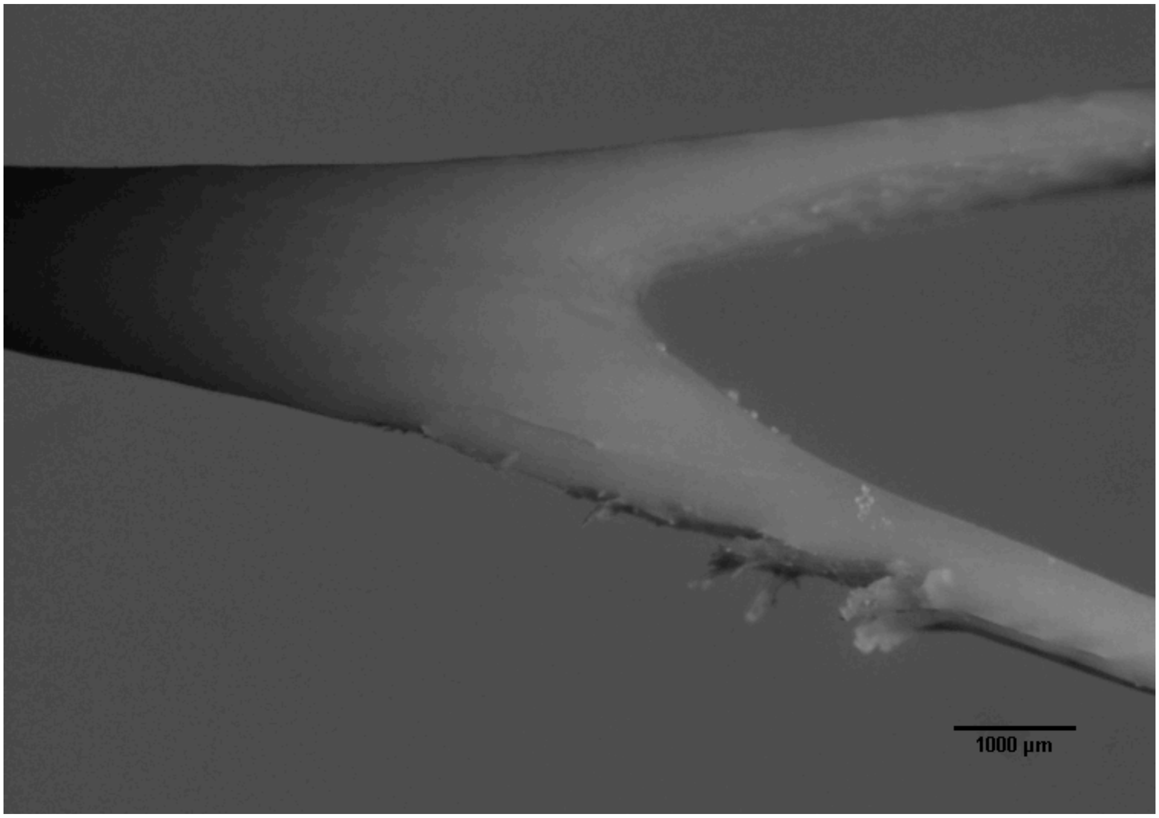
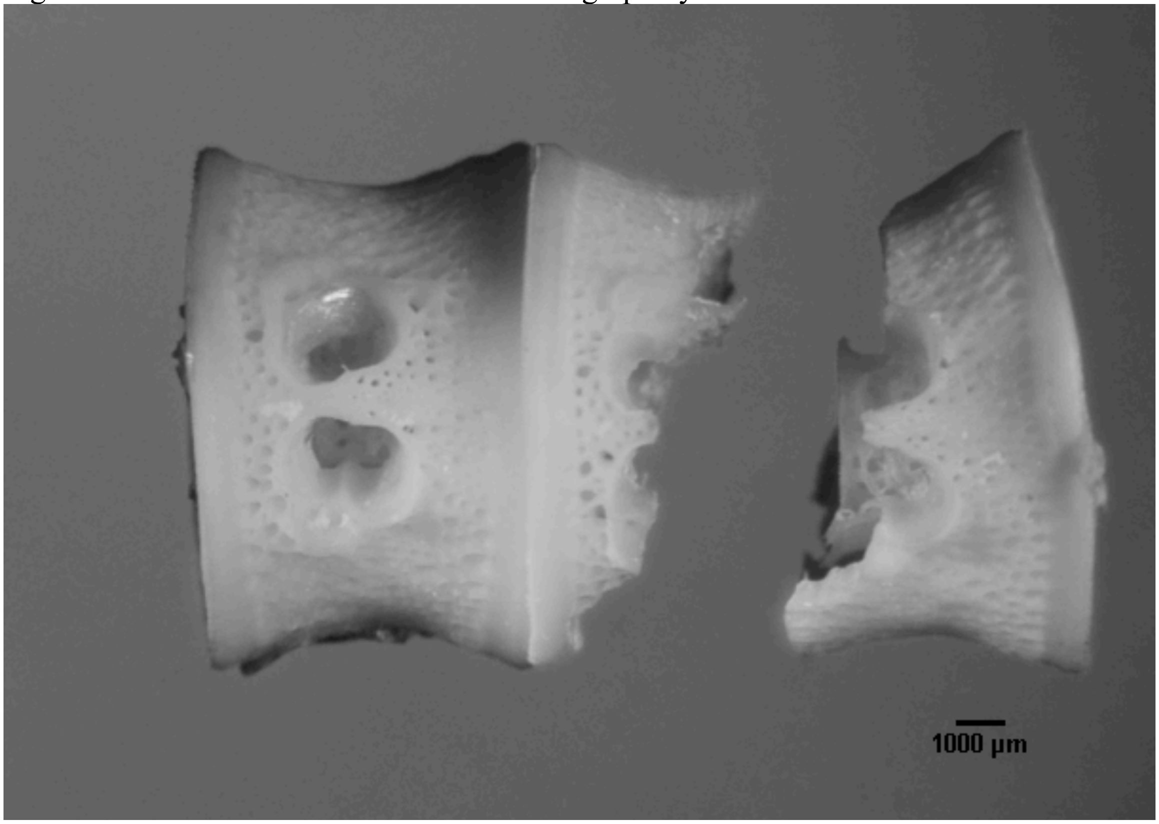


Figure 9. Thoracic vertebra cut in half. Photograph by L. M. Willis.

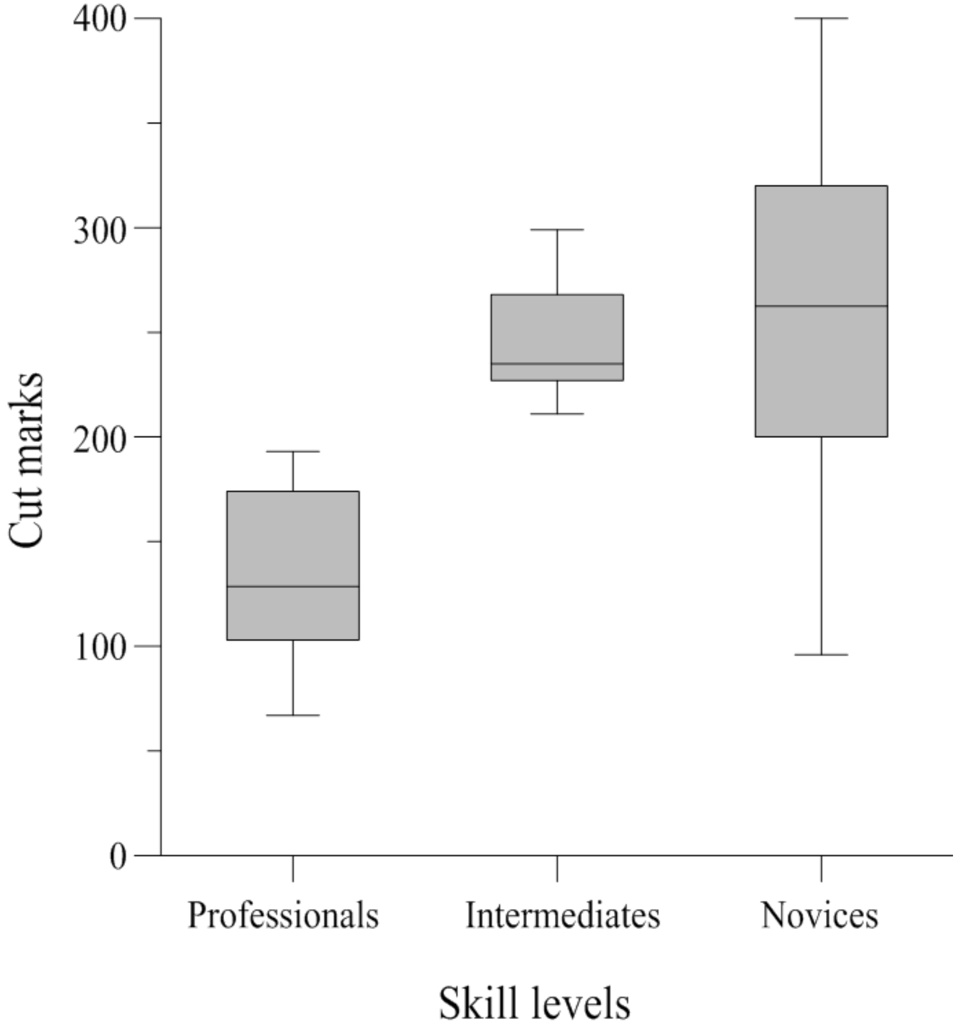


Results

Cut Mark Counts

The professional fishmongers produced an average of 132.9 cut marks per specimen, while the intermediate-level and novice butchers produced an average of 245.1 and 254.1 cut marks per specimen, respectively (Figure 10). The professional butchers produced significantly fewer cut marks than the intermediate-level (t = -6.54; df = 18; p < 0.001) and novice (t = -3.70; df = 18; p = 0.002) butchers. The difference in the average number of cut marks produced by the intermediate-level and novice butchers was not statistically significant (t = -0.293; df = 18; p = 0.773).

Figure 10. Boxplot showing cut mark counts per specimen for professional, intermediate, and novice butchers.



In addition to the overall count of cut marks, differences between the skill groups were also evident in the frequency with which the butchers completely severed the vertebral processes from the vertebrae (Figures 11 and 12). This action did not leave a distinct cut mark and did not contribute to the cut mark counts. It does, however, further highlight the differences between the skill groups. The professional butchers completely

Figure 11. Section of caudal vertebrae from specimen butchered by a fishmonger. Photograph by L. M. Willis.

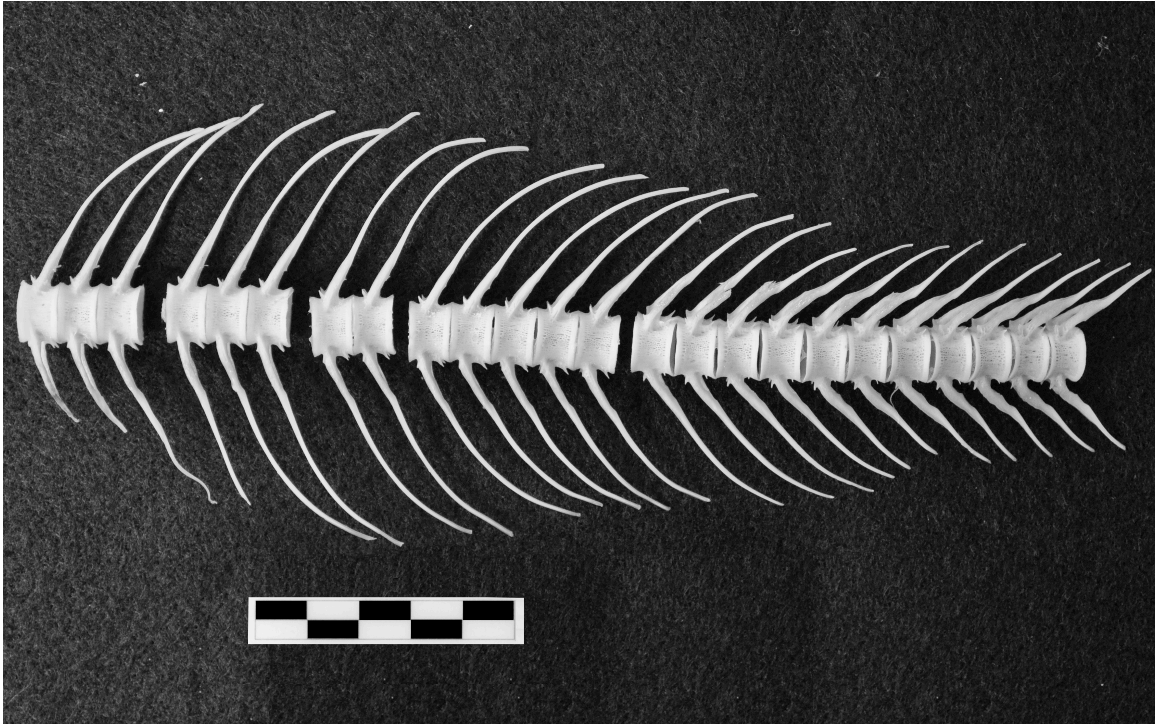


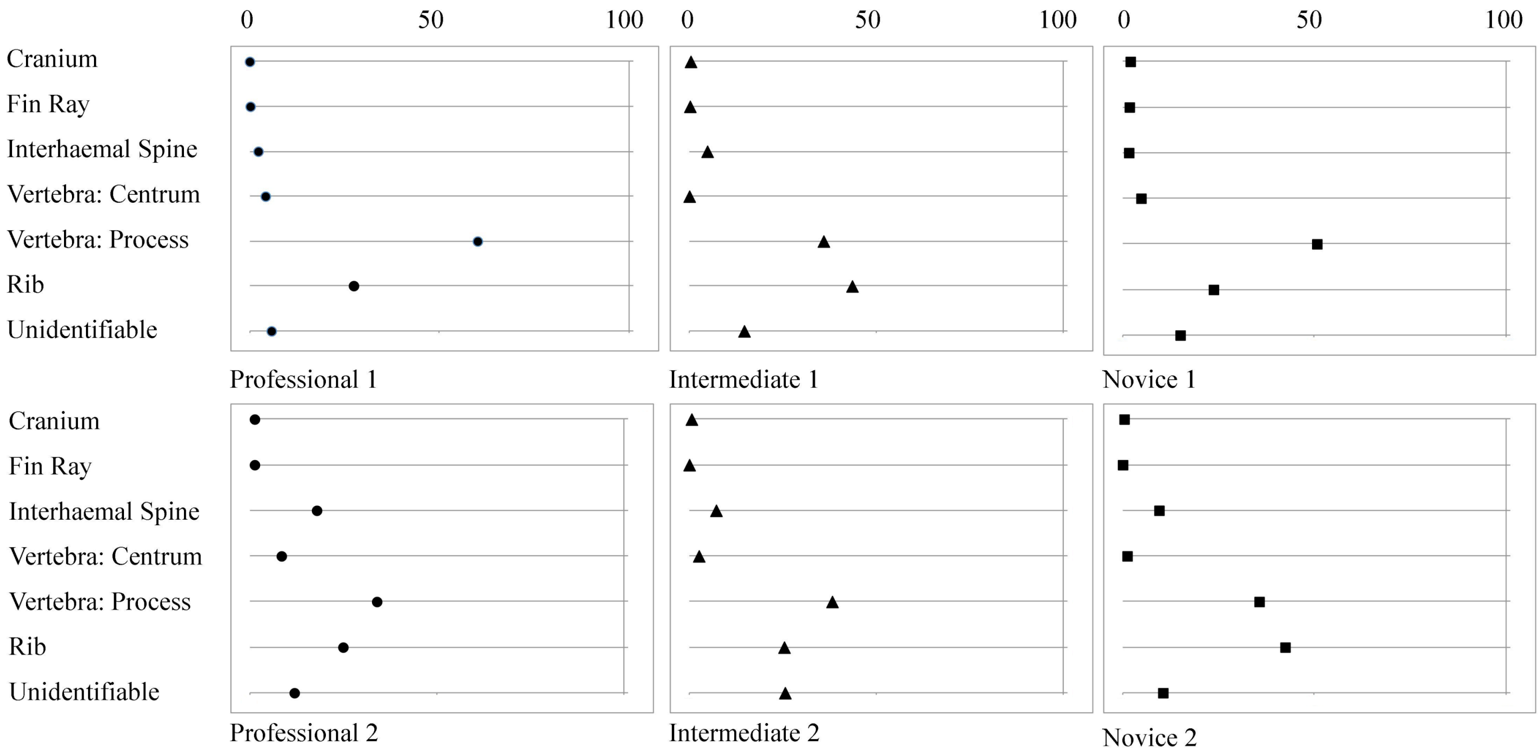
Figure 12. Section of caudal vertebrae from specimen butchered by a novice. Photograph by L. M. Willis.

severed the vertebral processes from 3.9 and 1.6 percent of precaudal and caudal vertebrae. In contrast, the novice butchers severed the vertebral processes from 72.3 and 51.9 percent of the vertebrae. Interestingly, the intermediate-level butchers were split—one severed only 1.1 percent of the vertebral processes, while the other severed 43.8 percent. This difference undoubtedly results from the fact that the intermediate-level group is obligatorily broad, encompassing the range of experience between two ends of the spectrum. While our two intermediate-level butchers reported similar histories, it is noteworthy that one of them matched the professionals in this respect.

Cut Mark Distribution

The distribution of cut marks varied within and between the skill levels. However, for all the butchers, regardless of skill level, the majority of the cut marks were distributed on the vertebral processes (between 34% and 60%, depending on the butcher) and ribs (24% to 44%) (Figure 13). The remaining cut marks were primarily distributed on interhaemal spines (2% to 18%), vertebral centra (0.1% to 8.5%), and unidentifiable bones or bone fragments (6% to 26%). Because the butchery method used for this study did not involve butchering the heads, few cut marks were found on cranial elements (between 0 and 2.1%, depending on the butcher). The few observed cut marks were located on elements from the branchial skeleton and the pectoral and pelvic girdles (e.g., ceratobranchial, posttemporal, coracoid, basipterygium), and likely resulted from cuts made near the gills to separate the head from the fillets (Figure 7b).

Figure 13. Percent distributions of cut marks.



As we have emphasized in previous studies (Willis et al. 2008; Willis and Boehm 2014), the distribution of cut marks primarily on the post-cranial elements may account for why cut marks are rarely reported on fish bone from archaeological sites. Unlike cranial elements, these bones (i.e., broken vertebral processes, ribs, interhaemal spines) are not useful for taxonomic identification. As a result, they may not be as carefully examined as the bones that can provide taxonomic data (i.e., cranial bones). Indeed, in those cases where cut marks were identified on archaeological fish assemblages, they were commonly distributed on cranial elements (e.g., Barrett 1997; Barrett et al. 1999; Belcher 1998; Çakirlar et al. 2014).

Butchery Times

Differences are also evident in the amount of time required for butchery. On average, the professional butchers gutted and filleted each specimen in 7.11 and 9.03 minutes, respectively. The intermediate-level butchers required an average of 10.08 and 10.62 minutes per specimen, and the novices averaged 21.82 and 19.28 minutes (Table 3). When compared by experience level, the professional butchers required significantly less time than the intermediate-level ($t = -2.90$; df = 18; $p = 0.010$) and novice ($t = -8.73$; df = 18; $p < 0.001$) butchers. The intermediate-level butchers required significantly less time than the novices ($t = -6.69$; df = 18; $p < 0.001$).

It is interesting to note that the time required by the novices decreased with each successive specimen (with the exception of specimen 5 for both of the novice butchers), while the butchery times for the intermediate-level and professional butchers had no discernible pattern.

Table 3. Butchery times (min).

Butcher	Specimen 1	 2	 3	 4	 5	Avg. Time (min)	Avg. Time per Skill Level
Novice 1	28.30	22.17	21.18	17.45	19.98	21.82	20.55
Novice 2	24.03	23.62	19.68	14.13	14.95	19.28	
Intermediate 1	8.47	9.05	11.58	11.03	10.25	10.08	10.35
Intermediate 2	8.35	7.33	10.73	14.63	12.05	10.62	
Professional 1	11.43	7.97	8.87	8.38	7.50	8.83	8.07
Professional 2	7.08	6.38	8.12	6.58	7.40	7.11	

Discussion

The Effect of Skill Level

Not unexpectedly, the results of this study indicate that a skilled fish butcher will produce upwards of 50 percent fewer cut marks on fish bone than novice or intermediate-level butchers. The novice- and intermediate-level groups were statistically indistinguishable. These results suggest that the butcher's degree of know-how influences the number of cut marks produced on fish bone to a much greater extent than knowledge of the task. For example, in our conversations with one of the fishmongers, he mentioned that he tries not to hit the bones so as to avoid dulling his tools. In contrast, the novices were unfamiliar with the anatomy of the salmon (i.e., lacked knowledge), and were therefore unable to intentionally avoid cutting the bones. While the intermediate-level butchers were more familiar with the location of the bones than the novices, they may have lacked the expertise required to avoid hitting the bones and/or were unconcerned with the effect it has on the tools (i.e., lacked know-how).

The similarity between novice and intermediate skill levels has also been observed in lithic reduction (Bril et al. 2010; Harlacker 2006; Nonaka et al. 2010) and pottery production (Kamp 2001:431). Our results mirror a flintknapping experiment by Harlacker (2006) in which 49 participants of varying skill reduced two stone cores into sharp, usable flakes. Harlacker's results indicated that advanced knappers differed from intermediate- and novice-level knappers on more variables and to a greater degree than intermediates and novices differed from each other. The consistency of this result across two distinct tasks (i.e., fish butchery and flintknapping) highlights the importance of recruiting expert craftspeople or butchers for experimental studies. Although we are unable to conclude how much experience is required to become an expert, several years of continuous practice should be considered a minimum. This is usually not feasible for most researchers, but notable exceptions exist (Dewbury and Russell 2007; Eren et al. 2011; Seetah 2008).

As previously noted, none of the participants were skilled with stone tools. One of the fishmongers reported that with his normal knives, he is able to fillet a whole salmon in about one minute; with the obsidian flakes it took him approximately seven minutes. A comparison of the cut marks produced by butchers with and without experience using stone tools would be a logical next step, and would strengthen the relationship between the experimental results and the archaeological record.

Archaeological Implications

Discerning skill in the archaeological record has recently become a hot topic in archaeological literature (e.g., Bamforth and Finlay 2008; Bleed 2008; Eren et al. 2011; Machin 2009; Olausson 2008; Tehrani and Riede 2008). While this research has generally focused on ceramic and lithic technology (e.g., Apel 2008; Crown 2001, 2007; Gandon et al. 2001; Grimm 2000; Ferguson 2008; Kamp 2001; Stout 2002), it is logical to assume that similar stages of learning—including practice and apprenticeship—would have occurred for faunal processing. However, this study demonstrates that identifying faunal processing skill level in the archaeological record will be a difficult task. The distribution of cut marks varied both within and between the three skill levels; therefore, our results suggest that cut mark distribution is a poor indicator for discerning expert from novice. Cut mark frequency may provide a promising avenue of research, given the statistical difference between professionals and less-skilled butchers (i.e., intermediates and novices). However, given the numerous factors that affect cut mark frequency—including raw material type (Abe 2002; Dewbury and Russell 2007; Seetah 2008); tool type and size (Greenfield 2006; Toth and Woods 1989; Walker and Long 1977; West and Louys 2007); preservation of cut marks (Fisher 1995; Lyman 1992, 2005; Willis and Boehm 2014); bone fragmentation (Abe 2002; Bartram 1993; Otarola-Castillo 2010; Rapson 1990); carcass condition (Egeland 2003); and animal size (Gifford-Gonzalez 1989; Lyman 1992; Pobiner and Braun 2005)—teasing apart skill from other taphonomic factors will be a difficult task.

Conclusion

Our results demonstrate that a butcher's experience level can affect the outcome of an experimental butchery study, and should be considered an important variable when devising a research plan. Although already common in most recent studies, we encourage future researchers to clearly articulate the experience level of the butcher used in experimental studies. This will allow researchers to assess whether other experimental results are comparable to their own, on the basis of the skill level of the butcher. Previous experimental data with no description of the butcher's skill level should be approached with caution.

In addition, this study contributes to the growing body of research focused on fish bone taphonomy. Compared to the numerous experimental studies examining various aspects of mammal bone taphonomy, relatively few archaeological experiments focus on the taphonomy of fish bones (e.g., Butler and Chatters 1994; Butler and Schroeder 1998;

Collins 2012; Lubinski 1996; Nagaoka 2005; Nicholson 1996b; Vale and Gargett 2002; Zohar et al. 2008). Even fewer specifically address potential signatures of human processing and consumption (e.g., Butler and Schroeder 1998; Gifford-Gonzalez et al. 1999; Willis and Boehm 2014; Willis et al. 2008; Zohar and Cooke 1997). With recent discoveries redefining how archaeologists view human evolution and the primacy of coastal and other aquatic resource use (e.g., Bailey 2004; Braun et al. 2010; Craig et al. 2013; Erlandson 2001, 2010; O'Connor et al. 2011; Stewart 2010; von den Driesch 2004; Zohar and Binton 2011), it is to our advantage to expand the breadth of our knowledge regarding the taphonomy of fish remains at archaeological sites.

Bridge

This chapter highlights the variation in experimental results caused by the experimenter's level of expertise. Although the number of cut marks produced by the professional butcher was significantly less than those produced by the intermediate- and novice-level butchers, cut marks were not wholly absent. Together with chapter II, the results of this chapter indicate that, if prehistoric peoples were butchering fish with methods similar to the method described here, cut marks on archaeological fish bone should be reported in much greater frequencies. An alternative explanation for the discrepancy between the experimental results and archaeological reports is post-depositional taphonomic processes. The following chapter summarizes the effects of burial on the visibility and location of experimentally-produced cut marks.

CHAPTER IV

FISH BONES, CUT MARKS, AND BURIAL: IMPLICATIONS FOR TAPHONOMY AND FAUNAL ANALYSIS

This work was published in volume 45 of the *Journal of Archaeological Science* in 2014. Andrew R. Boehm assisted in the retrieval of the specimens and conducted the pH tests. I processed the specimens and identified the cut marks. I was the primary author; Boehm provided editorial assistance.

Introduction

The vast majority of experimental studies of bone taphonomy (e.g., trampling, cut marks, cooking, scavenger modification, body-part frequencies, fluvial transport, etc.) have focused on mammal bones (e.g., Álvarez et al. 2012; Behrensmeyer et al. 1986; Church and Lyman 2003; Dewbury and Russell 2007; Domínguez-Rodrigo 1997; Domínguez-Rodrigo et al. 2009; Domínguez-Rodrigo et al. 2012; Egeland 2003; Fairnell 2008; Pante and Blumenschine 2010; Pobiner and Braun 2005; Potter 2005; Selvaggio 1994b; Seetah 2008; Ugan 2010). Comparatively fewer studies examine the effects of taphonomic processes on bird or fish bones (e.g., Broughton et al. 2007; Butler and Chatters 1994; Butler and Schroeder 1998; Collins 2012; Lubinski 1996; Nicholson 1996b). The focus on mammal bones is likely a reflection of the data presented from archaeological sites. For example, cut marks are rarely reported on bird or fish bones (Colley 1990:216-217; Butler 1996; but see Barrett 1997; Belcher 1998; deFrance 2005; Steadman et al. 2002), while cut marks on mammal bones are well documented from the

Paleolithic through the historic period (Binford 1981; Broughton 1999:138, 150; Bunn and Kroll 1986; Cruz-Uribe and Klein 1994; Domínguez-Rodrigo et al. 2005; Lupo 1994; Lyman 1992; Svoboda et al. 2005). It should be no surprise that experimental research has aimed to explain what appears to be a more common phenomenon in the archaeological record.

To help fill in the gaps in our understanding of cut marks on animal bones, we originally asked: Does butchering fish result in cut marks? (Willis et al. 2008). In our initial butchery experiment, we demonstrated that cut marks were ubiquitous on the fish skeletons we butchered. The results of that experiment were contrary to what was expected based on the infrequency of reported cut marks on archaeological fish bones. We concluded that the discrepancy between the experimental results and the number of cut marks reported on archaeological fish bones might be attributed to post-depositional taphonomic processes (e.g., root etching, bone degradation, etc.), which may obscure the visibility of cut marks. As many of the experimental cut marks were small and shallow (Willis et al. 2008:1443), it is conceivable that they were 'erased' from the bone surface by subsequent cultural practices (i.e., cooking) or weathering processes. However, this conclusion from our 2008 experiment was largely speculative.

In this paper we study the effects of burial (specifically, post-depositional taphonomic processes) on the number of cut marks visible on butchered fish skeletons. The burial duration for this experiment cannot approximate the length of deposition at most archaeological sites, but any decrease in the number of observed cut marks would indicate that prolonged burial could affect the visibility of cut marks on fish bone. Our results have implications for the study of fish bone assemblages worldwide, from early hominin occupations to historical times.

Methods

We buried 13 butchered fish for approximately 27 months, from May 2007 through September 2009. The buried carcasses and species included four spotted weakfish (*Cynoscion nebulosus*), three red drum (*Sciaenops ocellatus*), four hardhead catfish (*Ariopsis felis*), and two summer flounder (*Paralichthys dentatus*). The standard length (cm) and weight (g) for each specimen is recorded in Table 4. All of these species are marine dwellers; the spotted weakfish, red drum, and hardhead catfish were collected from the Gulf of Mexico near St. Petersburg, Florida, while the summer flounder were collected from the Atlantic Ocean near Gloucester, Massachusetts. Although two of the species used in this study (i.e., hardhead catfish and summer flounder) were used in the 2008 experiment, the specimens differ.

The specimens were butchered using either expedient stone tools knapped by M. Eren or a metal knife (see Table 5). The butchery methods for each of the specimens follow those described in Willis et al. (2008). Briefly, an incision was made along the length of the ventral side to remove the viscera. Next, the head was removed. Finally, cuts were made along either side of the vertebral column, separating the caudal fin and vertebrae from the fillets.

Table 4. Standard length (cm) and weight (g) for individual specimens. AF = hardhead catfish; PD = summer flounder, CN = spotted weakfish; SO = red drum.

Specimen	**Standard Length (cm)**	**Weight (g)**
AF-11	31	474.0
AF-12	27	309.1
AF-13	34	674.6
AF-14	31	508.8
PD-11	37	942.3
PD-12	31	486.6
CN-01	35	619.9
CN-02	27	252.2
CN-03	26	189.4
CN-04	23	190.4
SO-01	26	344.9
SO-02	40	1262.6
SO-03	49	1713.2

Table 5. Pre- and post-burial cut mark totals for individual specimens.

Specimen	**Pre-burial Cut Marks**	**Post-burial Cut Marks**	**Butchery Tool**
AF-11	84.6*	98	Stone (Chert)
AF-12	84.6*	99	Stone (Chert)
AF-13	84.6*	161	Stone (Chert)
AF-14	84.6*	92	Stone (Chert)
Average	*84.6*	*112.5*	
PD-11	307.8*	157	Stone (Chert)
PD-12	307.8*	67	Stone (Chert)
Average	*307.8*	*112*	
CN-01	27	15	Stone (Chert)
CN-02	73	7	Stone (Chert)
CN-03	14	4	Metal Knife
CN-04	14	4	Metal Knife
Average	*32*	*7.5*	
SO-01	170	18	Stone (Chert)
SO-02	274	291	Stone (Obsidian)
SO-03	280	243	Stone (Chert)
Average	*241.3*	*184*	

AF = hardhead catfish; PD = summer flounder, CN = spotted weakfish; SO = red drum. *Note that the pre-burial cut mark counts for hardhead catfish and summer flounder are the average number of cut marks per specimen from Willis et al. (2008).

The spotted weakfish and red drum were cold-water macerated and buried without any flesh remaining on the bones (Figure 14a). The cut marks on these skeletons were tallied prior to burial, allowing for a direct comparison of the pre- and post-burial cut mark frequencies and locations. Conversely, the hardhead catfish and the summer flounder were butchered and buried with the flesh on the bones (Figure 14b); therefore, we do not have pre-burial cut mark counts for these individuals. The average number of cut marks observed on hardhead catfish and summer flounder specimens butchered with stone tools in Willis et al. (2008) are compared to the post-burial cut mark totals (see Table 6 for the cut mark counts from Willis et al. (2008)).

The fish were buried individually in holes approximately 20 cm deep. The burial location was a residential area of Dallas, Texas; it was a well-drained site with grass cover and clayey soil (see below for pH data). We mapped the location of each specimen and took photographs with stationary landmarks to assist with the recovery.

After 27 months, each specimen and the surrounding soil was removed in bulk, and once back in the laboratory, was first dry-screened (1/32"), then water-screened (1/32"). Any bones that were observed during dry-screening were removed prior to water-screening. Any remaining bones or bone fragments were recovered after the sample was wet-screened.

Willis inspected every bone for cut marks using a 5x lens under strong light. Only unambiguous cut marks were tallied. Because we could not verify the cause, any crushing or shearing of the bone that may have been caused by the blade during butchering (or, alternatively, during deposition or retrieval of the bones; e.g. trowel, shovel) was not recorded.

Figure 14. A red drum skeleton, macerated prior to burial (a) and a hardhead catfish carcass, butchered and buried with flesh (b). Photographs by L. M. Willis.

a.

b.

Table 6. Cut mark totals for hardhead catfish and summer flounder butchered with stone tools from Willis et al. (2008). AF = hardhead catfish; PD = summer flounder.

Specimen	**Total Cut Marks**
AF-01	15
AF-02	59
AF-03	149
AF-04	116
AF-05	84
Average	*84.6*
PD-01	245
PD-02	325
PD-03	538
PD-04	380
PD-05	51
Average	*307.8*

Soil pH

During specimen retrieval, we collected soil samples from each burial location (n=13) and one control sample located approximately 5 m to the north. A. Boehm conducted the pH tests in a laboratory at Southern Methodist University. 25 mL of distilled water was added to 25 g of well-mixed soil (1:1 ratio) and allowed to sit for 30 minutes (Klute 1986). pH readings were taken using an Orion Smart Check 02000A pH/temperature meter calibrated with buffer solution 7 and buffer solution 4. Two independent tests were run for each sample, and the resulting pH readings were averaged. The pH values for all of the holes with fish skeletons were slightly alkaline, ranging from 7.71 to 7.99. The pH from the control sample was similar, with a value of 8.01. Bone generally preserves well in such alkaline soils (Lubinski 1996).

Results

Spotted Weakfish and Red Drum

In general, the results of our study suggest a decreased number of visible cut marks after burial. For spotted weakfish and red drum, where we have pre-burial cut mark totals, the average number of cut marks per specimen drops from 32 to 7.5 for spotted weakfish and from 241.3 to 184 for red drum (Table 6). The pre-burial difference in the number of cut marks between the two species is likely due to differences in the bone. Qualitatively, the bones of the spotted weakfish were smaller and more fragile than red drum bones; it is possible that bones of the spotted weakfish specimens were simply cut-through.

Changes in the distribution of pre- and post-burial cut marks differ between spotted weakfish and red drum (Tables 7 and 8). For the spotted weakfish specimens, the majority of pre-burial cut marks were located on the vertebrae (n=105; 82%), with a small number on ribs (n=16; 12.5%) and unidentifiable bones (n=7; 5.5%). After burial, although the overall count was dramatically reduced, the majority of cut marks were still identified on the vertebrae (n=27; 90%); no cut marks were identified on ribs, and three (10%) cut marks were identified on unidentifiable bone fragments. In contrast, for the red drum specimens, there was a notable shift before and after burial from cut marks on identifiable elements (i.e., vertebrae, ribs, interhaemal spines, etc.) to cut marks on unidentifiable bones and bone fragments. The total number of cut marks on identifiable red drum bones drops from 658 to 183, while the number of cut marks on unidentifiable red drum bones increases from 66 to 369. In other words, ~9 percent of the pre-burial cut

Table 7. Pre- and post-burial cut mark counts per element for individual specimens. CN = spotted weakfish; SO = red drum.

Specimen	**Element**	**Pre-burial Cut Marks**	**Post-burial Cut Marks**
CN-01	Vertebra (Centrum)	3	3
	Vertebra (Process)	14	10
	Rib	3	0
	Unidentifiable	7	2
CN-02	Vertebra (Centrum)	35	6
	Vertebra (Process)	26	0
	Rib	12	0
	Unidentifiable	0	1
CN-03	Vertebra (Centrum)	3	3
	Vertebra (Process)	11	1
CN-04	Vertebra (Centrum)	11	4
	Vertebra (Process)	2	0
	Rib	1	0
SO-01	Vertebra (Centrum)	23	14
	Vertebra (Process)	67	0
	Basipterygium	2	0
	Interhaemal Spine	14	0
	Rib	35	0
	Unidentifiable	29	4
SO-02	Vertebra (Centrum)	17	24
	Vertebra (Process)	109	46
	Cleithrum	2	1
	Upper Postcleithrum	2	0
	Basipterygium	4	0
	Interhaemal Spine	17	0
	Rib	106	0
	Unidentifiable	17	220
SO-03	Vertebra (Centrum)	50	38
	Vertebra (Process)	149	60
	Ceratobranchial	2	0
	Interhaemal Spine	23	0
	Rib	36	0
	Unidentifiable	20	145

Table 8. Percent distribution of pre- and post-burial cut mark totals by element for experimental species.

Species	**Element**	**Percentage Pre-burial Cut Marks**	**Percentage Post-burial Cut Marks**
Spotted Weakfish	Vertebra	82.0	90.0
	Rib	12.5	0.0
	Subtotal - Cut Marks on Identifiable Elements	*94.5*	*90.0*
	Unidentifiable	5.5	10.0
Red Drum	Basipterigium	0.8	0.0
	Ceratobranchial	0.3	0.0
	Cleithrum	0.3	0.2
	Upper Postcleithrum	0.3	0.0
	Vertebra	57.3	33.0
	Interhaemal Spine	7.5	0.0
	Rib	24.4	0.0
	Subtotal - Cut Marks on Identifiable Elements	*90.9*	*33.2*
	Unidentifiable	9.1	66.8
Hardhead Catfish	Basipterygium	0.0	0.2
	Cleithrum	5.7	5.6
	Coracoid	0.0	1.3
	Hyplural	0.0	1.6
	Pectoral Spine	6.1	1.8
	Second Dorsal Spine	2.4	1.1
	Vertebra	58.9	35.3
	Fin Ray	0.9	0.0
	Rib	24.8	17.3
	Subtotal - Cut Marks on Identifiable Elements	*98.8*	*64.2*
	Unidentifiable	1.2	35.8
Summer Flounder	Postcleithrum	0.1	0.0
	Vertebra	44.4	18.3
	Fin Ray	0.6	0.0
	Interhaemal Spine	1.9	0.0
	Pterygiophore	43.9	5.4
	Rib	1.2	0.0
	Subtotal - Cut Marks on Identifiable Elements	*92.3*	*23.7*
	Unidentifiable	7.7	76.3

marks were located on unidentifiable red drum bones, compared to ~67 percent post-burial. We address the reason for this shift in the discussion section below.

As previously stated, many of the cut marks on the specimens from Willis et al. (2008) and on the pre-burial spotted weakfish and red drum were shallow and small. As figures 15 and 16 demonstrate, those cut marks that remained visible after burial tended to be quite deep.

Figure 15. Cut marks on a red drum vertebra post-burial. Photograph by L. M. Willis.

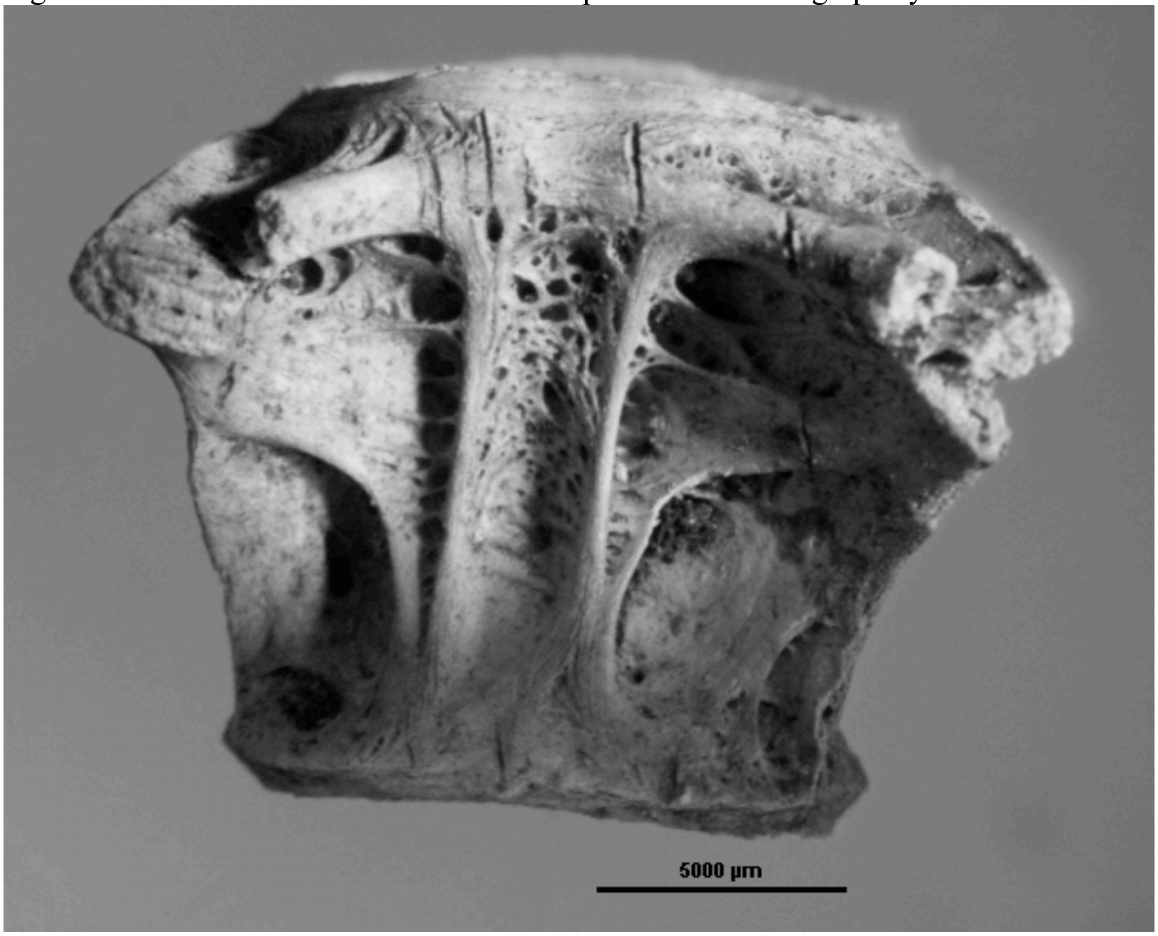
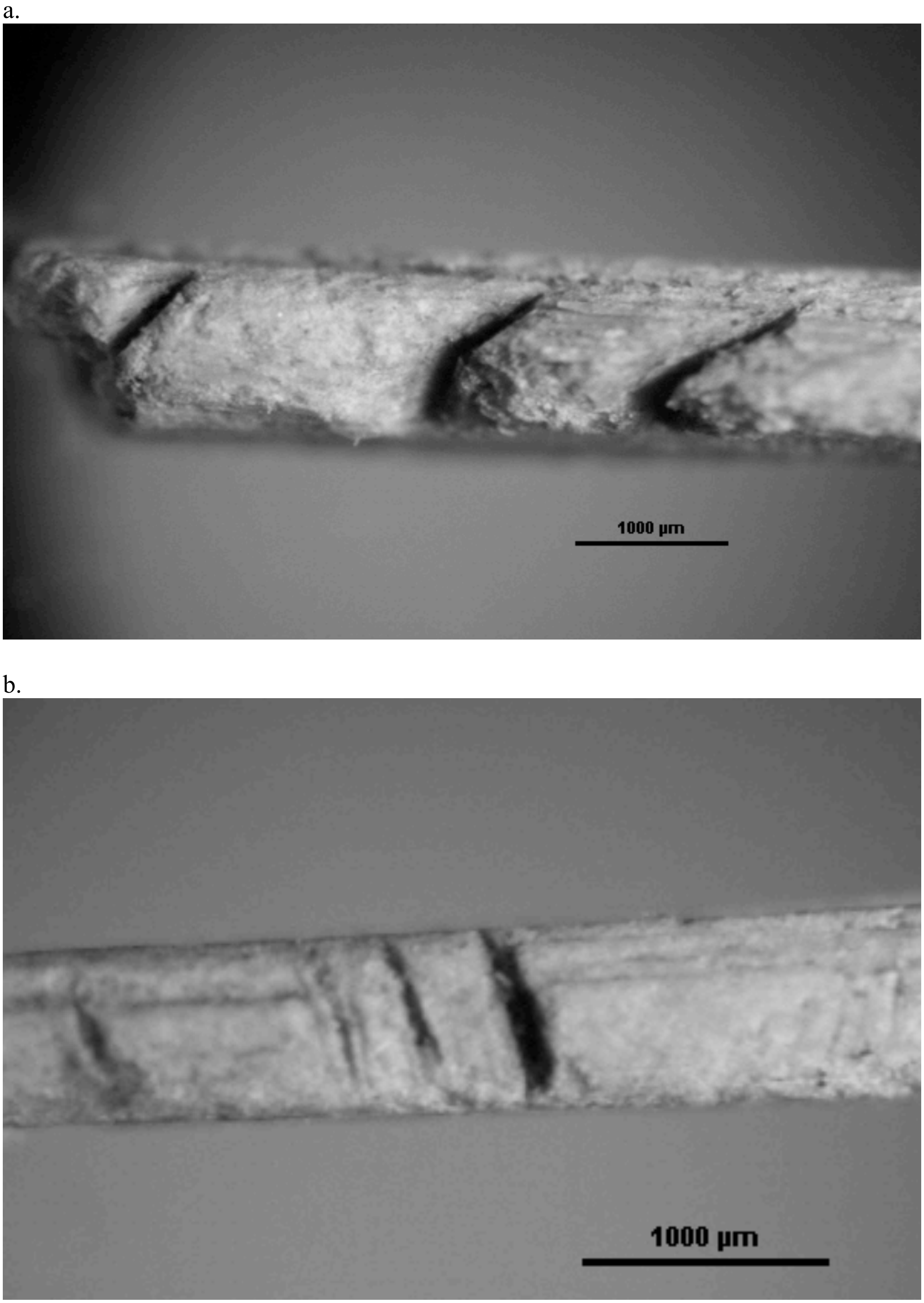


Figure 16. Cut marks on unidentifiable red drum (a) and summer flounder (b) bone fragments post-burial. Photographs by L. M. Willis.



Hardhead Catfish and Summer Flounder

Clearly, the results for those species buried with the flesh on (i.e., hardhead catfish and summer flounder) need to be considered with a wary eye. Given that we do not have pre-burial cut mark counts for these individual fish, we have to rely on the average number of cut marks observed on the catfish and flounder individuals butchered with stone tools from Willis et al. (2008). However, the original counts vary widely—between 15 and 149 total cut marks per catfish and 51 and 538 cut marks per flounder. Because of this, the average number of pre-burial cut marks for catfish is actually smaller than the average from the post-burial catfish skeletons (Table 6). This is an issue that only a larger sample size could resolve.

There is a notable increase in cut marks on unidentifiable bones between the specimens from the original butchery experiment and those specimens that were buried (Table 5). For example, only ~1 percent of the cut marks on hardhead catfish bones were located on unidentifiable bones or bone fragments in Willis et al. (2008), compared to ~36 percent for those specimens that were buried. Similarly, for summer flounder, ~8 percent of the cut marks were on unidentifiable bones or bone fragments in the original butchery experiment, compared to ~76 percent for those specimens that were buried.

Specimen Recovery

Care was taken to ensure that the results of this study accurately reflect the number of cut marks on the skeletons after burial, rather than represent a reduced sample due to recovery issues. During recovery, we removed a large amount of soil in bulk around each burial location in an attempt to curb potential losses due to vertical or horizontal movement.

There does appear to be some mixing between two of the red drum specimens, but it is unclear whether this occurred during the retrieval of the skeletons or during the processing stages after recovery. However, because the results are presented by species rather than individual specimen, this error does not impact the results.

Discussion

The results from this study demonstrate that, generally, the number of cut marks visible on fish bones decreases after only 2.25 years of burial. The decrease in cut marks is most dramatic on those species with smaller, more fragile bones (i.e., spotted weakfish, which averaged a 76 percent decrease in visible cut marks, and summer flounder, which averaged a 64 percent decrease)—species on which the cut marks tended to be more ephemeral prior to burial. On the red drum, the pre-burial cut marks were deeper and, thus, more likely to still be visible after burial. We observed a 24 percent decrease in the number of visible cut marks after burial for the red drum specimens.

Additionally, prior to burial, the majority (>90%; see Table 8) of cut marks were located on identifiable elements (e.g., vertebral processes and ribs). Due to fragmentation during burial, a higher percentage of cut marks (i.e., upwards of 76%, depending on the species; see Table 8) were located on unidentifiable bone fragments after burial. For example, the majority of the vertebral processes broke off of the centra during burial and/or recovery. As a result, cut marks located on a vertebral process prior to burial would be located on an unidentifiable bone fragment post-burial, assuming the cut marks remained visible. Based on these results, we can expect to see cut marks distributed on unidentifiable fish bones from archaeological assemblages in instances where fish were processed similarly to the methods used in this study.

The combined effect of these two influences—decreased cut mark visibility and bone fragmentation—likely contribute to the infrequency with which cut marks are identified on archaeological fish bone. Add to this the fact that fish bones generally preserve less well than mammal bones (Nicholson 1996a, 1998; Szpak 2011), and we have a recipe for underestimating or overlooking the occurrence of fish processing in the past. The relative dearth of cut marks on fish bone, as compared to mammal bone, may partially reflect preservation bias rather than differences in processing intensity between the classes.

In regard to the soil pH, the results of previous experimental and actualistic studies suggest that there is no consistent relationship between soil pH and bone preservation for fish (e.g., Collins 2012; Lubinski 1996; Nicholson 1996a, 1996b, 1998). Regardless, the pH values for the soil in our burial locations ranged from 7.71 to 7.99. As the primary mineral in bone, hydroxyapatite, is most stable at a pH of 7.9 (Lubinski 1996), we do not expect that soil pH influenced our results. The observed reduction in cut marks may be attributed to other post-depositional taphonomic processes, such as soil abrasion, cryoturbation, argilliturbation, root etching, the actions of insects and/or the actions of microscopic organisms.

Conclusion

Despite a relatively short period of burial, we observed an overall decrease in the number of cut marks, as well as a substantial increase in the percentage of cut marks on unidentifiable bone fragments. The short duration of this experiment make the results all the more interesting when compared to the length of deposition of (pre)historic archaeological sites. We feel this study represents a good foundation for understanding the effects of post-depositional processes on the survivorship of cut marks on fish bones. To build on these important results, future studies could examine the post-depositional visibility of cut marks on other bony fish taxa or under varying soil conditions.

Most importantly, this study emphasizes the need for archaeologists to examine unidentifiable fish bone fragments for cut marks. More often than not, these small, unidentifiable fragments are rarely inspected for evidence of butchering practices. Together with the results from Willis et al. (2008), this experiment demonstrates that cut marks are more likely to be distributed on unidentifiable bones and bone fragments when fish were processed in the past. Accordingly, in rare cases where cut marks were identified on archaeological fish remains (e.g. Barrett 1997; Belcher 1998; Pobiner 2007), they tended to be distributed on vertebrae, spines, pterygiophores, and unidentifiable elements.

The importance of aquatic resource use to the human past has become increasingly evident (Erlandson 2001). Recent research highlights the role of aquatic resources in human evolution (Braun et al. 2010; Broadhurst et al. 2002; Cunnane and Stewart 2010; von den Driesch 2004; Stewart 2010) and human migrations (Allen and O'Connell 2008; Bailey et al. 2007; Bulbeck 2007; Erlandson et al. 2007; Stringer 2000).

A greater understanding of the taphonomy of fish bones will contribute to our ability to distinguish natural from cultural assemblages and to infer prehistoric processing techniques.

Bridge

The results of this chapter indicate that burial, even on a relatively short time scale, can reduce the visibility of cut marks on archaeological fish bone. Further, the cut marks are distributed on unidentifiable bone fragments, as the fish bones fragment during or after burial and recovery. Together, chapters II, III, and IV form a continuous research program aimed at improving our understanding of the effects of butchery and burial on the production, location, and long-term visibility of cut marks on archaeological fish bones. In the following chapter, I apply the results from these experiments to a reanalysis of the fish bone from column E6 at the Daisy Cave site (CA-SMI-261), a multi-component shell midden located on California's San Miguel Island. Results from the previous experiments demonstrated that cut marks on fish bone tend to be small and distributed on unidentifiable bone fragments. Using the knowledge I have gained, I re-examined over 7,500 fish bones and bone fragments to identify cut marks not identified in the original analyses.

CHAPTER V

A REANALYSIS OF FISH BONE FROM DAISY CAVE (CA-SMI-261), SAN MIGUEL ISLAND, CALIFORNIA: THE EVIDENCE FOR BUTCHERY

Torben C. Rick performed the original analysis of the fish bones under the guidance of J. M. Erlandson (see Rick et al. 2001). I reanalyzed the fish bone assemblage discussed in this chapter, specifically searching for evidence of cut marks related to butchering practices. I was the primary author; Erlandson provided sampling advice, contextual information, and editorial support.

Introduction

California's northern Channel Islands provide a wealth of information regarding the earliest coastal settlements in North America. The earliest sites on the islands demonstrate significant seafaring capabilities, a rich and elaborate material culture, and diverse foraging and fishing activities (Erlandson et al. 2011; Johnson et al. 2002; Rick et al. 2013). Among these sites is Daisy Cave (CA-SMI-261), located on San Miguel Island. Daisy Cave once contained a long and well-stratified sequence of shell midden strata dated between about 11,600 and 1,000 cal BP, the result of sequential occupations dated to the Terminal Pleistocene, Early Holocene, Middle Holocene, and Late Holocene. In most areas of the site, the preservation of faunal remains in these strata is exceptional.

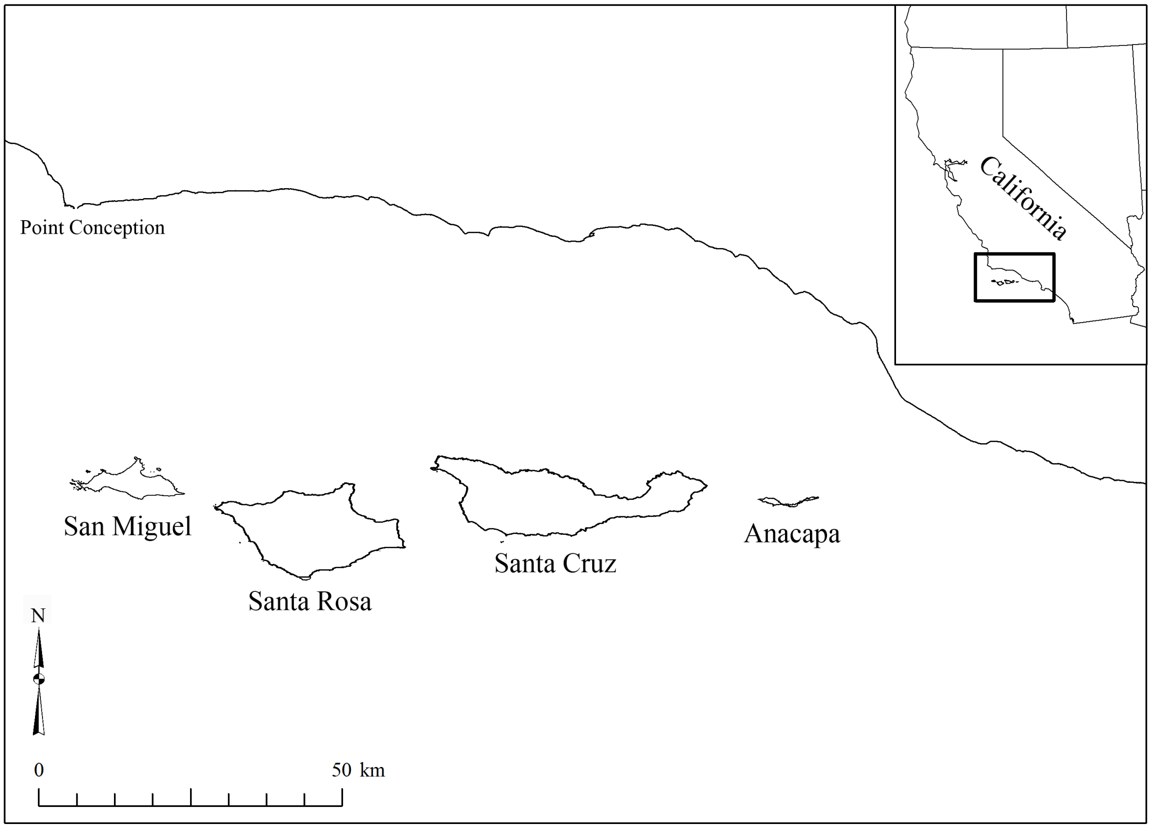
Fish comprised a substantial portion of the faunal assemblage in those strata dating to the Early Holocene, with edible meat weight estimates indicating that fish contributed approximately 50–65 percent of the meat during this period (Rick et al. 2001). During the Late Holocene, fish remained essential to the diet, contributing an estimated 40 percent of the meat weight represented by the recovered faunal remains (Vellanoweth et al. 2000). Despite the unusually high concentration of fish bone and the excellent preservation, no cut marks were identified on the nearly 30,000 fish bones originally analyzed from Daisy Cave. The lack of identified cut marks reported on the Daisy Cave specimens is not unusual, as zooarchaeologists studying fish remains from the California Coast have traditionally focused on a narrow range of identifiable elements and have not focused on butchery practices.

In this paper, I apply the results of a program of experimental archaeological research aimed at improving our understanding of the effects of butchery and burial on the production and identification of cut marks on archaeological fish bone (i.e., Willis and Boehm 2014; Willis et al. 2008) to a reanalysis of a portion of the fish bone assemblage from Daisy Cave.

Environmental Setting

Trending east to west, California's northern Channel Islands include Anacapa, Santa Cruz, Santa Rosa, and San Miguel islands (Figure 17). Today, they range between 20 and 44 km from the Santa Barbara Coast (Schoenherr et al. 1999). Never connected to the mainland during the Quaternary, the diversity of terrestrial flora and fauna on the islands is relatively depauperate compared to the adjacent mainland. San Miguel Island (SMI), located 42 km from the Santa Barbara Coast, is home to only three native

Figure 17. Map of the northern Channel Islands. Figure by A. R. Boehm.



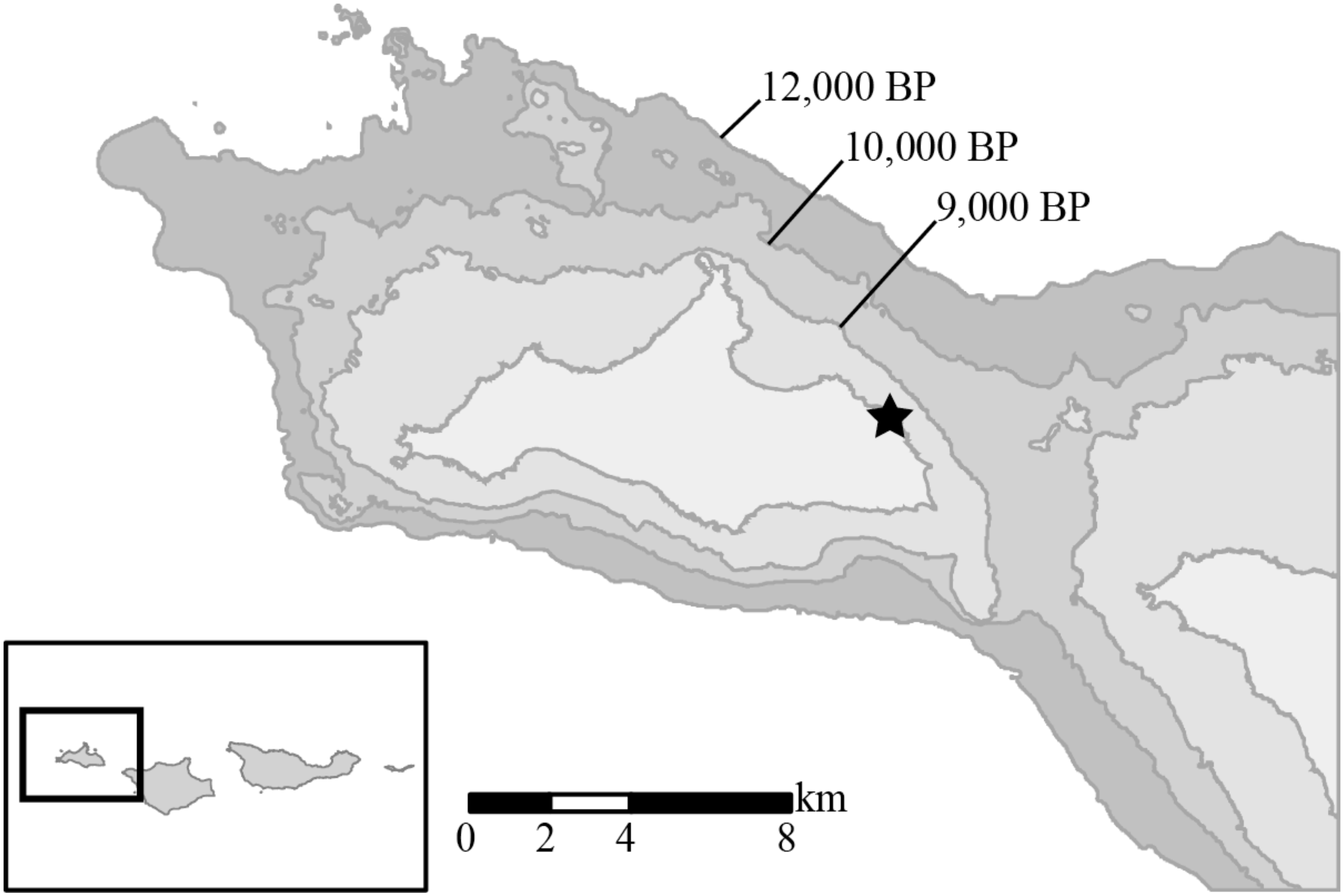
terrestrial mammals—the SMI deer mouse (*Peromyscus maniculatus streatori*), the SMI fox (*Urocyon littoralis littoralis*), and the California bat (*Myotis californicus*)—two of which were probably introduced by humans (Rick et al. 2012). The diversity of edible plants is also limited on the island, although some important geophytes are abundant, including the blue dick, *Dichelostemma capitatum*, (Gill 2013; Reddy and Erlandson 2012). In contrast to the terrestrial ecosystem, the upwelling of nutrient-rich waters and luxuriant kelp forests support a rich and diverse suite of marine resources, including seaweeds, shellfish, fish, birds, and marine mammals. Freshwater sources are somewhat limited on the island, but rainwater and fog-drip trapped in extensive sand dunes provide drinkable water via numerous freshwater streams and springs (Schoenherr et al. 1999:262-263).

During the last glacial maximum, the four northern islands formed one large landmass known as Santarosae (Orr 1968; Johnson 1972). Kennett et al. (2008) estimated that by ca. 10,000 cal BP—contemporaneous with the earliest substantial human use at Daisy Cave—sea levels were approximately 65 m below current levels and the eastern end of Santarosae was approximately 10 km from the mainland. The Terminal Pleistocene occupations at Daisy Cave and other sites of the northern islands demonstrate that people used boats to colonize the islands by at least 13,000 to 12,000 years ago (Erlandson et al. 2011; Johnson et al. 2002).

Daisy Cave

Today, Daisy Cave (CA-SMI-261) is located on the northeastern shore of San Miguel Island (Figure 18). Facing north, the site is exposed to the strong and prevailing northwest winds for much of the year, but the cave interior offers shelter from these winds. The earliest unequivocal cultural deposit dates to ca. 11,600 cal BP (Erlandson et al. 1996), making it among the oldest shell middens in North America. Stratified archaeological deposits are found in three distinct areas of the site—a fissure approximately 11 m deep and between 1.5 to 3 m wide; a rockshelter approximately 4 m by 5 m; and a shell midden on the slope in front of the rockshelter. Excavations focused along the drip-line of the rockshelter produced a long and essentially undisturbed sequence of occupational strata, in which calcareous soil matrices laced with seabird guano led to extraordinary preservation of faunal remains and a wide variety of artifacts,

Figure 18. Terminal Pleistocene and Early Holocene shoreline estimates for San Miguel Island, with the approximate location of Daisy Cave indicated by the star. Dates are in calendar years before present (cal BP). Figure by L. Reeder-Myers.



including numerous bone fishing gorges and knotted cordage fragments that may represent net fragments (Connolly et al. 1995; Rick et al. 2001).

This paper focuses on three major archaeological components dating between the Early Holocene and the Late Holocene (Table 9). The Terminal Pleistocene deposit (i.e., stratum G) contained very small quantities of shell, fish bone, and chipped stone artifacts (Erlandson et al. 1996). The Early Holocene strata, F and E, reflect a much more intensive use of the site between about 10,200 and 8600 cal BP, and produced an abundance of fish bone (Rick et al. 2001). The Middle Holocene stratum C, dated to about 6600 cal BP, consists of a thin shell midden dominated by California mussel (*Mytilus californianus*) shells, with only limited vertebrate remains (Erlandson et al. 1996). The Late Holocene deposit (i.e., stratum A), dated to about 3300 cal BP, is similar to the Early Holocene deposits, with evidence of intensive occupation, including abundant shellfish and fish bone (Vellanoweth et al. 2000).

Today, Daisy Cave is situated immediately adjacent to the shoreline, approximately 10 m above sea level. The shoreline of San Miguel Island has changed dramatically since the Last Glacial Maximum, however, with sea levels rising throughout the Terminal Pleistocene and Early Holocene (Figure 18). Paleogeographic reconstructions suggest that at the time of the earliest human occupation (ca. 11,600 cal BP), the site was located approximately 3.5 to 4 km from the shore (Reeder-Myers et al. 2014). At 10,000 cal BP (stratum F), the site was approximately 2.0 km from the shore, and between 8,600 and 9,000 cal BP (stratum E), Daisy Cave was approximately 750 m from the shore (ibid.). The intensification of site use and fish bone density during the Early Holocene may be a result of the site's increasing proximity to the shoreline.

Table 9. A radiocarbon chronology for Daisy Cave.

Provenience	Lab Number	Material Dated	Uncorrected 14C Age	13C/12C Adjusted	Calendar Age Range (cal BP)[a]
Unit G3, 15-30 cm		Giant chiton shell	1050 ± 80	1400 ± 80	1078-1401
Col. E6, Str. A1	CAMS-8864	Charred twig	-	3220 ± 70	3330-3610
Col. E6, Str. A1	Beta-49997	Black abalone	3070 ± 80	3510 ± 80	2850-3300
Col. E6, Str. A3	CAMS-9095	Charred twig	-	3110 ± 60	3170-3450
Col. E6, Str. A3	Beta-15619	Red abalone	2990 ± 90	3430 ± 90	2750-3200
Col. E6, Str. C	CAMS-8862	Charred twig	-	6000 ± 70	6670-7010
Col. E6, Str. C	Beta-15620	Black abalone	5940 ± 110	6380 ± 110	6290-6800
Col. E6, Str. C	Beta-52359	CA mussel	6090 ± 80	6500 ± 80	7270-7520
Col. E6, Str. E1	CAMS-8866	Charred twig	-	7810 ± 60	8430-8780
Col. E6, Str. E1	CAMS-14379	CA mussel	-	8380 ± 60	8410-8800
Col. E6, Str. E1	CAMS-14380	CA mussel	-	8400 ± 60	8440-8850
Col. E6, Str. E1	CAMS-14360	CA mussel	-	8440 ± 80	8470-8950
Col. E6, Str. E1	Beta-15621	Black abalone	8030 ± 100	8460 ± 100	8450-8990
Col. E6, Str. E1	CAMS-14361	CA mussel	-	8500 ± 80	8550-8990
Col. E6, Str. E4	Beta-15622	Black abalone	-	8730 ± 120	8730-9400
Col. E6, Str. E4	CAMS-8865	Charred twig	-	8040 ± 60	8700-9090
Col. E6, Str. F1	Beta-16523	CA mussel	8470 ± 120	8900 ± 120	9000-9520
Col. E6, Str. F1	CAMS-8867	Charred twig	--	8600 ± 60	9480-9700
Col. E6, Str. F3	Beta-49948	CA mussel	8940 ± 90	9360 ± 90	9560-10,120
Col. E6, Str. F3	CAMS-8863	Charred twig	-	8810 ± 80	9600-10,170
Col. E6, Str. F/G	CAMS-33375	Marine shell	-	9620 ± 70	9990-10,400
Col. E6, Str. G	Beta-52360	Black turban	10,180 ± 70	10,600 ± 70	11,180-11,730
Col. E6, Str. G	Beta-14660	Red abalone	10,260 ± 90	10,700 ± 90	11,240-11,930
Col. E6, Str. G	CAMS-9094	Wood charcoal	-	10,390 ± 130	11,800-12,640

a. All dates were calibrated using Calib 7.0 (Stuiver and Reimer 1993, 2014) and two sigma age ranges are presented. A ΔR of 261 ± 21 years was used for all shell samples (Jazwa et al. 2012), and $^{13}C/^{12}C$ ratios were either determined by the radiocarbon labs, or an average of +430 years was applied (Erlandson 1988).

Previous Research

Although amateurs and antiquarians appear to have explored Daisy Cave in the late-19th and early-20th centuries (see Erlandson et al. 1996:357-359) they were focused primarily on human burials inside the cave. Charles Rozaire carried out the first well-documented excavations of Daisy Cave between 1967 and 1968. Rozaire's chronology was based solely on temporally-sensitive artifacts, however, leading him to conclude that the site was occupied only during the last 3,000 years (Rozaire 1978). D. A. Guthrie, D. P. Morris, and P. E. Snethkamp revisited Daisy Cave in 1985–1986, excavating two small test pits and two column samples, the latter in natural stratigraphic layers. They obtained the first radiocarbon dates from the site, which demonstrated its potential for containing cultural occupations dating to the Early Holocene and Terminal Pleistocene (Erlandson et al. 1996). Between 1992 and 1998, Erlandson directed the excavation of four 0.5 by 1 m test units along the dripline of the rockshelter, with all sediments excavated stratigraphically and screened over 1/8-inch mesh. These efforts confirmed the presence of a low density shell midden containing chipped stone artifacts dating to ~11,600 cal BP and greatly expanded the sample of artifacts and faunal remains from stratified deposits dating to the Early, Middle, and Late Holocene. By this time, the youngest intact strata at Daisy Cave dated to about 3000 years ago, all the younger strata having been excavated by Rozaire's team or lost to subsequent erosion.

As mentioned above, the excavations at Daisy Cave produced a wealth of faunal material and artifacts. Preservation at the site is excellent, with limited bone fragmentation and little evidence of mixing, crushing, or compaction. Rather, the excavators encountered articulated mussel valves, articulated fish vertebral columns and other groups of elements, and even articulated fish scales. Due to the presence of woven artifacts, the excavations were also done meticulously. For Column E6, all excavated samples were removed to the mainland and were wet-screened in the laboratory, where abrasion of bones that mimicked cut marks is highly unlikely.

Rick et al. (2001) analyzed 27,430 (1.8 kg) fish bones from six units excavated between 1986 and 1998. Specifically, the authors examined the fish bone from strata dating to the Terminal Pleistocene and Early Holocene, including strata G (~11,600 cal BP) and F and E (ca. 10,000 to 8600 cal BP). Throughout the sequence, the majority of the fish bone comes from the two primary occupational strata dated to the Early Holocene, with the highest abundance of fish bone in stratum E. Using a conservative identification approach (cf. Gobalet 1997:320), Rick et al. (2001) identified 18 different fish taxa, including at least 252 individuals. The majority (90% NISP and weight) of the identified taxa (i.e., sheephead, sculpins, rockfish, and surfperch) inhabit rocky nearshore and kelp bed habitats. According to Rick et al. (2001), the abundance of these taxa, paired with the presence of 30 whole or fragmentary bone bipoints, suggest hook-and-line fishing was probably the primary method of capture. The presence of small clupeids and surfperch, along with abundant cordage, suggests that nets were also used. Although approximately 10 percent of the assemblage was burned, the authors mentioned no unequivocal signs of butchering or other processing. Similarly, an analysis of 107.1 g of fish bones from Stratum A mentioned no cut marks or signs of butchery (Vellanoweth et al. 2000).

Motivation and Methods

Previous experimental work by Willis and colleagues (Willis and Boehm 2014; Willis et al. 2008) demonstrated that butchering fish can produce upwards of 500 cut marks per skeleton. The experimental specimens ranged from spotted weakfish (average length = 28 cm) and hardhead catfish (average length = 29 cm) to larger Coho salmon (average length = 61 cm) and Chinook salmon (average length = 69 cm). Although the total number of cut marks can be affected by various factors—including the species of fish, the butcher's experience (Chapter III) and post-depositional taphonomic processes (Chapter IV; Willis and Boehm 2014)—cut marks continue to be present. The most frequently identified taxa in the Daisy Cave assemblage (i.e., sheephead, sculpins, rockfish, and surfperch) are similar in size to the experimental species. Assuming the fish from the Daisy Cave site were butchered prior to consumption, we would expect to see some cut marks on the bones from the assemblage.

Experimental results indicate that cut marks are most prevalent on vertebral processes, ribs, pterygiophores, and unidentifiable bones and bone fragments. These elements do not provide taxonomic information about the assemblage, and many times the elements themselves are not identifiable if they become fragmented before, during, or after deposition. For these reasons, we suspect that many researchers—ourselves included—have not taken the time to carefully inspect these bones for evidence of butchery, and may have overlooked cut marks on fish bone.

To test this hypothesis, Willis re-examined 7,494 fish bones from column E6—one of the best-preserved units at Daisy Cave. This column included 498 bones identified to family, genus, or species, and 6,996 undifferentiated teleost bones. Using strong light and a 20-power hand lens (cf. Blumenschine et al. 1996), Willis inspected each bone for evidence of cut marks. Cut mark photographs were taken using Nikon AZ100 with NIS-Elements microscope imaging software.

A Few Notes on Cut Mark Identification

An abundance of literature is dedicated to differentiating cut marks from trampling marks (e.g., Andrews and Cook 1985; Behrensmeyer et al. 1986; Domínguez-Rodrigo et al. 2009; Fiorillo 1989; Olsen and Shipman 1988), rodent gnawing (e.g., Lyman 1987; Shipman and Rose 1983), and carnivore damage (e.g., Binford 1981:46-47; Eickhoff and Herrmann 1985; Potts and Shipman 1981; Shipman and Rose 1983). Given the size and fragility of fish bones at Daisy Cave, we do not expect carnivore damage (potentially from introduced dogs; see Rick et al. 2008) to be an issue, as the fish bones would likely break or be swallowed whole, potentially deleting them from the record. Mice are abundant on San Miguel Island, and their bones are found throughout the sequence, but the midden appears to have accumulated rapidly and no evidence of rodent gnawing was observed during our analysis. The only potential source for pseudo-cut marks is sediment abrasion caused by trampling, soil mixing, or screening. As mentioned above, the deposits at Daisy Cave are exceptionally well-preserved, with little or no evidence of trampling or mixing, and abrasion from screening should not produce localized modifications that mimic ancient cut marks produced by stone tools.

The morphology of a cut mark is dependent on a number of factors, including tool type and material (Choi and Driwantoro 2007; de Juana et al. 2010; Greenfield 2002; Walker and Long 1977; West and Louys 2007), the angle of the tool (Bello and Seligo

2008; Merritt 2012), pressure (Potter 2005; Walker and Long 1977), bone density (Merritt 2012), and the effect of soft tissues (Shipman and Rose 1983). However, cut marks are generally characterized as V-shaped, elongate, linear grooves with multiple, fine parallel striations on the walls (Shipman 1981; Shipman and Rose 1983; Walker and Long 1977). It is important to note that this description is based on cut marks produced during experiments using only mammal bones. From the experimental work presented in Chapters II, III, and IV, we know that cut marks on fish bone tend to be much smaller and shallower than cut marks on mammal bones (also see Archer and Braun 2013; Archer et al. 2014; Gifford-Gonzalez et al. 1999). Similarly, in an ethnographic study of a Turkana fish processing camp, Gifford-Gonzalez et al. (1999) reported that deep cut marks were rare even for fish over 1 meter in length.

Results

From just under 7,500 fish bones, Willis identified 62 cut marks on 28 bones (Tables 10 and 11). No cut marks were observed on bones from stratum F (ca. 10,000-9,000 cal BP; NISP = 532) or the E/F transition (ca. 9,000 cal BP; NISP = 129). Twenty four cut marks were identified on 11 bones from stratum E (ca. 9,000-8,600 cal BP; NISP = 4,820); two cut marks on one bone from stratum C (ca. 6,600 cal BP; NISP = 450); and 36 cut marks on 16 bones from stratum A (ca. 3,300 cal BP; NISP = 1,563). Cut marks were identified on approximately one-quarter of a percent of bones from the Early Holocene (i.e., stratum E) and Middle Holocene (i.e., stratum C) subassemblages, while approximately 1 percent of the bones from the Late Holocene subassemblage (i.e., stratum A) displayed cut marks. The soil pH at Daisy Cave is slightly alkaline, with relatively consistent levels throughout the strata (Table 12). Although there is some disagreement about the effect of pH on the preservation of fish bone (see Collins 2012; Lubinski 1996; Nicholson 1996a, 1996b, 1998), the consistency of the pH levels suggests this is not a major source of the variable preservation of cut marks through time. It is possible, however, that the greater antiquity of the Middle and Early Holocene strata, roughly 2-3 times as old as the 3000-3300 year old stratum A, may have caused greater weathering that progressively eroded cut marks over time, despite the apparently excellent preservation of the whole assemblage.

Overall, cut marks occurred on vertebrae (including vertebral processes and centra), a rib, and on undifferentiated fish bone fragments (Figures 19-22). The majority of the cut marks (~55%) were located on undifferentiated fish bone fragments, with ~31 percent located on vertebral processes, ~8 percent on vertebral centra, and ~6 percent on a rib. The pattern of distribution was consistent throughout the column, as strata A and E had similar cut mark distributions.

Twenty of the cut marks were located on bones previously identified to family, genus, or species (i.e., Rick et al. 2001; Vellanoweth et al. 2000). All of these were located on vertebral processes or centra. Approximately 16 percent of the observed cut marks were located on cabezon vertebral processes (12.9%) and centra (3.2%) (Figures 21 and 22). Approximately 6.4 percent of the cut marks were on rockfish vertebrae, 4.8 percent on surfperch and prickleback vertebrae, respectively, and 1.6 percent on a labridae vertebra. All of these species live in rocky nearshore and/or kelp bed habitats.

Table 10. Total number of cut marks and cut marked bones by stratum.

	Stratum	NISP	Cut Marks	% Cut Marks by NISP	Number of Cut Marked Bones	% Cut Marked Bones by NISP
Late Holocene	A	1563	36	2.30	16	1.02
Middle Holocene	C	450	2	0.44	1	0.22
Early Holocene	E	4820	24	0.50	11	0.23
	E/F Transition	129	0	0	0	0
	F	532	0	0	0	0

Table 11. Cut marks on Daisy Cave fish bone from column E6.

Stratum	Taxa	Element	Cut Marks	Clusters
A1	Labridae	Caudal Vertebra, Process	1	1
A1	Rockfish	Caudal Vertebra, Process	1	1
		Caudal Vertebra, Centrum	3	3
A1	Teleost	Undifferentiated	3	1
A1	Teleost	Undifferentiated	1	1
A1	Teleost	Undifferentiated.	8	1
A1/A2 Trans.	Prickleback	Precaudal Vertebra, Process	3	3
A1/A2 Trans.	Teleost	Undifferentiated	1	1
A1/A2 Trans.	Teleost	Undifferentiated	2	1
A1/A2 Trans.	Teleost	Undifferentiated	2	2
A1/A2 Trans.	Teleost	Undifferentiated	3	1
A2 Trans.	Cabezon	Precaudal Vertebra, Process	1	1
A2 Trans.	Cabezon	Caudal Vertebra, Process	2	2
A3	Surfperch	Caudal Vertebra, Process	2	1
A3	Surfperch	Caudal Vertebra, Process	1	1
A3	Teleost	Undifferentiated	1	1
A3	Teleost	Undifferentiated	1	1
C	Cabezon	Caudal Vertebra, Centrum	2	1
E1	Teleost	Vertebral Process	2	1
E1	Teleost	Vertebral Process	1	1
E1	Teleost	Rib	4	1
E1	Teleost	Undifferentiated	2	1
E1	Teleost	Undifferentiated	1	1
E2	Teleost	Undifferentiated	3	2
E2	Teleost	Undifferentiated	2	1
E2	Teleost	Undifferentiated	2	2
E4	Cabezon	Caudal Vertebra, Process	5	2
E4	Teleost	Undifferentiated	1	1
E4	Teleost	Undifferentiated	1	1
TOTAL NUMBER OF CUT MARKS			**62**	

Table 12: Analysis of sediment samples from the Daisy Cave strata.

Stratum	Munsell Color	Color Description	pH	% Organic Matter	Soluable Salts (mS/cm)
A1	10YR6/3	Pale brown	8.0	10.99	42.3
A3	10YR6/4	Light yellowish brown	8.1	11.5	75.2
B	10YR6/6	Brownish yellow	8.0	7.98	44
C	10YR6/4	Light yellowish brown	8.0	9.19	41.6
D	10YR6/4	Light yellowish brown	8.0	8.11	46.1
E1a	10YR5/3	Brown	8.0	9.76	51.8
E2	10YR5/3.5	Brown	8.1	8.93	40.9
E3	10YR4/2.5	Dark grayish brown	7.7	11.32	55.1
F1	10YR5.5/4	Yellowish brown	7.9	7.57	49.9
F2	10YR5/3	Brown	8.0	5.84	32.3
G	10YR4.5/3	Brown	8.3	6.85	23.3
H	10YR4.5/3	Brown	8.2	8.66	27.3
I	10YR3.5/3	Dark brown	8.2	15.37	36.1
J	10YR6.5/4	Light yellowish brown	8.3	6.63	34.3
K	10YR7/3	Very pale brown	8.2	8.0	22.6
L	10YR7.5/3	Very pale brown	8.2	7.82	14.1
M	10YR6.5/4	Light yellowish brown	8.3	5.5	13.2
N	10YR5.5/3	Pale brown	8.0	11.1	17.4
O	10YR6.5/3	Very pale brown	8.2	6.0	12.6

Note: %OM values based on loss-on-ignition; soluble salts = mS/cm.

Figure 19. Cut marks on undifferentiated teleost bone fragments from stratum A at Daisy Cave. Photographs by L. M. Willis.

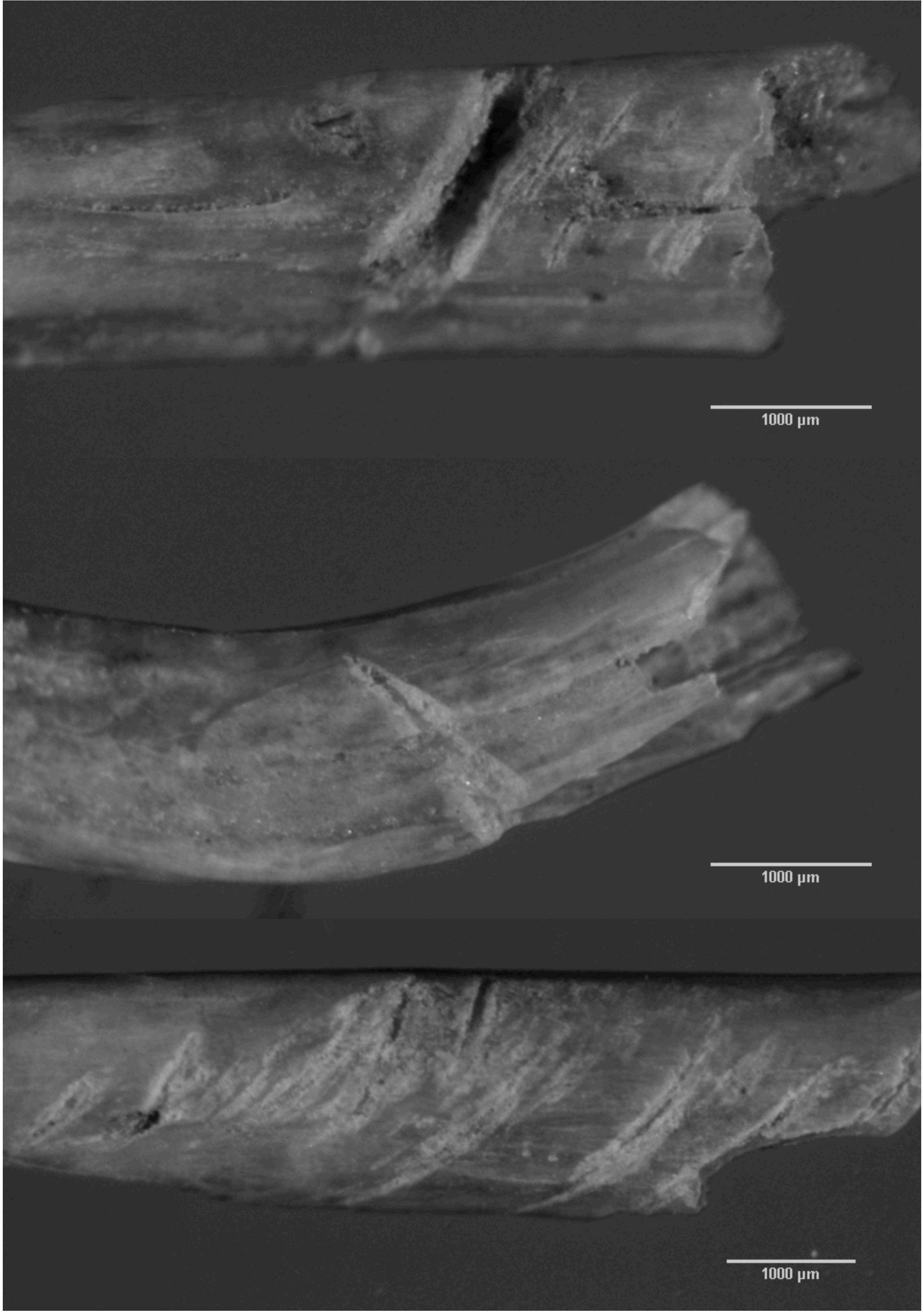


Figure 20. Cut marks on undifferentiated teleost bone fragments from stratum E at Daisy Cave. Photographs by L. M. Willis.

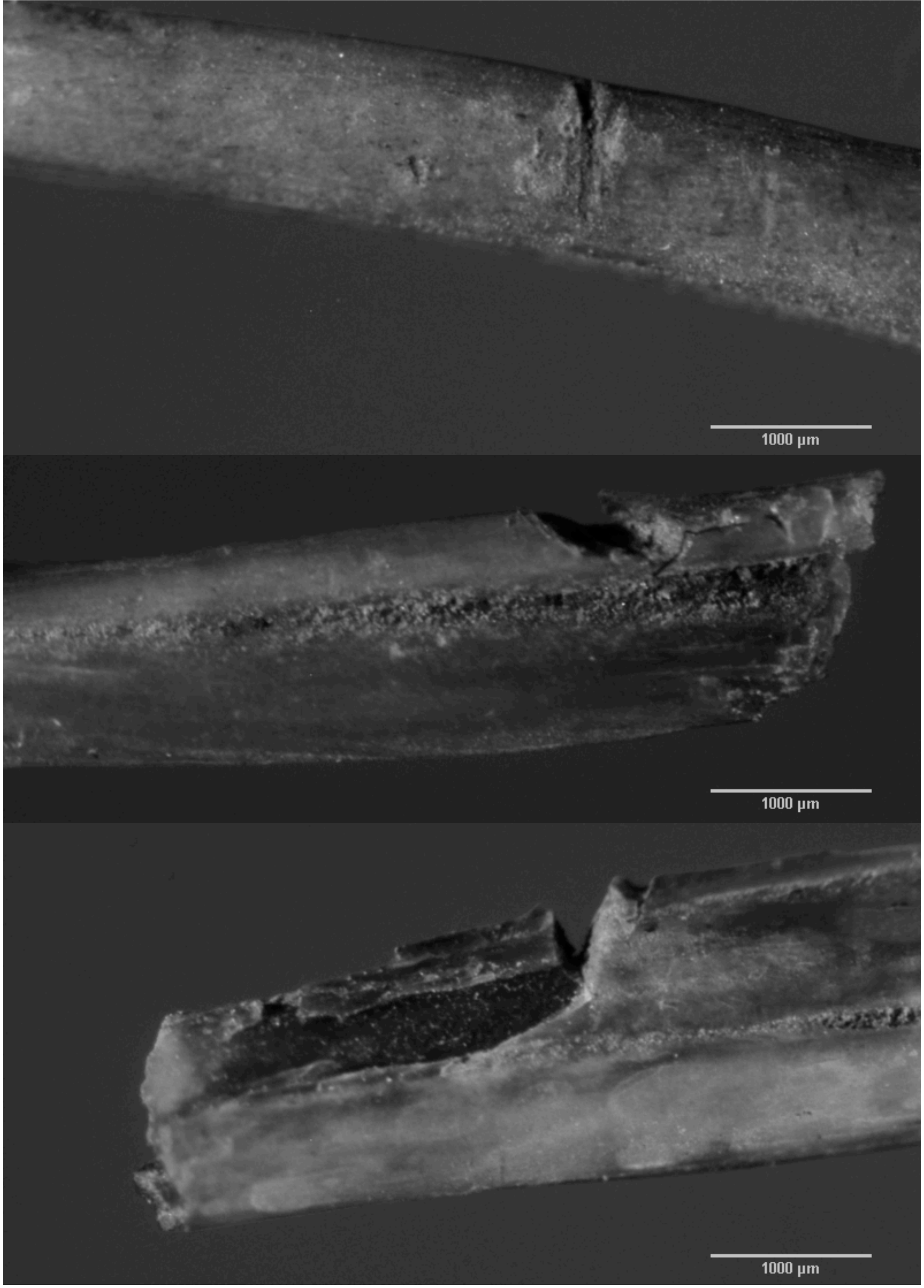


Figure 21. Cut marks on a cabezon vertebral process from stratum A at Daisy Cave. Photograph by L. M. Willis.

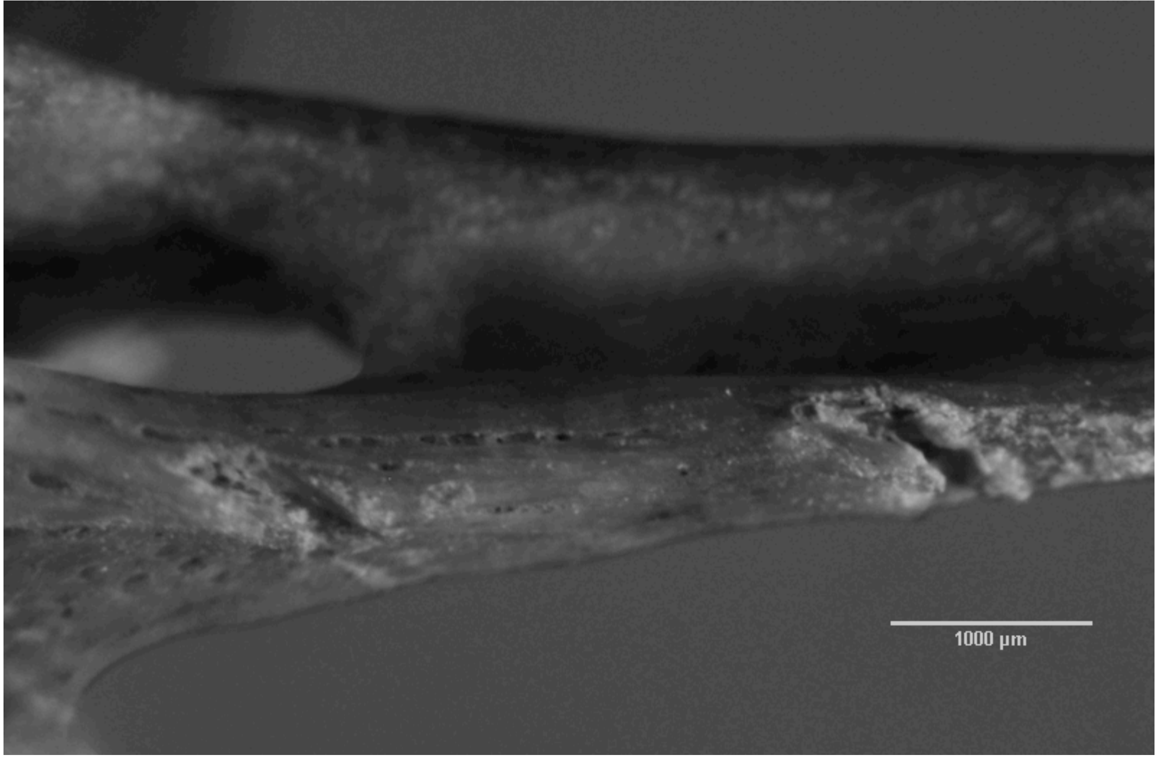
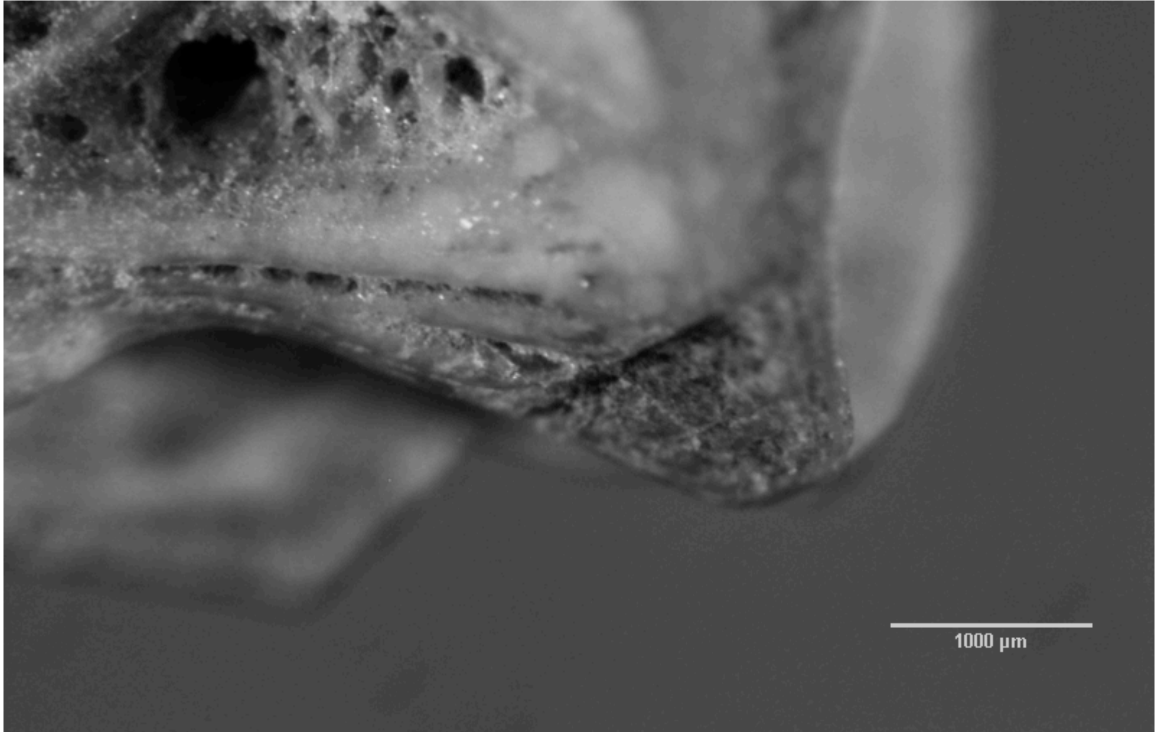


Figure 22. Cut mark on a cabezon vertebral centrum from stratum C at Daisy Cave. Photograph by L. M. Willis.



Discussion and Conclusions

The distribution of cut marks primarily on unidentifiable bones and vertebral processes mirrors the experimental results presented in Chapters II, III, and IV. As stated in those chapters, the experimental method—based on ethnographic accounts of salmon drying from the Pacific Northwest—involved removing the heads, but leaving them whole. However, it is possible that the method(s) used by Channel Islanders between 3,000 and 10,000 years ago did involve butchering the heads (cf. Archer and Braun 2013:3; Belcher 1998:122; Stewart and Gifford-Gonzalez 1994). To ensure that our expectations from the experimental results were not biasing the identification of cut marks, Willis inspected *all* of the bones from the E6 column sample—including 144 cranial elements—for cut marks. None were observed on the cranial bones. Although the lack of cut marks on cranial elements does not preclude a butchery method that involved breaking apart the crania, no evidence for it exists in the column assemblage.

Cut marks were identified on bones dating to the Early, Middle, and Late Holocene. No cut marks were observed on bones dating to the Terminal Pleistocene (i.e., stratum G) or the earliest Holocene (i.e., stratum F); however, these subassemblages had relatively low NISP. Unsurprisingly, the majority of the cut marks (97%) were observed on bones from those strata (i.e., E and A) that represent the most intensive use of the site. It is important to note that Stratum A (Late Holocene) had the highest number of identified cut marks (n = 36) and cut marked bones (n = 16), despite having 50 percent fewer NISP than stratum E (Early Holocene). At this time, it is unclear whether the increase in identified cut marks through time is a reflection of differential preservation or changes in cultural practices (i.e., butchery processes).

Given the relatively low number of cut marks identified on the nearly 7,500 fish bones, some researchers may question the utility of looking for cut marks on fish bone. Willis spent approximately 40 hours reexamining the fish bone from the Daisy Cave column assemblage. While this may seem like a significant investment for the return, the amount of time required would be substantially reduced were it incorporated into the initial analysis of an assemblage. Furthermore, the number of identified cut marks on the Daisy Cave column sample is not an indication of the number of cut marks on fish bones from other archaeological sites (cf. Lyman 2005). Analysts may choose to begin with a sample, as we did, to assess whether cut marks are visible on the assemblage. If so, our results suggest that the sample should include a substantial number of bones (>1,000) to insure that the presence or absence of cut marks is accurately determined. In cases where cut marks are more common, zooarchaeologists can expand the analysis to the entire assemblage, including unidentified fish bone fragments, to address questions about fish processing at the site.

Although the proportion of cut marks in the overall Daisy Cave column assemblage remains relatively low, these results are nonetheless significant. Our results highlight the potential bias against butchery evidence introduced by standard analytic techniques. Without a more thorough examination of fish remains, particularly unidentified bones and bone fragments, cut marks will continue to be overlooked in archaeological assemblages. An improved protocol for identifying cut marks on fish bones has implications for identifying early hominin use of fish and distinguishing between human and animal or natural agency in the accumulation of fish remains. Cut marks have recently been identified on fish assemblages dating back to 1.95 million years ago (Archer et al. 2014; Braun et al. 2010), and aquatic resource use is at the forefront of research into hominid brain development (Stewart 2010). Through additional experimental work, it may eventually be possible to infer cultural processing techniques from cut mark patterns on fish bone.

Most importantly, our results demonstrate that expectations of cut mark morphology based on a familiarity with mammal bone cut marks does not help in the identification of cut marks on fish bone. Cut marks on fish bone tend to be very small—perhaps unsurprising given the relative size of many fish versus terrestrial game mammals—and shallow (Archer et al. 2014; Willis et al. 2008). Willis' ability to identify cut marks on the Daisy Cave fish assemblage stems from her experience of looking at thousands of experimentally-produced cut marks on fish bones from a variety of species. The small size and shallow nature of cut marks on the Daisy Cave fish bones may help explain why most of them were not identified during previous analyses focused on species identification.

Many experiments and actualistic studies have aimed to clarify the characteristics of cut marks (for a review of the literature, see Lyman 1994; Fisher 1995), but nearly all of these studies involved mammal bones. Very few studies present actualistic or experimental results on the frequency and location of cut marks on fish bones (e.g., Archer et al. 2014; Stewart 1994; Stewart and Gifford-Gonzalez 1994; Willis and Boehm 2014; Willis et al. 2008). Other than Butler and Schroeder's (1998) investigation of the effects of human and coyote digestive processes on fish bone, we are not aware of any studies that compare the variations in bone surface modifications caused by different actors (i.e., humans, carnivores, etc.) and effectors (i.e., cutting edge, tooth, etc.) (terminology cf. Gifford-Gonzalez 1991) on fish bone.

Given the differences between fish and mammal bone—in terms of relative size and the structural properties of the bone—it seems likely that cut marks would leave different signatures on fish and mammal bones. Indeed, a recent study by Archer and Braun (2013) demonstrated that researchers with extensive experience identifying surface modifications on mammal bones incorrectly identify and under-report surface modifications on fish and crocodile bones. They suggested that the participants' failure to identify the marks can be attributed to their lack of familiarity with where and how cut marks are likely to occur on fish and crocodile bones.

A comprehensive understanding of aquatic resource use has implications for our understanding of hominid diet and resource use, behavioral modernity, and social complexity. However, establishing the cultural origin of these assemblages remains problematic, given the paucity of evidence about bone surface modifications. Exposure to the characteristics of cut marks on fish bone through experimental and actualistic research is essential for developing a referential framework to identify cut marks on archaeological assemblages. Furthermore, experiments aimed at distinguishing cut marks from sediment abrasion on fish bone would contribute greatly to our ability to confidently identify surface modifications. As researchers continue to recognize the importance of coastal adaptations to the evolution of hominids, the development of modern behavior, and to human dispersals (Erlandson and Fitzpatrick 2006), this would be a fruitful avenue for future research.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Despite increased recognition of the importance of coastal and lacustrine environments in human history, fish taphonomy and butchery practices remain under-researched topics in archaeology. To address this significant gap in data, I developed a continuous experimental research program (cf. Schiffer et al. 1994) aimed at improving our understanding of where and how cut marks are produced on fish bones, and the effects of burial on their long-term visibility. My research grew out of a seemingly-simple research question: does butchering fish produce identifiable cut marks and, if so, why is there a discrepancy between the experimental results and the archaeological literature?

Unlike "one-shot affairs" (Schiffer et al. 1994:198), which can be criticized for being too particularistic and/or inapplicable to a broad range of archaeological sites or contexts, continuous experimental programs consist of nested studies that, when taken together, form a foundation for interpreting a given aspect of the archaeological record. Similarly, the goal of the experiments presented here was not to explain a particular phenomenon encountered at a specific archaeological site, but rather to unpack the complexities of fish bone surface modifications. Addressing fish butchery and burial through an experimental program allowed me to create testable hypotheses, isolate and control variables, and use large sample sizes—the very benefits of experimental archaeology over more traditional archaeological excavations. Each experiment was designed to build on the former, strengthening our understanding of the effects of butchery and burial on fish bone cut marks. Furthermore, these successive experiments ultimately provided a series of expectations for how and where cut marks may appear that can assist in the identification of cut marks on archaeological fish assemblages.

Research Summary

In brief, Chapter II demonstrated that butchering fish can produce cut marks on fish bone—upwards of 500 per skeleton, depending on the species, butcher, and butchery method. We chose to use three species of fish from different regions (i.e., the Pacific, Atlantic, and Florida Gulf coasts) and representing different body sizes and morphologies (i.e., summer flounder, Coho salmon, and hardhead catfish) in an effort to make the results applicable to a wide range of archaeological fish assemblages. Comparing those specimens butchered with stone tools, the smaller-bodied hardhead catfish (average length = 29 cm) averaged 85 cut marks per skeleton, while the larger-bodied Coho salmon (average length = 61 cm) averaged 278 cut marks per skeleton. Summer flounder (average length = 34 cm)—similar in length to hardhead catfish—averaged 308 cut marks per skeleton; the higher number of cut marks is likely due to the difference in body morphology. The results of this initial experiment were surprising, given the infrequency with which cut marks are reported on archaeological fish bone (Colley 1990:216-217; Lyman 1994:439). Possible explanations for the discrepancy between the experimental results included the skill level of the experimental butchers, decreased or lost visibility due to post-depositional taphonomic processes, and/or a lack of referential framework among researchers for where and how cut marks appear on fish bone. Each of these was addressed in turn in the remaining chapters.

Chapter III examined how a butcher's level of expertise can affect the number and distribution of cut marks on fish bone. Participants of varying skill level (i.e., novice, intermediate, and professional) butchered a total of 30 Chinook salmon. Our results indicated that professional butchers differ from novice- and intermediate-level butchers in the number of cut marks produced and the amount of time required to butcher the fish. Specifically, the professional butchers produced approximately 50 percent fewer cut marks than the novice- and intermediate-level butchers; the novice- and intermediate-level butchers were statistically indistinguishable. Our results indicate that the distribution of cut marks on particular elements is not correlated with a butcher's skill, as the distribution of cut marks varied both within and between the skill levels. However, even professional butchers produced an average of 133 cut marks per Chinook salmon. If prehistoric peoples were butchering fish, we would still expect to see cut marks on archaeological fish assemblages—assuming that post-depositional processes did not erase the evidence of them.

Chapter IV highlighted the effects of soil burial on the visibility of cut marks on fish bone. Even after a relatively short time period (27 months), the number of cut marks identified on the specimens decreased by up to 76 percent, depending on the species. The decrease in cut marks was highest on those species with smaller, more fragile bones (i.e., spotted weakfish, which averaged a 76 percent decrease in visible cut marks, and summer flounder, which averaged a 64 percent decrease)—species on which the cut marks tended to be more ephemeral prior to burial. On the red drum, the pre-burial cut marks were deeper and, thus, more likely to still be visible after burial. Red drum averaged a 24 percent decrease in the number of visible cut marks after burial. Perhaps more importantly, over 90 percent of the observed cut marks were located on identifiable elements (i.e., vertebral processes and ribs) prior to burial; depending on the species, as few as 24 percent were located on identifiable elements after burial and recovery. This shift resulted from the fragmentation of the bones during burial and/or recovery and processing. As unidentifiable elements do not provide taxonomic information about the assemblage, evidence of butchery may be overlooked by most zooarchaeologists when using current, standard analytic techniques. When combined with the effects of burial on the long-term visibility of cut marks, it is not surprising that cut marks are rarely reported on archaeological fish bone.

Chapter V presented the results of a re-analysis of approximately 7,500 fish bones from Daisy Cave (CA-SMI-261), a multi-component shell midden located on the northern coast of San Miguel Island. Despite the fact that fish were a substantial portion of the faunal assemblage, previous analyses did not identify any cut marks on the assemblage. Using the referential framework I acquired through the experiments, I identified 62 cut marks on bones dating from the Early to Late Holocene. Similar to the experimental results, cut marks were distributed primarily on undifferentiated fish bone fragments (~55%) and vertebral processes (~31%). The majority of the cut marks were identified on bones from strata corresponding to the most intensive use of the site (i.e., E and A). In other words, those strata with a greater abundance of fish bones had more identified cut marks. Stratum A, which dates to the Late Holocene, did have the highest number and percentage of cut marks, but it is unclear whether this is due to preservation issues or changes in cultural practices.

Together, the results of these experiments and the application of the results to the Daisy Cave column sample can inform us on the general effects of taphonomy and burial on the preservation of cut marks. Assuming fish butchers in the past were skilled at this practice, we could expect the initial number of produced cut marks to be similar to the cut marks produced by the professional fishmongers in Chapter III—still a relatively large number, compared to what is reported archaeologically. Even after a short burial duration, Chapter IV demonstrates that the number of visible cut marks can decline by upwards of 75 percent. On an archaeological timescale, cut marks were observed on only 1 percent of the bones from the Late Holocene, 0.25 percent of the bones from the Middle and Early Holocene, and on approximately 0.004 percent of the Daisy Cave column assemblage overall. Together, these results indicate a substantial decrease in the visibility of cut marks with greater age. As mentioned above, when the effects of burial are paired with standard analytic techniques and the lack of framework among zooarchaeologists for where and how cut marks appear, the likelihood of identifying evidence of past fish butchery is greatly impaired.

Implications and Future Research

Recent discoveries in archaeology are redefining how we view human evolution, the primacy of coastal and other aquatic resource use, and human migrations (e.g., Bailey 2004; Cunnane and Stewart 2010; Dillehay et al. 2008; von den Driesch 2004; Erlandson 2001, 2010; Erlandson and Fitzpatrick 2006; Jerardino and Marean 2010; O'Connor et al. 2011; Stewart 2010). As fishing is generally a critical aspect of these adaptations, it is to our advantage to expand the breadth of our knowledge regarding the taphonomy of fish remains at archaeological sites. However, the vast majority of current taphonomic research focuses on mammal remains. A limited amount of experimental or actualistic research has addressed aspects of fish taphonomy, including digestion (Butler and Schroeder 1998); bone density and preservation (Butler and Chatters 1994; Collins 2012; Lubinski 1996; Nicholson 1996b); screen size and recovery (Nagaoka 2005; Vale and Gargett 2002); cut marks (Archer et al. 2014; Stewart 1994; Stewart and Gifford-Gonzalez 1994; Willis and Boehm 2014; Willis et al. 2008; Zohar and Cooke 1997); and analyst accuracy (Archer and Braun 2013). Although this list may seem extensive, it is a proverbial drop-in-the-bucket compared to the literature available for mammals regarding these same taphonomic concerns and more.

As mentioned in Chapter V, a recent blind test of nine experienced zooarchaeologists demonstrated that surface modifications on fish bones are frequently misidentified and under-reported (Archer and Braun 2013). The zooarchaeologists in the study reported that their unfamiliarity with aquatic bone surface morphology, with aquatic bone surface modifications, and with where surface marks will appear on the bones of aquatic animals as a result of specific activities made it difficult to correctly and confidently identify the modifications (ibid. 14). Without a referential framework for the characteristics of cut marks on fish bone, it is likely that researchers will continue to misidentify surface modifications. It is my hope that the research presented here will provide such a framework and encourage archaeologists to seek out or develop control collections of fish bone surface modifications (cf. Blumenschine et al. 1996).

The research presented here contributes to a growing body of literature addressing fish bone taphonomy, and has implications for how archaeological experiments are designed and executed, and for the protocols archaeologists use to analyze archaeological fish bone. This experimental work has been cited in recent studies of hominin brain development (Stewart 2010) and hominin aquatic resource use (Archer et al. 2014; Braun et al. 2010). In addition to the contributions to how archaeologists identify early hominin use of fish (Braun et al. 2010; Joordens et al. 2009; Stewart 2010), the implications of this research include identifying butchery and processing practices among fishing peoples (Gifford-Gonzalez et al. 1999), and distinguishing between human and animal or natural agency in the accumulation of fish remains (Butler 1990; Erlandson and Moss 2001; Moss 2004).

My research suggests that a framework for cut mark identification based on a familiarity with mammal bone surface modifications may not assist in the identification of fish bone surface modifications. This framework has implications for how archaeologists distinguish cultural from natural deposits—whether these include potential mass die-off events (Butler 1993, 1996) or deposits created by animals that feed on aquatic fauna (Erlandson and Moss 2001). The identification of cultural bone surface modifications can alleviate questions about the depositional agent. However, without the knowledge of what cut marks on fish bones tend to look like and on what elements they are likely to occur, archaeologists are at a disadvantage for identifying past evidence of butchery.

Given the dearth of research on fish bone taphonomy, the directions for future research are nearly endless. A key avenue for future research would be developing a protocol for distinguishing cut marks from sediment abrasion caused by trampling, argilliturbation, screening, or soil compaction. Other areas for future research include examining the production of cut marks using different species of fish, butchery methods, and tool types (e.g., shell, bamboo), and investigating the effects of different depositional environments on the long-term visibility of cut marks. It would be interesting, for instance, to examine whether cut marks on large species of fish such as swordfish or large tunas are more similar to those produced by the butchering of mid- to large-size mammals.

Ultimately, a goal of experimental research on fish bone taphonomy would be to identify cultural practices of fish processing based on the patterns of cut marks identified on archaeological fish assemblages. This type of inference requires cumulative experimental research aimed at unraveling the different signatures of a wide variety of butchery methods, tool types, fish species, and so forth. As discussed in earlier chapters, a myriad of factors affect the frequency and quality of cut marks on bone, including—but not limited to—tool type, size, and material, bone fragmentation, carcass size and condition, the angle and pressure of the tool edge, butchery method, and a butcher's skill. The ability to infer butchery patterns based on cut mark distributions on mammal bones is still contested (see Lyman 2005), even after an abundance of experimental work has been devoted to this particular topic (see Domínguez-Rodrigo and Yravedra 2009:884-885 for a review of the literature). Future studies should concentrate on developing expectations for how each of these variables affects cut mark production and distribution on fish bones. The experiments presented here represent a literal first step toward understanding and interpreting fish butchery and cut mark taphonomy in the archaeological record.

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