THESIS

3-D MICROMORPHOLOGICAL COMPARISON OF HUMAN AND CARNIVORE TOOTH MARKS

Submitted by

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ABSTRACT

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The archaeological record may reveal a deep history of ancient human cannibalism, but modern researchers face substantial challenges when it comes to confirming such a history. While archaeologists often examine ancient human remains for signs of human consumption (cut marks, burned bone, etc.), such evidence is only suggestive of ancient human cannibalism, not definitive – as these markings could result from non-consumptive practices, such as artistic modifications, funerary rituals, and natural fires. The most direct evidence of ancient human cannibalism is the presence of human tooth marks on ancient human bone, as these marks can be directly linked to the act of consumption. However, due to similarities between human and carnivore tooth marks, distinguishing between the two when using traditional analytical methods is challenging.

Therefore, the goals of this research were twofold: one, to develop a quantitative database that accurately characterizes the morphology of human tooth marks, and two, to statistically compare human tooth mark data with that of carnivores to develop more reliable human tooth mark identification criteria. An experiment was conducted in which ten human participants consumed the meat of two cooked pig bones using only their teeth, producing a total of 126 human tooth marks. These marks were then 3-D scanned using a Sensofar S Neox 3-D optical profilometer and subsequently measured using Digital Surf's MountainsMap® software. Lastly, the human tooth marks were statistically compared to 898 experimentally produced bone surface modifications of known origin, including 275 carnivore tooth marks.

Results indicate that human tooth marks are distinguishable from those produced by carnivores – 91.3% of the 126 human tooth marks were correctly classified as human-made when compared to the sample of 275 carnivore tooth marks. Additionally, human tooth marks were classified correctly 86.5% of the time when compared to 898 experimentally produced bone surface modifications including stone tool cut marks, trample marks, hammerstone percussion marks, and carnivore tooth marks.

Overall, this 3-D analysis and statistical comparison demonstrates that human tooth marks are quantitatively distinct from carnivore tooth marks and other bone surface modifications. Applying these findings to the archaeological record will significantly advance researchers' understanding of ancient human diets related to the consumption of meat and bone, including those that may even be cannibalistic.

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CHAPTER 1 INTRODUCTION

1.1 Problem Statement

Since the foundational work of Efremov (1940) and Müller (1951) in the early 20th century, methods for analyzing bone surface modifications (BSM) have advanced considerably (Gifford, 1981; Harris et al., 2017; James & Thompson, 2015), enabling researchers to identify BSMs with greater accuracy. Accurate BSM identifications are essential to our interpretations of the past, as they directly link the static archaeological record to the behavioral and ecological dynamics of the past (Binford, 1981). BSMs have been critical to insights into ancient hominin subsistence strategies (Blumenschine, 1995; Blumenschine et al., 2007; Domínguez-Rodrigo & Barba, 2006, 2007; Pante et al., 2012), early hominin cognitive development (Domínguez-Rodrigo et al., 2014; Lewis & Harmand, 2016), as well as palaeoecological (Fernández-Jalvo et al., 2011; Pizarro-Monzo et al., 2022; Pobiner & Egeland, 2008) and paleoenvironmental settings for hominin evolution (Brett & Baird, 1986; Reed et al., 2011). However, despite these advancements, accurately differentiating between stone tool cut marks, hammerstone percussion marks, carnivore tooth marks, and other types of BSMs remains a challenge due to the lack of standardized analytical techniques and reliable BSM identification criteria (Harris et al., 2017; James & Thompson, 2015; Njau, 2012). As a result, debates have emerged within the paleoanthropological community regarding BSM identification, as researchers often disagree on the actor responsible for creating a particular mark leading to contradicting interpretations of the past (James & Thompson, 2015).

For example, at the FLK *Zinjanthropus* site in Olduvai Gorge, Tanzania, Blumenschine (1995) argued that ancient carnivores had primary access to faunal remains based on estimates of carnivore tooth marks, suggesting that hominins at the site were scavengers. However, Domínguez-Rodrigo and Barba (2006) challenged this conclusion, claiming that Blumenschine's tooth mark estimates were inflated due to misidentification of bioerosion marks as carnivore tooth marks. They instead proposed that ancient hominins had primary access to the remains, and carnivores had secondary access. Since Domínguez-Rodrigo and Barba's (2006) reinterpretation, the FLK *Zinjanthropus* debate has continued, yet the question as to who had primary access to the remains has yet to be agreed upon (Blumenschine et al., 2007; Domínguez-Rodrigo & Barba, 2007; Domínguez-Rodrigo et al., 2014; Pante et al., 2012, 2015).

The FLK *Zinjanthropus* example clearly illustrates the previously mentioned issue: the ongoing debates among researchers over the identification of BSMs – and, consequently, their related implications – are due to the absence of standardized analytical methods and reliable criteria for accurately identifying BSM types. Because both studies utilized different analytical approaches to examine the BSMs, the researchers developed contrasting conclusions as to what the BSMs are or indicate about the past (Blumenschine, 1995; Domínguez-Rodrigo & Barba, 2006). This pattern is evident in numerous other cases worldwide, including DIK-55 in Ethiopia (Domínguez-Rodrigo et al., 2010, 2011, 2012; McPherron et al., 2010, 2011), Bluefish Cave in Canada (Bourgeon et al., 2017; Cinq-Mars, 1979; Krasinski & Blong, 2020; Litynski & Pante, 2023), Krapina Cave in Croatia (Frayer et al., 2020; Miracle, 2007; Radovčić et al., 1988; Trinkaus, 1985; White, 2001), among others. Standardized analytical methods and reliable BSM identification criteria would reduce discrepancies in mark classification, thereby minimizing conflicting interpretations of the past. As demonstrated, accurate BSM identification is not only desirable, but essential for constructing more reliable interpretations of the past.

Of the numerous topics related to these taphonomic debates, one is the differentiation of modern human (*Homo sapiens*) tooth marks from carnivore tooth marks. Human tooth marks are particularly difficult to distinguish from those of carnivores (Binford, 1978; Fernández-Jalvo & Andrews, 2011; Pesquero et al., 2018), especially when viewed with a naked eye (Blumenschine et al., 1996). The difficulty stems from the morphological similarities between the two, including damage types, mark morphologies, and the overall gross skeletal damage each actor inflicts to bone. This ambiguity has led to research focused on differentiating human tooth marks from those of carnivores (Elkin & Mondini, 2001; Fernández-Jalvo & Andrews, 2011; Martínez, 2009; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024), as well as investigations focused on identifying incidents of ancient human cannibalism (Andrews & Fernández-Jalvo, 2003; Bello et al., 2015, 2016; Boulestin & Coupey, 2015; Cáceres et al., 2007; Sala & Conrad, 2016; Santana et al., 2019).

Despite the growing body of research focused on human tooth marks, no study – experimental or ethnographic – has developed criteria that accurately differentiates human tooth marks from those of carnivores. This is partly due to a lack of methodological rigor in many studies, which often fail to systematically compare human and carnivore tooth marks to one another (Fernández-Jalvo & Andrews, 2011; Funk et al., 2016; Lloveras et al., 2009, Petrovic et al., 2019; Romero et al., 2016a, 2016b; Saladié et al., 2013). Additionally, few studies utilize experimental tooth mark collections to aid in the identification of fossil tooth marks (Bello et al., 2015; Blasco, 2008; Blasco & Peris, 2009; Hernando et al., 2022; Sanatana et al., 2019). This absence of accurate criteria also stems from the continued use of subjective, qualitative criteria that incorrectly attributes features such as peeling, crenulated edges, and double-arched punctures as uniquely human (Fernández-Jalvo & Andrews, 2011; Lloveras et al., 2009; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024), despite these features being repeatedly observed on carnivore-chewed bone (Arilla et al., 2014, 2019, 2023;

Binford, 1981; Maguire et al., 1980). These methodological shortcomings are frequently overlooked, resulting in the widespread acceptance of flawed criteria to identify human tooth marks. As a result, researchers who believe they are identifying human tooth marks on ancient bones may potentially be misidentifying carnivore tooth marks. To address this gap in the literature, this research looks to establish criteria that more accurately differentiates human and carnivore tooth marks through quantitative analysis (Pante et al., 2017), providing a more precise alternative to the current, qualitative criteria.

This research utilizes high-resolution three-dimensional (3-D) scanning technology and software to generate a more accurate characterization of human tooth mark morphology at the microscopic level. By employing this quantitative method, current and future researchers will be better equipped to distinguish human tooth marks from other BSMs, including carnivore tooth marks. The goals of this thesis are to:

1. Determine whether rib peeling is exclusive to hominid-chewed bone, a damage type believed to be unique to the taxonomic family.
2. Generate a sample of experimentally produced human tooth marks.
3. Create a database of human tooth mark measurements to identify and model the micromorphological features of experimentally produced human tooth marks.
4. Determine whether micromorphological features in human tooth marks can quantitatively differentiate them from carnivore tooth marks, stone tool cut marks, hammerstone percussion marks, and mammalian trample marks.
5. Identify any morphological similarities that exist between human tooth marks and carnivore tooth marks in our sample to guide future research objectives.

By meeting these objectives, this research will deepen taphonomists' insight into the morphological distinctions between human tooth marks and other BSMs. This enhanced knowledge can then be applied to investigations of hominin dietary patterns and ancient human cannibalism, ultimately improving our understanding of the past.

1.2 Zooarchaeological & Taphonomic Theory

This research is grounded in middle-range theory, a framework aimed at achieving:

> *"Accurate means of identification, and good instruments for measuring specified properties of past cultural systems. We are seeking reliable cognitive devices; we are looking for 'Rosetta stones' that permit the accurate conversion from observation on statics to statement about dynamics. We are seeking to build a paradigmatic frame of reference for giving meaning to selected characteristics of the archaeological record through a theoretically grounded body of research" (Binford, 1981, p. 25).*

Middle-range theory is crucial for investigating the past, as it allows researchers to make verifiable inferences by translating the "static" archaeological record into well-supported insights about past "dynamic" behaviors (Binford, 1981). However, such verifiable inferences require "experimental research conducted with documented living systems" (Binford, 1981, p. 27) to establish the necessary cause-and-effect relationship between past dynamic behaviors and their preserved static traces in the archaeological record (Binford, 1981; Gifford-Gonzalez, 1991). Specifically, the observable outcomes of a given behavior can only be meaningfully applied to the archaeological record once they are first understood in the present.

In the context of experimental taphonomy, studies relating to BSM production establish cause-and-effect links between dynamic behaviors, such as flesh removal, and the resulting static traces, such as stone tool cut marks (Binford, 1981; Gifford-Gonzalez, 1991). This same principle underpins the present study, which examines how the consumption of meat and bone by humans leave distinct trace marks in the archaeological record – specifically, human tooth marks. However, this connection can only be confirmed through experimental research. Therefore, this study applies middle-range theory by generating a sample of experimentally produced human tooth marks to aid in the identification of human tooth marks.

While middle-range theory is a useful framework, it is important to be aware of its limitations. First, middle-range theory aims to establish universal behavioral laws to justify inferences about the past based on modern behavior. However, human behavior is highly variable across time and culture, making the establishment of universal laws unlikely. Second, present-day experiments cannot fully replicate past conditions; modern biases and historically inaccurate assumptions may influence both the outcomes and their interpretation. As a result, the experiment conducted in this study does not capture the full complexity of human behavior or the cultural systems surrounding meat and bone consumption. Finally, although middle-range theory has been subject to various critiques, a fundamental limitation persists: inferences drawn from modern experiments are inherently constrained, as the past cannot be directly observed and absolute certainty about past events and behaviors is unattainable (Pierce, 1989; Raab & Goodyear, 1984). Therefore, while middle-range theory serves as a useful framework for interpreting the past, it is inherently limited in scope, and conclusions drawn from experimental archaeology should not be regarded as definitive.

1.3 Scope of Thesis

This thesis was carried out in three phases. Phase one involved examining remains from a previously conducted carnivore feeding experiment (Capaldo, 1995). This was done to determine if any of the carnivore-chewed remains had evidence of peeled rib, a trait that is considered a "diagnostic signature of hominoid/hominin"-chewed bone (Pickering et al., 2013, p. 1295).

Phase two was based on experimental research, where three controlled feeding experiments were performed to create a sample of modern human tooth marks. Ten human participants were given two cooked pig (*Sus scrofa domesticus*) bones and instructed to use only their teeth to remove the meat and bite the bone. These experiments aimed at documenting the morphology of human tooth marks.

Phase three focused on analysis, utilizing the 3-D scanning and analysis method developed by Pante et al. (2017). A total of 126 experimentally produced human tooth marks were 3-D scanned, measured, and compared to other experimentally produced BSMs, including 405 stone tool cut marks, 275 carnivore tooth marks, 130 mammalian trample marks, and 88 hammerstone percussion marks. This analysis enabled a quantitative comparison of human tooth marks and other BSMs, particularly those made by carnivores.

1.4 Chapter Summary

Taphonomy has advanced significantly since its inception, improving researchers' ability to identify BSMs and interpret past behaviors. However, accurately distinguishing BSM types from one another remains challenging due to the lack of standardized analytical techniques and reliable BSM identification criteria (Harris et al., 2017; James & Thompson, 2015; Njau, 2012). Disagreements over mark identifications have led to ongoing debates in the field, as seen in conflicting BSM interpretations at various sites worldwide (James & Thompson, 2015). One particularly difficult BSM distinction is between human and carnivore tooth marks, as they share many of the same morphological features. Despite research efforts, no criteria have been developed that accurately distinguishes human tooth marks from those of carnivores. This is because human tooth mark studies often lack methodological rigor, resulting in flawed human tooth mark identification criteria (Fernández-Jalvo & Andrews, 2011; Funk et al., 2016; Lloveras et al., 2009, Petrovic et al., 2019; Romero et al., 2016a, 2016b; Saladié et al., 2013).

This research addresses this issue by developing quantitative criteria for distinguishing human tooth marks from those of carnivores using high-resolution 3-D scanning technology. Grounded in middle-range theory (Binford, 1981), this study establishes a cause-and-effect relationship between meat and bone consumption by humans and the resulting trace marks. Ultimately, this study enhances researchers’ understanding of the quantitative differences between human and carnivore tooth marks, providing more reliable criteria for identifying human tooth marks. These findings can then be applied to the archaeological record to shed light on hominin dietary patterns and potential instances of ancient human cannibalism.

CHAPTER 2 BACKGROUND

Research on human tooth marks has expanded significantly in recent years, largely driven by efforts to understand "the pattern in which hominids may leave behind archaeologically observable tooth marks" (Petrovic et al., 2019, p. 1). As a result, many researchers now argue that human tooth marks possess distinct characteristics that differentiate them from those left by carnivores (Fernández-Jalvo & Andrews, 2011; Laroulandie, 2005; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024). However, as discussed in Chapter 1, these claims are problematic because many human tooth mark studies often lack methodological rigor (Fernández-Jalvo & Andrews, 2011; Lloveras et al., 2009; Petrovic et al., 2019; Romero et al., 2016a, 2016b), causing researchers to overlook or fail to recognize the many similarities between human and carnivore tooth marks (Binford, 1981; Elkin & Mondini, 2001; Gifford-González, 1989; Maguire et al., 1980; Oliver, 1993). As a result, other researchers unknowingly accept inaccurate human tooth mark criteria as accurate (Blasco, 2008; Blasco & Peris, 2009; Rougier et al., 2016; Saladié & Rodíguez-Hidalgo, 2017). Thus, this chapter will demonstrate why the current criteria for identifying human tooth marks are flawed and how methodological shortcomings have contributed to these inaccuracies.

2.1 Human & Carnivore Bone Consumption

To assess how researchers identify human and carnivore tooth marks, it is first necessary to determine if both modern humans and carnivores chew bone. The answer is unequivocally yes – both humans and carnivores partake in this behavior. Ethnoarchaeological studies and firsthand observations confirm that humans chew bone (Binford, 1978; Brain, 1967, 1969; Landt, 2007; Lupo & O'Connell, 2002; Martínez, 2009), just as similar experiences and research confirms this behavior for carnivores (Binford, 1981; Brain, 1967, 1969; Fosse et al., 2012; Gidna et al., 2014;

van Valkenburgh, 1996). Studies such as these help researchers link modern dietary behaviors to those of the past, leading to more accurate interpretations of prehistory (Binford, 1981; Gifford-Gonzalez, 1991).

While ethnoarchaeological research confirms that both modern humans and carnivores chew bones, contemporary experiments offer insight into the trace marks left by these actors. Through controlled experiments, researchers have studied the tooth marks that result from meat and bone consumption by humans (Elkin & Mondini, 2001; Fernández-Jalvo & Andrews, 2011; Funk et al., 2016; Lloveras et al., 2009; Petrovic et al., 2019; Romero et al., 2016a, 2016b; Saladié et al., 2013), as well as carnivores (Binford et al., 1988; Blumenschine, 1988; Capaldo, 1995; Muttart, 2017; Nascou & Morin, 2014; Njau & Blumenschine, 2006; Parkinson et al., 2015). Findings from the previously mentioned human tooth mark studies have contributed to the development of the current, yet insufficient, criteria for identifying human tooth marks.

2.2 Methodological Shortcomings of Human Tooth Mark Research

To accurately distinguish human tooth marks from those of carnivores, it is crucial to employ valid and reliable methods of taphonomic analysis (James & Thompson, 2015). This includes systematic comparisons of BSMs and their features (Brain, 1981; Lyman, 1994), as well as the use of experimental BSM collections to identify unknown BSMs (Binford, 1981; Gifford-Gonzalez, 1991). Without these methods, researchers run the risk of developing and using flawed BSM identification criteria, as demonstrated with the current human tooth mark criteria detailed in Section 2.3.

2.2.1 Lack of Systematic Comparisons

In taphonomy, the systematic comparison of BSMs – the structured analysis of two or more mark types to identify similarities and differences – is essential (Brain, 1981; Lyman, 1994). This comparison is important because it minimizes subjectivity as to how researchers describe and identify BSMs by ensuring that assessments are based on standardized criteria rather than inconsistent, qualitative mark descriptions (James & Thompson, 2015). In the case of human and carnivore tooth marks, systematic comparisons of the two allow researchers to establish clear, well-defined criteria that accurately distinguish the former from the latter. However, developing objective criteria to differentiate these mark types remains challenging, as few studies systematically compare human and carnivore tooth marks (Fernández-Jalvo & Andrews, 2011; Funk et al., 2016; Lloveras et al., 2009, Petrovic et al., 2019; Romero et al., 2016a, 2016b; Saladié et al., 2013).

For instance, some studies summarize subjective descriptions of damage caused by human and carnivore teeth, but do not compare experimentally produced human and carnivore tooth marks to one another (Fernández-Jalvo & Andrews, 2011; Saladié et al., 2013). Others acknowledge the difficulty of distinguishing the two tooth mark types, but do not explore the issue further (Lloveras et al., 2009; Romero et al., 2016b). Some studies merely mention the existence of carnivore-chewed bone (Petrovic et al., 2019; Romero et al., 2016a), while others exclude carnivore tooth marks from their analysis altogether (Funk et al., 2016).

When studies do conduct systematic comparisons of human and carnivore tooth marks, they do so in a limited manner. Typically, they either compare human tooth marks to those of a single carnivorous species (Rosell et al., 2019) or examine only one or two shared characteristics of human- and carnivore-chewed bone, not multiple (Pérez-Ripoll, 2005; Pickering et al., 2013). This lack of systematic and comprehensive analysis has resulted in a gap in our understanding of the distinctions between human and carnivore tooth marks. As a result, researchers mistakenly believe they have identified features exclusive to human-chewed bone when, really, they are describing traits common to both human- and carnivore-chewed bone (Fernández-Jalvo &

Andrews, 2011; Laroulandie, 2005; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024).

This gap in knowledge has led to the development of two key problems: qualitative similarities between human and carnivore tooth marks have gone unrecognized by many and features incorrectly assumed to be exclusive to human-chewed bone have been accepted as accurate. As a result, researchers have established flawed criteria for identifying human tooth marks. This criteria has become the foundation of studies focused on hominin dietary behavior (Blasco et al., 2019; Hernando et al., 2022; Morin et al., 2019; Rodríguez-Hidalgo et al., 2017) and ancient human cannibalism (Bello et al., 2015, 2016; Saladié & Rodríguez-Hidalgo, 2017; Santana et al., 2019), ultimately resulting in potentially inaccurate interpretations of the past.

2.2.2 Insufficient Use of Experimental Collections

An additional methodological weakness in human tooth mark research is the insufficient use of experimental collections to aid in the identification of fossil tooth marks (Blasco, 2008; Blasco & Peris, 2009; Hernando et al., 2022; Sanatana et al., 2019). Experimental collections are crucial because they help establish a direct link between a tooth mark and its actor – whether human or carnivore – thereby helping define the features of each mark type (Binford, 1981; Gifford-Gonzalez, 1991). Without the use of experimental collections, researchers must rely on unreliable human tooth mark criteria to identify human tooth marks (Fernández-Jalvo & Andrews, 2011; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024). For example, Sanatana et al. (2019) examined human skeletal remains from Cueva de El Toro and claimed ancient human cannibalism took place due to the presence of suspected human tooth marks on the remains. However, because the researchers did not compare the suspected human tooth marks with confirmed human tooth marks, they relied on flawed human tooth mark criteria to make their identifications (Fernández-Jalvo & Andrews, 2011; Saladié et al., 2013). Therefore, due to their insufficient use of experimental collections and the use of questionable identification criteria, Sanatana et al. (2019) interpretations cannot be considered reliable. This example underscores the importance of using experimental collections when identifying human tooth marks in the fossil record.

2.2.3 Summary of the Methodological Shortcomings

Methodological shortcomings associated with human tooth mark studies include the lack of systematic comparisons (Fernández-Jalvo & Andrews, 2011; Funk et al., 2016; Lloveras et al., 2009, Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013) and the failure to utilize experimental collections (Bello et al., 2015; Blasco, 2008; Blasco & Peris, 2009; Hernando et al., 2022; Sanatana et al., 2019). As a result, researchers have developed and expanded the use of flawed human tooth mark criteria – described in detail in the following section – to identify said marks (Fernández-Jalvo & Andrews, 2011; Laroulandie, 2005; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024). While it is possible that fossil tooth marks have been correctly identified as human-made, this is due to chance rather than the use of accurate human tooth mark identification criteria. Thus, to accurately and confidently identify human tooth marks in the fossil record, it is essential that researchers use valid methods of analysis that aid in the development of accurate human tooth mark identification criteria.

2.3 A Comparison of Human & Carnivore Tooth Marks: Qualitative Features

As previously noted, methodological shortcomings have led researchers to establish flawed qualitative criteria that they argue can reliably differentiate human and carnivore tooth marks from one another. However, as discussed below, these criteria fail to achieve that goal. The following section will examine why the current qualitative criteria used to identify human tooth marks are inadequate, focusing on three main categories: damage types, mark morphologies, and gross skeletal damage.

2.3.1 Damage Types

One of the primary ways in which taphonomists identify tooth-induced BSMs is by the types of damage inflicted to skeletal remains (Binford, 1981; Gifford-Gonzalez, 2018; Lyman, 1994). Damage types common to both human- and carnivore-chewed bone include pits, punctures, scores, and furrows, as both actors have been observed creating these damage types (Binford, 1981; Saladié et al., 2013). Yet determining whether a human or a carnivore chewed a bone based solely on these four common damage types has proven ineffective (Andrés et al., 2012; Binford, 1981; Delaney-Rivera et al., 2009; Elkin & Mondini, 2001; Solomon, 1985). Therefore, researchers have set out to determine if human teeth inflict damage patterns that are unique to the species, as this would enable a more precise distinction between human- and carnivore-chewed bone (Elkin & Mondini, 2001; Fernández-Jalvo & Andrews, 2011; Lloveras et al., 2009; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024).

Researchers have identified three damage types they argue are unique to human consumption, either occurring independently or together. These include crenulated (or saw-toothed) edges, peeled bone, and bent ends (Fernández-Jalvo & Andrews, 2011; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024). Crenulated edges form when human molars penetrate flat bone, creating irregular outlines (Blasco & Peris, 2009; Fernández-Jalvo & Andrews, 2011; Romero et al., 2016a; Saladié et al., 2013, 2024). Peeled bone refers to the separation of a bone's outer lamella from its core, revealing a rough, fibrous surface on both bone portions (Pickering et al., 2013; Turner & Turner, 1999; White, 1992). Pickering et al. (2013) argues that rib peeling is "a diagnostic signature of hominoid/hominin" meat and bone consumption (p. 1295). However, others contend that the presence of peeling on any skeletal element serves as evidence of human consumption (Fernández-Jalvo & Andrews, 2011; Saladié et al., 2013, 2024). Despite these differences, the notion that peeled bone signifies human meat and bone consumption has gained widespread acceptance (Bello et al., 2015, 2016; Boulestin & Coupey, 2015; Hernando et al., 2022). Associated with peeled bone is the phenomenon of bent ends, which describes the bending of thin bone fragments along their long axis, resulting in a curved appearance and partially peeled bone. This type of damage is thought to occur when humans use their hands to apply force to one end of a bone while gripping the other end between their teeth (Fernández-Jalvo & Andrews, 2011; Pickering et al., 2013; Saladié et al., 2013).

Initially, these damage types seem to differentiate bones chewed by humans from those chewed by carnivores. However, upon closer examination, crenulated edges, peeled bone, and bent ends are not exclusive to human-chewed bone at all. Multiple carnivorous species have repeatedly been documented producing the same damage types. For example, hyenas (Brain, 1981; Maguire et al., 1980), coyotes (Lyman, 1994; Petersen, 2013), bears (Arilla et al., 2014, 2023; Sala & Arsuaga, 2013), foxes (Arilla et al., 2019; Krajcarz & Krajcarz, 2014), badgers (Arilla et al., 2020; Cohen & Kibii, 2019), wolves (Binford, 1981; Fosse et al., 2012; González et al., 2023), and numerous other carnivore species (Cohen & Kibii, 2015; Errickson et al., 2024; Pickering et al., 2011; Stiner et al., 2012) create crenulated edges. Likewise, peeled bone is not exclusive to human-chewed bone. Many carnivores, including bears (Arilla et al., 2014), foxes (Arilla et al., 2019), leopards (Pickering et al., 2011), lions or hyenas (which species caused the damage is unknown) (Pickering et al., 2013, p. 1303), badgers (Arilla et al., 2020), and leopards (Pickering et al., 2011) produce peeled bone. Lastly, it has been documented that bears (Arilla et al., 2014, 2023) and foxes (Arilla et al., 2019) can create bent bone ends.

Although this overview is not an exhaustive list of all carnivores capable of producing crenulated edges, peeled bone, and bent ends, it highlights an important point: humans are not the only species capable of creating these damage types. Thus, as demonstrated, human teeth do not produce unique types of damage, as both human and carnivore teeth are capable of producing pits, punctures, scores, furrows, crenulated edges, peeled bone, and bent ends. If a unique damage type does exist for human-chewed bone, it has yet to be identified.

2.3.2 Mark Morphologies

In addition to damage types, researchers have also identified mark morphologies they believe are exclusive to human-chewed bone. These morphologies include double-arched pits and punctures ("double-arched morphologies"), shallow crescent-shaped pits, and triangular pits and punctures ("triangular morphologies") (Fernández-Jalvo & Andrews, 2011; Petrovic et al., 2019; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024).

Double-arched morphologies refer to pits or punctures with two curved indentations forming a "∩∩" shape along a marks edge. This morphology is thought to be the result of human molars, as the "∩∩" shape closely resembles their contour (Fernández-Jalvo & Andrews, 2011; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024). Shallow, crescent-shaped pits are exactly as described – shallow indentations with a crescent or semi-circular form. These pits are believed to result from slightly pointed, unicuspid human incisors (Fernández-Jalvo & Andrews, 2011; Martínez, 2009; Petrovic et al., 2019; Romero et al., 2016a, 2016b; Saladié et al., 2013; Stefanović et al., 2019). Lastly, triangular morphologies describe pits and punctures with a distinct triangular shape. These marks are argued to be the result of human premolars (Fernández-Jalvo & Andrews, 2011; Romero et al., 2016b).

While it may seem that the morphologies of human tooth marks are distinct from those of carnivores, they are not. Controlled experiments have shown that carnivores also create these “exclusively human” mark morphologies. For example, bears (Arilla et al., 2023) and canids (González et al., 2023) produce double-arched morphologies. Arilla et al. (2023) notes that “double-arched punctures are a type of bitemark mainly generated by animals with bunodont dentition” (p. 4), suggesting that such morphologies are not unique to a single species but can be produced by animals with bunodont or bunodont-like teeth, such as bears. Regarding shallow, crescent-shaped pits, researchers have observed foxes (Arilla et al., 2019), bears (Rosell et al., 2019), and hyenas (Maguire et al., 1980) creating these mark morphologies. Lastly, carnivores such as crocodiles (Njau & Blumenschine, 2006), hyenas (Maguire et al., 1980), and canids (Gifford-Gonzalez, 2018; Krajcarz & Krajcarz, 2014) produce triangular mark morphologies.

As with the discussion related to damage types, this is not an exhaustive list of all carnivore species capable of producing double-arched morphologies, shallow crescent-shaped pits, or triangular morphologies. However, it demonstrates that both humans and carnivores can produce these mark morphologies, indicating that such morphologies are not exclusive to human-chewed bone.

2.3.3 Gross Skeletal Damage

As a final effort to establish that human tooth marks are distinguishable from those of carnivores, some propose that the level of gross skeletal damage inflicted by each actor serves as a distinguishing factor (Gifford-Gonzalez, 2018; Landt, 2007; Romero et al., 2016a). The gross damage patterns believed to be unique to human-chewed bone include crushed edges, also referred to as “mashed” or “smashed” edges, and less overall bone destruction.

Crushed edges refer to the flattening of bone epiphyses due to the repeated gnawing, chewing, and sucking to extract grease and marrow, primarily using premolars and molars (Binford, 1981; Oliver, 1993). This process often generates small cracks in the cancellous bone that extends into the cortical bone (Binford, 1981; Saladié et al., 2013, 2024). Gifford-Gonzalez

(2018) is particularly confident in crushed edges as a defining feature of human chewed bone, asserting that it “is probably the most diagnostic of human modifications relative to carnivore marks” (p. 245). Additionally, numerous studies suggest that human teeth inflict less overall damage to skeletal remains (Elkin & Mondini, 2001; Landt, 2007; Lloveras et al., 2009; Romero et al., 2016a; Saladié et al., 2013). However, the claim that human teeth produce a level of gross skeletal damage distinguishable from that caused by carnivore teeth is incorrect, as similar damage patterns appear in both human- and carnivore-chewed bone. For example, researchers have documented several carnivores, including bears (Arilla et al., 2014, 2023; Haynes, 1983), badgers (Arilla et al., 2020), and canids (Arilla et al., 2019; Binford, 1981), producing crushed edges. Even omnivorous species like chimpanzees have been known to create crushed edges when gnawing bone (Pobiner et al., 2007).

The notion that humans are unlike carnivores in that they primarily only inflict slight damage to bones is inaccurate. Both humans (Brian, 1969; Fernández-Jalvo & Andrews, 2011; Maguire et al., 1980; Saladié et al., 2013) and carnivores (Blumenschine et al., 1986; Faith et al., 2007; Gidna et al., 2013; Sala et al., 2014; Thompson & Lee-Gorishti, 2007) can produce varying degrees of bone damage – ranging from slight to severe – depending on multiple factors, such as the relative size of the predator and prey (Pobiner & Blumenschine, 2003). Moreover, both human and carnivores have been documented consuming entire bones (Álvarez et al., 2012; Lawanson & Rae, 2024; Ngouodjou, 2024; Skinner & Chimimba, 2005). Thus, the claim that humans only moderately damage bones is unfounded. Overall, humans are not unique in regards to the gross skeletal damage they cause, as both humans and carnivores can produce crushed edges and varying levels of bone destruction.

2.3.4 Summary of the Qualitative Similarities

Many researchers believe that human tooth marks possess unique traits that distinguish them from those of carnivores (Fernández-Jalvo & Andrews, 2011; Landt, 2007; Laroulandie, 2005; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024). However, as demonstrated, this claim is inaccurate. Numerous carnivorous species, including bears (Arilla et al., 2014, 2023; Sala & Arsuaga, 2013), foxes (Arilla et al., 2019; Krajcarz & Krajcarz, 2014), badgers (Arilla et al., 2020; Cohen & Kibii, 2019), wolves (Binford, 1981; Fosse et al., 2012; González et al., 2023), dogs (Binford, 1981; González et al., 2023), hyenas (Brain, 1981; Maguire et al., 1980), coyotes (Lyman, 1994; Petersen, 2013), and many others (Cohen & Kibii, 2015; Errickson et al., 2024; Njau & Blumenschine, 2006; Pickering et al., 2011; Stiner et al., 2012) generate similar or identical damage patterns to those produced by human teeth. Therefore, the current qualitative criteria used to identify human tooth marks are insufficient, as they rely on criteria that are common to both humans and carnivores.

2.4 Advantage of Quantitative Analyses for Human Tooth Mark Identification

While it has been demonstrated that the current, qualitative human tooth mark identification criterion does little to accurately distinguish human and carnivore tooth marks from one another, it's important to examine why quantitative identification criteria is better in this context. In general, qualitative descriptions are problematic because they often lack precision, making it unclear what separates one tooth mark type from another. For instance, Blumenschine and Marean (1993) describe carnivore tooth marks as “subcircular depressions” and “roughly circular”, while Fernández-Jalvo and Andrews (2011) describe human tooth marks as “shallow, transverse, or oblique” and “triangular, dispersed, and rare”. While informative, these phrases are vague and do not clearly define how a “roughly circular” human tooth mark differs from a “roughly circular” carnivore tooth mark, as both human and carnivore tooth marks have the ability to be "roughly circular". As such, the current qualitative criteria for identifying human tooth marks fail to provide reliable distinctions.

Due to the unreliability of qualitative descriptions, many researchers now favor quantitative methods for identifying and distinguishing BSMs (Andrés et al., 2012; Bello & Soligo, 2008; Duches et al., 2016; Pante et al., 2017). While not without limitations, quantitative approaches are generally viewed as more reliable because they minimize the subjectivity inherent in traditional qualitative methods. By reducing human bias, quantitative analyses allow for more objective and consistent identification of BSMs, enabling clearer distinctions between human and carnivore tooth marks without relying on unstandardized identification criteria.

Therefore, this research does not suggest that accurately distinguishing human and carnivore tooth marks is impossible, but rather that more effective methods exist. By applying the quantitative method of analysis developed by Pante et al. (2017), this study aims to establish more objective and accurate criteria for identifying human tooth marks in the fossil record through a controlled comparison of known human and known carnivore tooth marks.

2.5 Chapter Summary

Research on human tooth marks has expanded considerably in recent years, primarily driven by the goal to differentiate human tooth marks from those of carnivores (Petrovic et al., 2019). As a result, researchers have developed criteria they believe accurately distinguishes the two tooth mark types (Fernández-Jalvo & Andrews, 2011; Laroulandie, 2005; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024). However, this criterion is flawed, as it describes damage types, mark morphologies, and gross skeletal damage patterns that are common to both human- and carnivore-chewed bone (Arilla et al., 2014, 2023; Maguire et al., 1980). This flawed criterion is due to the lack of methodological rigor in human tooth marks studies, particularly the lack of systematic comparisons and the underuse of experimental tooth mark samples (Fernández-Jalvo & Andrews, 2011; Pickering et al., 2013; Romero et al., 2016a, 2016b). Therefore, this research aims to better define the true differences between human and carnivore tooth marks by quantitatively comparing experimentally produced human and carnivore tooth marks in a systematic manner. While this study does not apply its findings to fossil samples, it provides the necessary foundation for future researchers to do so.

CHAPTER 3 MATERIALS AND METHODS

This study generated a controlled yet representative sample of human tooth marks, facilitating a systematic comparison of the micromorphological variations between human tooth marks (n=126) and other BSMs, including stone tool cut marks (n=405), hammerstone percussion marks (n=88), mammalian trample marks (n=130), and of course, carnivore tooth marks (n=275) (Blumenschine, 1988; Keevil, 2018; Muttart, 2017; Njau & Blumenschine, 2006; Pante et al., 2017; Pobiner, 2007, Pobiner et al., 2023). The experimental procedures were carefully selected to minimize the influence of factors other than human teeth on the experimental remains, ensuring accurate identification of human tooth marks. Additionally, the analytical methods were intentionally chosen to enhance reliability and maximize the reproducibility of results (Pante et al., 2017). Therefore, while the primary objective is to identify the quantitative differences between human and carnivore tooth marks, comparing human tooth marks with other BSM types further clarifies the quantitative criteria of human tooth marks.

3.1 Phase One: Analysis of Carnivore Consumed Ribs

3.1.1 The Samples

Before conducting the feeding experiments, a preliminary faunal analysis was performed to evaluate Pickering et al.'s (2013) claim that "peeling of cortical layers of ungulate ribs as [is] taphonomically diagnostic of hominoid/hominin meat- and bone-eating behavior" (p. 1295). An assemblage of carnivore-consumed ribs collected by Capaldo (1995) was examined and compared with published data from a human-consumed rib assemblage studied by (Pickering et al. (2013).

Capaldo's (1995) research documented the consumption of carcasses by various carnivore species in the Serengeti and Ngorongoro ecosystems of Tanzania. These carnivore species included, but were not limited to[1], spotted hyenas, golden and black-backed jackals, vultures, marabou storks, crocodiles, falcons, and black kites (a carnivorous bird). Capaldo (1995) conducted three carcass feeding studies, referred to as “simulations”: the Serengeti simulation (SERS) in Serengeti National Park, the Ngorongoro simulation (NGOS) in the Ngorongoro Conservation Area, and the Olduvai simulation (OLDS) in Olduvai Gorge. Each study involved multiple experiments, as each was designed to test different hypotheses. For a detailed breakdown of these studies and experiments, refer to Capaldo’s (1995) PhD dissertation.

The human tooth mark dataset originates from Pickering et al. (2013), who compiled and analyzed faunal remains from two earlier studies (Brain, 1967, 1981). The first sample, known as the Soutrivier Village (SV) sample, consists of goat remains butchered and consumed by modern humans. All the human-chewed remains were collected before any carnivores could further modify the bones. The second sample, known as the Gobabeb (GOB) sample, also involves goat remains butchered and consumed by humans, but no measures were put in place to prevent carnivores from further modifying the bones. As a result, it is impossible to determine with absolute certainty which marks on the GOB remains were caused by human or carnivore teeth. However, because humans did chew these bones, the GOB data was included in this analysis. For further details on these samples, refer to Pickering et al. (2013).

Materials and results from both studies (Table 3.1) were compared to test Pickering et al.’s (2013) claim that rib peeling damage is unique to hominids. However, before making this comparison, it was necessary to inspect the carnivore-chewed ribs to identify the types of damage carnivores can produce.

[1] Because the carcasses were left exposed overnight without researcher observation, other carnivorous species not listed may have also interacted with remains.

Table 3.1) Data sources used to evaluate Pickering et al.'s (2013) claim that only hominins can produce peeled ribs. An asterisk denotes this actor may have interacted with the remains, but it is not certain.

Source	Faunal Remain Samples	Location	Actor(s)
Capaldo (1995)	Serengeti simulation (SERS)	Tanzania	Carnivores
	Ngorongoro simulation (NGOS)	Tanzania	Carnivores
	Olduvai simulation (OLDS)	Tanzania	Carnivores
Pickering et al. (2013)	Soutrivier Village sample (SV)	Tanzania	Humans
	Gobabeb sample (GOB)	Namibia	Humans & carnivores*

3.1.2 Examination of Rib Specimens

The carnivore-chewed bones from Capaldo's (1995) study are currently housed in the 3-D Imaging and Analysis Laboratory at Colorado State University (CSU). Bones collected from each experiment are kept in designated boxes of varying sizes, labeled with its corresponding experiment name (e.g., SERS 04, NGOS 6).

Although the SERS, NGOS, and OLDS collections contain various skeletal elements, only the ribs were studied because peeling is usually located on the sternal end of ribs, and this was also the focus of Pickering et al.'s (2013) study. Only one experiment was examined at a time to prevent mixing remains from different experiments. After retrieving a box from storage, all rib bones were identified and set aside for further study. Each rib was then examined under a 100w incandescent, oblique light source using a 10x hand lens to identify various types of tooth-induced damage, including classic and general peeling, fractures, crenulated edges, pits, punctures, and scores, as defined by Binford (1981) and Pickering et al. (2013) (Table 3.2). Butchery-related marks were also documented, as the remains were butchered by humans with a metal knife prior to carnivore consumption (Brain, 1967, 1969; Capaldo, 1995; Pickering et al., 2013). The identified butchery marks included chop marks, cut marks, and scrape marks, as defined by Binford (1981) and Blumenschine et al. (1996) (Table 3.2).

Table 3.2) Definitions used to identify the various BSMs observed on Capaldo's (1995) carnivore chewed rib sample.

Term	Definition	Source
Classic Peeling	"Layer(s) of lamella(e) is/are missing in strip(s) from the rib's dorsal, ventral, or both cortices."	Pickering et al., 2013, p. 1299
General Peeling	"The whole dorsal or ventral cortex of a rib is peeled back for some length, revealing the internal trabeculae."	Pickering et al., 2013, p. 1299
Fracture	"Non-chopping or indeterminate" bone breakage	Pickering et al., 2013, p. 1305
Incipient Fracture	"Strips of lamella(e) is/are only partially peeled back...not fully removed from the specimen."	Pickering et al., 2013, p. 1300
Crenulated Edges	"Ragged chewing along fracture edge"	Pickering et al., 2013, p. 1305
Pits	"Circular to polygonal marks with crushed internal surfaces"	Pickering et al., 2013, p. 1305
Punctures	"Tooth...penetrating the bone leaving distinctive holes in cancellous bone."	Binford, 1981, p. 44
Scores	The result of teeth dragging across compact bone, commonly linear and broad	Binford, 1981, p. 46
Chop Marks	Linear, large, broad, deep, V-shaped marks	Binford, 1981
Cut Marks	"Low breadth: depth ratio for individual striae, with deep V-shaped cross section. Internal surface with longitudinal microstriations, lacks crushing"	Blumenschine et al., 1996, p. 496
Scrape Marks	"Broad shallow fields oriented parallel to long axis of bone, often with dimpling."	Blumenschine et al., 1996, p. 496

Rather than recording the number of each mark type on a specimen, data collection was based on their presence or absence. For example, if a rib specimen exhibited chop marks, it was recorded that chop marks were present regardless of whether there was one or multiple. Additionally, BSM documentation was categorized by anatomical location – either the vertebral, midshaft, or sternal portion. Pickering et al. (2013, p. 1305) defines the vertebral portion as "distal to rib head, tubercle, and angle, but proximal to rib midshaft point", the midshaft as the central portion of the bone, and the sternal portion as "distal to rib midshaft point". Therefore, each carnivore-chewed rib specimen was examined for the presence or absence of the previously mentioned BSMs, and their specific location(s) on the bone. After analyzing all the ribs from a specific experiment for BSMs, they were returned to their box and placed back into storage. This process was repeated for all the SERS, NGOS, and OLDS collections.

3.1.3 Data Transformation

After data collection, the information was converted into percentages to determine the frequency of each BSM type by anatomical location. Once the data from the SERS, NGOS, and OLDS collections were processed, the SV and GOB data underwent the same process (Pickering et al., 2013). The two datasets were then compared to identify similarities and differences between human- and carnivore-chewed bones. Although bone peeling was the primary focus of this analysis, data for the other mark types were also quantified to better understand the types of damage caused by humans and carnivores.

3.2 Phase Two: The Experiment

3.2.1 IRB Protocol & Human Research Participants

To complete this thesis, human research participants were necessary. In compliance with regulations governing research involving human subjects, approval from the Institutional Review Board (IRB) was required. Therefore, under the discretion of the CSU IRB, IRB protocol #4958, *A 3-D Micromorphological Analysis of Human (Homo sapiens) Bite Mark Surface Modifications on Domestic Pig (Sus scrofa domesticus) Bone*[2], was approved on Wednesday, October 11th, 2023 (Appendix A). This ensures that the use of human participants in this research adheres to ethical standards and safeguards participants' rights, welfare, and safety.

[2] The title of IRB Protocol #4958 differs slightly from the title of this thesis due to a recent revision to the thesis title.

In accordance with the IRB approval, those recruited through electronic communication, direct communication, and/or flyers, were required to meet the following criteria to participate:

1. Be at least 18 years of age by the study date
2. Have healthy teeth (i.e., no discomfort while chewing food)
3. Be willing to consume pork products

Any individual who failed to meet one or more of these criteria were excluded from participation. Those who met all the requirements and expressed interest in participating were provided a consent form prior to their involvement. A total of ten research participants (Table 3.2) voluntarily took part in the study, helping researchers gain a deeper understanding of what human tooth marks look like on bone.

Table 3.3) Details of the human research participants involved in IRB protocol #4958.

Research Participant	Sex (Male/Female)	Age (Years)	Skeletal Elements Consumed	Number of Marks: Rib Bone	Number of Marks: Leg Bone	Number of Marks: Total
1	Female	24	Rib & Tibia	10	5	15
2	Female	24	Rib & Tibia	6	4	10
3	Female	29	Rib & Femur	5	6	11
4	Female	24	Rib & Femur	0	11	11
5	Female	25	Rib & Femur	14	7	21
6	Male	23	Rib & Femur	0	3	3
7	Female	24	Rib & Femur	5	4	9
8	Male	34	Rib & Femur	0	10	10
9	Male	27	Rib & Femur	5	9	14
10	Female	23	Rib & Femur	7	15	22
Total				**52**	**74**	**126**

3.2.2 The Faunal Remains

To conduct this study, the faunal remains had to meet specific criteria. First, the bones needed to be large enough for humans to consume without completely crushing them, excluding smaller, thinner bones like those of poultry. Additionally, the bones had to be from animals commonly butchered, ensuring consistent availability. It was also important that the bones had a relatively uniform cortical bone density, as this enhances experimental control and comparability of tooth marks (Braun et al., 2016; Lam & Pearson, 2005). Moreover, there had to be enough of the same or similar skeletal elements to maintain consistency in bone surfaces and material, further improving experimental control and comparability. Lastly, given the study's relevance to human cannibalism, it was crucial to use an ethical, credible, and reliable analogue for human bone (Matuszewski et al., 2019). As a result, modern domestic pig (*Sus scrofa domesticus*) bones – specifically ribs and femora and/or tibiae – were chosen for the study because they met all these criteria. The bones used were assumed to come from size two suids, a size classification that includes all animals weighing between 50 and 250 pounds (Bunn, 1982).

The ten rib bones, specifically pork loin back-ribs, were sourced from Costco Wholesale in Timnath, Colorado. These ribs were cut at the midshaft, leaving the proximal head intact. It is assumed these bones were cut using a single-blade mechanized bone saw. The ribs were obtained fresh and were never frozen prior to the experimental trials, as freezing can compromise the bone's structural integrity (Andrade et al., 2008; Grunwald, 2016; Karr & Outram, 2015). Meat was not removed from the ribs before the experimental trials (Figure 3.1A).

The eight femora and two tibiae were sourced from Friendly Nick's Butcher in Fort Collins, Colorado. Like the rib bones, these bones were obtained fresh and were never frozen prior to the experimental trials. Given the ability to control the processing of these bones, the butcher was instructed to leave the proximal and distal ends of the bones intact to avoid the introduction of cut marks. As a result, the femora and tibiae were purchased whole. Since pig femora and tibiae typically have a substantial amount of meat surrounding them, additional processing was required. The butcher was instructed to trim most of the meat from these bones, leaving just enough for participants to consume the meat normally while still gaining access to the bone. The butcher took care to remove the meat without touching the knives to the bone, as this was also done to prevent the introduction of cut marks (Figure 3.1B).

Figure 3.1) Raw pork ribs utilized in one of the three human research trials (A) and a raw pork femur utilized in one of the three human research trials (B).

3.2.3 Preparation of the Faunal Remains

As previously mentioned, the pig remains were never frozen. Instead, they were placed directly into a standard refrigerator upon purchase and stored there until they were cooked for the experimental trials. The timing of the meat purchases and the experimental trials was coordinated to ensure the raw meat did not spoil in the fridge, as the butcher indicated that whole cuts of raw pork can last up to five days in refrigeration (N. Chase, personal communication, October 23rd, 2023). As an extra precaution, the pig leg bones were vacuum-sealed in a plastic vessel at the butcher shop to prevent spoilage, while the pig ribs were purchased in a vacuum-sealed package provided by the producer. A detailed timeline of when the pig remains were purchased, cooked, and consumed is provided in Table 3.3.

Table 3.4) Timeline for acquiring, cooking, and serving the pig remains.

	Remains Purchased	**Remains Cooked**	**Remains Consumed**
Trial 1 – November 2nd, 2023			
Femora	October 28th, 2023	November 2nd, 2023	November 2nd, 2023
Ribs	October 30th, 2023	November 2nd, 2023	November 2nd, 2023
Trial 2 – November 6th, 2023			
Femora & Tibiae	November 4th, 2023	November 6th, 2023	November 6th, 2023
Ribs	November 5th, 2023	November 6th, 2023	November 6th, 2023
Trial 3 – November 13th, 2023			
Femora	November 11th, 2023	November 13th, 2023	November 13th, 2023
Ribs	November 11th, 2023	November 13th, 2023	November 13th, 2023

On the morning of each experimental trial, the fresh pig ribs were taken out of the refrigerator. Ribs were dried with paper towels and seasoned with Liquid Smoke©, Worcestershire sauce, yellow mustard, and barbeque sauce. This was followed by a dry rub composed of sea salt, smoked paprika, lemon pepper, cayenne pepper, garlic powder, onion powder, and black pepper. After applying the dry rub, the ribs were placed in a 9 x 13-inch baking pan lined with aluminum foil. The ribs were then returned to the refrigerator while the oven preheated, and the pig legs were prepared.

The preparation process for the pig legs was like that of the ribs, yet there were a few differences. For the femora, no further steps were necessary beyond applying the sauces and seasonings. Yet additional steps were required for the tibiae. The tibiae were purchased with the fibulae, astragali, and calcanei still attached, as the butcher could not confidently remove these bones without damaging the tibiae surface. Since the fibulae were embedded within the meat surrounding the tibiae, they remained attached. However, because the astragali and calcanei were more accessible, they were removed by hand. After removing the astragali and calcanei from both tibiae, meat preparation continued following the same process that was used for the ribs.

Once the oven was preheated, both the ribs and the legs were removed from the refrigerator and placed on the bottom rack of an Amana 30-inch freestanding electric range. To reduce the risk of compromising the structural integrity of the bones, which can be affected by exposure to high heat (Etok et al., 2007; Rodríguez et al., 2023), the meat and bones were cooked "low and slow" over a six-hour period. Specifically, they were cooked at 225°F for the first four hours, 250°F for the fifth hour, and 275°F for the sixth hour to ensure the meat reached an internal temperature of at least 145°F. The internal temperature of the meat was checked using a standard digital meat thermometer. While the current minimum internal temperature of pork is 145°F (Van, 2011), a temperature of 160°F was preferred to ensure the safety of the participants.

As noted, exposing bone to high temperatures can affect its structural integrity (Etok et al., 2007; Rodríguez et al., 2023). However, ensuring the safety of research participants was the top priority when deciding how to prepare the pig remains. Given the many health risks associated with consuming raw meat (Ali et al., 2010; Chalmers et al., 2020; Velebit et al., 2015), the pig meat and bones were fully cooked prior to human consumption. Consequently, this decision prioritized participant safety over fully maintaining the structural integrity of the bones, resulting in a trade-off that affected certain aspects of experimental precision.

One limitation of this decision is the inability to assess whether human tooth marks differ between raw and cooked bone, which is relevant given the likelihood that ancient *homo* species likely consumed raw meat and bone (Hardy et al., 2017; Zink & Lieberman, 2016). As a result, the findings cannot fully replicate the conditions under which ancient people ate meat prior to the invention of cooking. Additionally, the cooking process in general may have slightly altered the dimensions of the tooth marks. Although the remains were cooked slowly and at low temperatures to minimize structural damage (Etok et al., 2007; Rodríguez et al., 2023), some bone structural alteration was likely unavoidable. Therefore, while cooking the meat and bones introduced certain limitations, ensuring the safety of research participants took precedence, even at the expense of some experimental precision.

Once cooked, the pig ribs and legs were removed from the oven to cool for five minutes. After cooling, the whole rack of ribs (Figure 3.2A) was placed in a 16-inch roasting pan, and at least four legs (Figure 3.2B) (four was the maximum number of research participants in any one experimental trial) were placed into an eight-quart pot. The ribs and legs were then transferred to the experimental study location, Room 350 in the General Services Building at CSU.

Upon arriving at the experimental study location, the rack of ribs was removed from the roasting pan and carefully cut into single pieces using a standard metal kitchen knife. Care was taken to ensure the knife did not touch the bones. This allowed each study participant to receive one rib for the experiment. The pig legs required no further preparation beyond being removed from the pot, as they were already in individual portions.

Figure 3.2) The cooked pork ribs consumed in one of the three human research trials (A) and a cooked pork femur consumed in one of the three human research trials (B).

3.2.4 Experimental Trials

On each of the three experimental study days, participants were asked to arrive at Room 350 in the General Services Building at CSU at the specified time. Upon arrival, they were required to submit their signed consent form. Participants without the required documentation would not be able to partake in this study, though all arrived prepared.

After submitting their consent forms, participants were directed to sit at a seat equipped with the following materials: a paper plate with one cooked pig rib, a paper plate with one cooked pig leg, two plastic polyethylene storage bags, one black permanent marker, one black pen, one tooth mark tally sheet (Figure 3.3), an image depicting how to properly hold the bones

(Figure 3.4), a diagram of human teeth anatomy (Figure 3.5), and diagrams indicating where to remove meat and bite the femora (Figure 3.6), tibiae (Figure 3.7), and ribs (Figure 3.8).

Participant Name:

Rib Meat:

- Front teeth (Incisors & Canines) =
- Middle teeth (Canines & Premolars) =
- Back teeth (Premolars & Molars) =

Rib Bone:

- Front teeth (Incisors & Canines) =
- Middle teeth (Canines & Premolars) =
- Back teeth (Premolars & Molars) =

Leg Meat:

- Front teeth (Incisors & Canines) =
- Middle teeth (Canines & Premolars) =
- Back teeth (Premolars & Molars) =

Leg Bone:

- Front teeth (Incisors & Canines) =
- Middle teeth (Canines & Premolars) =
- Back teeth (Premolars & Molars) =

Figure 3.3) The tooth mark tally sheet used by each research participant.

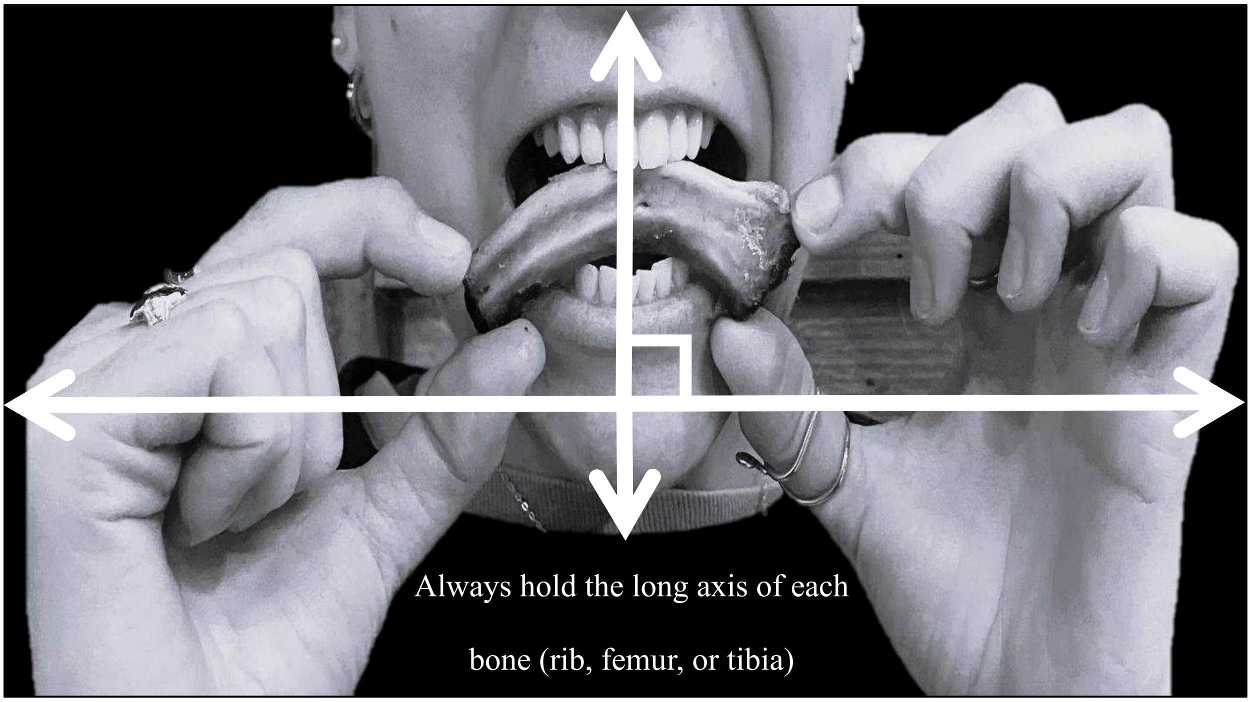


Figure 3.4) A diagram illustrating the correct way for research participants to hold the bone when removing meat or biting the bone.

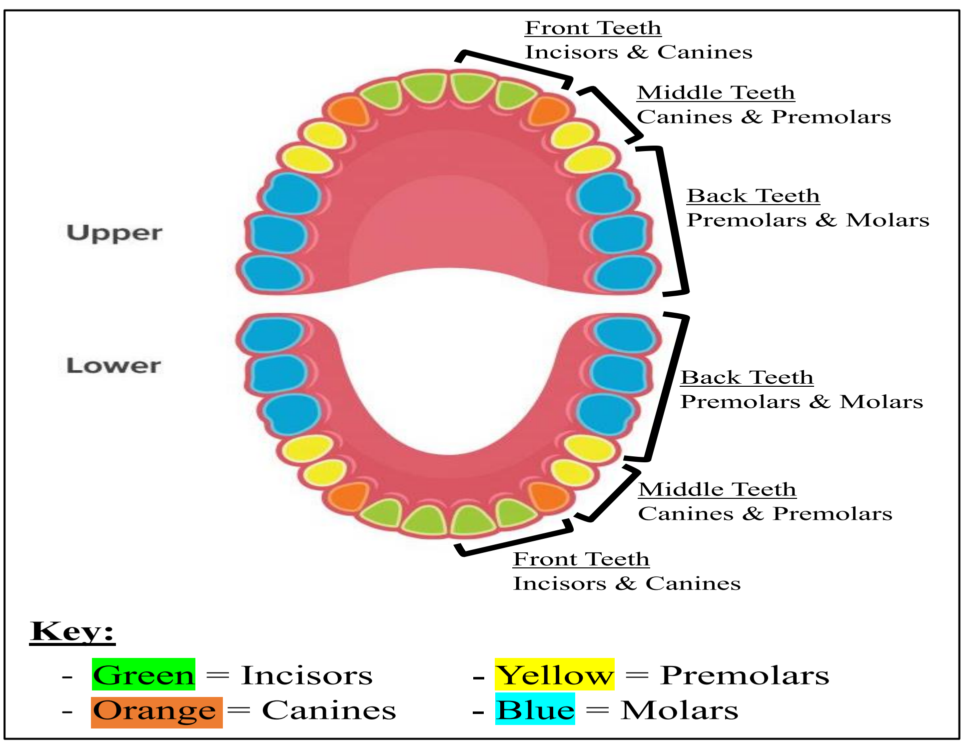


Figure 3.5) A diagram used by research participants to identify the teeth they used when removing meat or biting the bone (MediLexicon, n.d.).

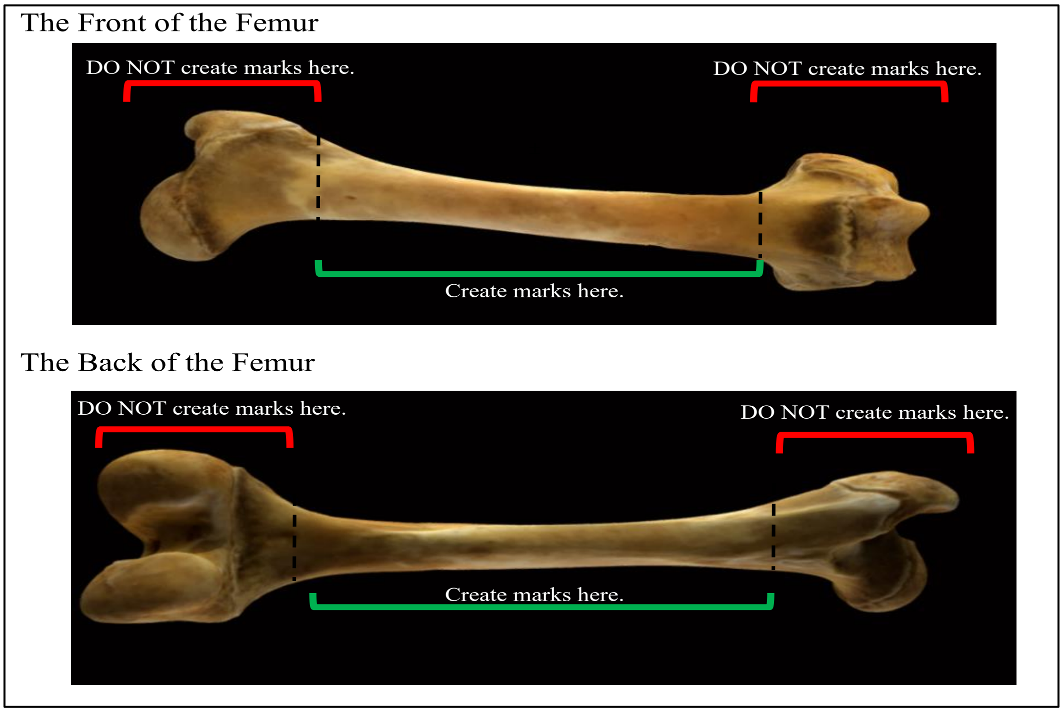


Figure 3.6) The diagram indicating where research participants were to bite the femora (University of Reading, 1967a).

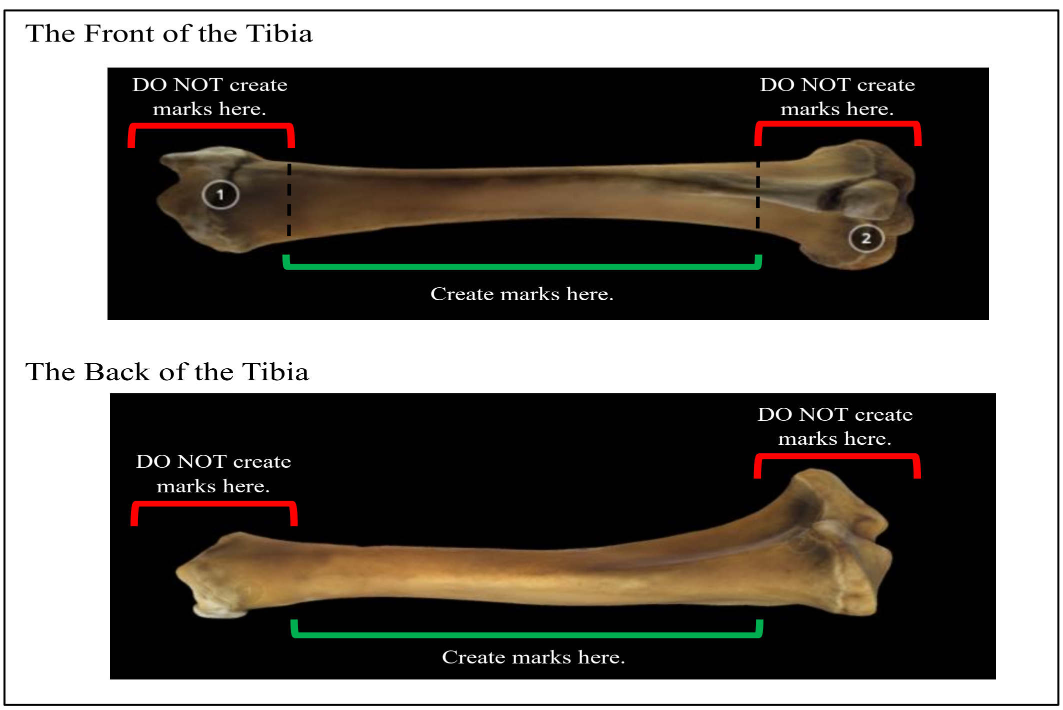


Figure 3.7) The diagram indicating where research participants were to bite the tibiae (University of Reading, 1967b).

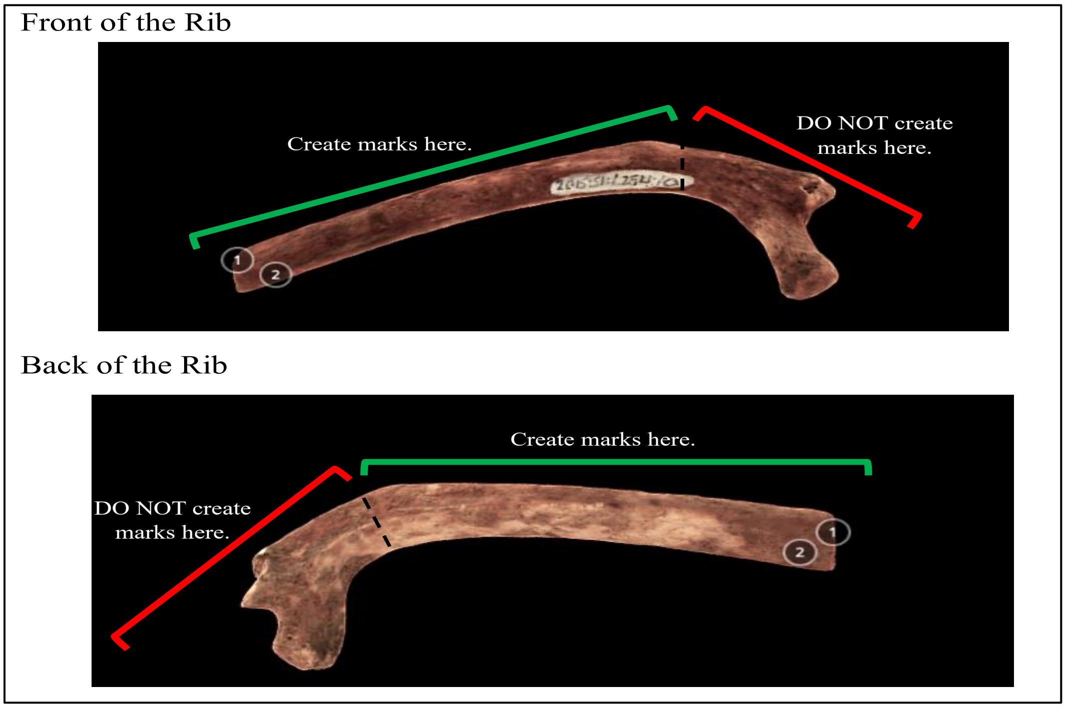


Figure 3.8) The diagram indicating where participants were to bite the ribs (ProgramproFollow, 1964).

After settling in, each participant received a printed copy of instructions (Appendix B). In addition to the printed copy, the instructions were read aloud to the participants. Afterward, the research participants were given the opportunity to ask questions. If there were no questions, participants were free to begin. Once a participant submitted their two plastic polyethylene storage bags with the respective remains and their tooth mark tally sheet, they fulfilled their responsibilities as a human research participant in accordance with CSU IRB protocol #4958.

3.2.5 Cleaning the Faunal Remains

Following each experimental trial, the pig bones were assigned a unique bone identification (ID) number that corresponded to a research participant's number (Table 3.4). The bone IDs became the primary bone identifiers moving forward. The ID numbers were written on the respective storage bags using a permanent marker. Next, the remains – still in their storage bags – were placed into a standard refrigerator to prevent any remaining tissues from molding.

Table 3.5) Research participants and their corresponding bone ID numbers.

Research Participant	Rib Bone ID	Leg Bone ID
1	1	11
2	2	12
3	3	13
4	4	14
5	5	15
6	6	16
7	7	17
8	8	18
9	9	19
10	10	20

Bones were cleaned of remaining tissue and grease following a protocol like that used by Keevil (2018), Muttart (2017), and Pobiner (2007). Specifically, the rib and leg bone from a single research participant were placed in a standard cooking pot containing tap water and Dawn® dish soap. The bones simmered in this mixture on low heat until they were adequately defleshed. Any remaining ligaments, tendons, or tissues were carefully removed using warm water, soft-bristled toothbrushes, and wooden skewers. While these tools do not leave BSMs, care was taken to ensure no additional marks were made during this part of the cleaning process.

After the bones were fully defleshed, they were then submerged in a solution of tap water and 18% hydrogen peroxide (in a ratio of three parts water to one part hydrogen peroxide) to bleach, sterilize, and degrease them. Once this step was complete, the bones were left in an open-air environment to dry. When fully dried, the cleaned bones were transferred into new polyethylene storage bags with the correct participant information transferred onto each. This replacement was necessary, as the original storage bags contained residues that would mold.

Before proceeding, it is important to emphasize two key aspects of the bone cleaning process. One, the bones associated with one research participant were never separated from one another at any point while cleaning. This was done to ensure there was no confusion as to which pig remains belonged to which research participant. Two, the bones associated with one research participant were kept separate from those of other participants, safeguarding data integrity. For example, the rib bone of participant one was never cleaned alongside the rib bone of participant six. Although time-consuming, this method ensured accurate bite mark tracking per participant.

3.2.6 Identifying & Molding the Human Tooth Marks

Once all 20 bones were fully cleaned and dried, next was to examine them for any human tooth marks. Marks were identified using a 10x hand lens under a 100w incandescent, oblique light source. The identified tooth marks included pits and scores, as defined by Binford (1981) and Maguire et al. (1980). No furrows, punctures, or other types of tooth marks were observed.

After identifying the tooth marks, silicone molds of the marks were created to facilitate 3-D scanning, a process described in Section 3.3, “Phase Three: 3-D Scanning & Analysis”. This step was necessary because when attempting to scan a tooth mark directly from a leg bone (bone ID 14), the profilometer failed to capture the mark accurately due to the variable reflectivity of the bones’ surface. Yet when scanning a human tooth mark from a mold, the mark was captured properly. Therefore, due to the scanner's limitations to capture the marks directly from the bone, molds of the marks were necessary. Molds were created with AccuTrans white forensic silicone casting material. This polyvinylsiloxane silicone is commonly applied in forensic investigations to produce detailed reproductions of evidence, such as footprints, fingerprints, and tool marks on various surfaces. It was deemed suitable for this research due to its ability to capture fine details. Additionally, this silicone is safe for use on bone as it does not harm the bone's surface.

To begin molding the marks, an individual tooth mark or a cluster of marks was first identified. Once located, the silicone mold was applied directly to the bone, fully covering the area with the tooth mark. A notecard was then pressed firmly onto the back of the silicone before it dried to eliminate air bubbles and ensure the tooth mark’s details were captured. The silicone mixture required at least 45 seconds to dry. After 45 seconds, the mold was carefully removed from the bone with the notecard still attached. If the mold successfully captured the tooth mark or cluster of marks, the notecard was labeled with the corresponding bone ID, mold ID (an identification number assigned to each mold), and mark ID (an identification number assigned to each tooth mark) (Figure 3.9). If a mark was not fully captured or the mold did not set correctly, the mark was re-molded. This process was carried out for all tooth marks on all 20 bones.

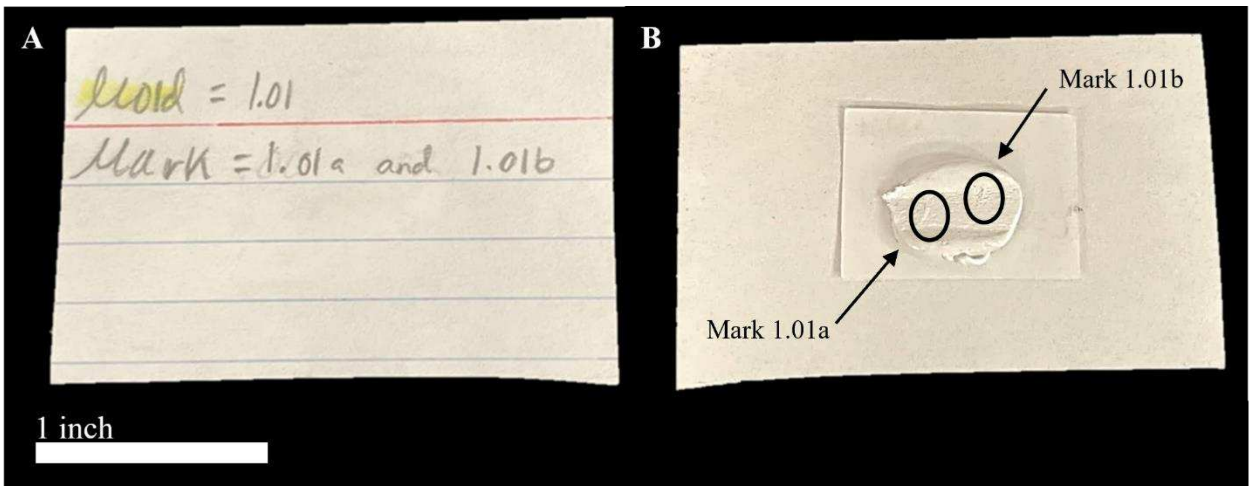


Figure 3.9) Silicone mold 1.01, showing the mold ID ("Mold") and mark IDs ("Mark") (A), along with the mold itself with the human bite marks circled in black (B).

3.2.7 The Comparative Sample: BSMs Types

As previously mentioned, this research utilizes a sample of an additional 898 experimentally produced BSMs of known origin (Blumenschine, 1988; Keevil, 2018; Muttart, 2017; Njau & Blumenschine, 2006; Pante et al., 2017; Pobiner, 2007, Pobiner et al., 2023). Because the primary focus of this research is to determine whether human tooth marks are quantitatively distinct from those of carnivores, a detailed description of the carnivore tooth mark sample is provided. While still important, the other BSMs – stone tool cut marks, hammerstone percussion marks, and mammalian trample marks – are only briefly discussed.

This research includes a sample of 275 carnivore tooth marks of known origin, produced by mammals and reptiles through both naturalistic and controlled feeding experiments (Table 3.5). Detailed descriptions of the experiments, methodologies, and the rationale behind these approaches can be found in Blumenschine (1988), Muttart (2017), Njau and Blumenschine (2006), and Pobiner (2007). All experimentally produced carnivore tooth marks were scanned and analyzed in the 3-D Imaging and Analysis Laboratory at CSU following the scanning procedure developed by Pante et al. (2017).

Table 3.6) A summary of the carnivore tooth marks used in this research.

Species	**Setting**	**Location**	**Source**	**N=**
African Wild Dog	Captive	Denver, USA	Muttart, 2017	31
Gray Wolf	Captive	Livermore, USA	Muttart, 2017	29
Spotted Hyena	Wild	Ngorongoro, Tanzania	Blumenschine, 1988	29
Spotted Hyena	Captive	Denver, USA	Muttart, 2017	30
Striped Hyena	Captive	Denver, USA	Muttart, 2017	30
African Lion	Wild	Ol Pejeta, Kenya	Pobiner, 2007	29
African Lion	Captive	Denver, USA	Muttart, 2017	28
Nile Crocodile	Captive	Bagamoyo, Tanzania	Njau & Blumenschine, 2006	43
Brown Bear	Captive	Denver, USA	Muttart, 2017	26
Total				**275**

Along with the carnivore tooth marks, this study also includes an additional 623 experimentally produced BSMs of known origin. These include 405 stone tool cut marks created using a variety of raw materials (quartzite, chert, etc.) and tool types (biface, flake, etc.); 130 mammalian trample marks made by modern domestic cows (*Bos taurus*) on various soil types (sand, gravel, etc.); and 88 hammerstone percussion marks from anvil-and-hammerstone production (Pobiner et al., 2023). Like the carnivore tooth marks, these cut marks, percussion marks, and trample marks were also scanned and analyzed in the 3-D Imaging and Analysis Laboratory at CSU following the procedures outlined by Pante et al. (2017).

3.3 Phase Three: 3-D Scanning & Methods of Analysis

With the sample of human tooth marks now generated, the study moved into its analytical phase. This phase involved 3-D scanning the human tooth marks using a Sensofar S Neox 3-D optical profilometer, processing the data with Digital Surf's MountainsMap® software, and performing statistical analyses using Paleontological Statistics Software Package (PAST) 4.16c and JMP® Student Edition, version 18. These processes were repeated for all 126 experimentally produced human tooth marks. For justification of this analytical approach and the rationale behind the BSM processing and measurements methods used, refer to Pante et al. (2017).

3.3.1 3-D Scanning the Human Tooth Marks

To 3-D scan a human tooth mark, a high-resolution color image must first be taken using a Sensofar S Neox 3-D optical profilometer (manufactured in 2018), a device that assesses the micro- and nano-geometry of surfaces. This image is essential, as it provides the context for the subsequent scan that captures the 3-D surface topography of a mark (Sensofar, 2024). For an accurate picture, the mark must be properly positioned in terms of both orientation and level under the profilometer's lens. Without proper alignment, a tooth mark may not be fully captured. Thus, accurate mark positioning is crucial. To orient each tooth mark, the molds were manually adjusted so that the mark was aligned perpendicularly along its y-axis. For leveling, the molds were manually adjusted to ensure the mark was as level as possible along both the x and y axes.

Once properly positioned, the mark was 3-D scanned. All human tooth marks were scanned with the profilometer's 5x lens, which has a z-axis resolution of 75 nanometers. Specifically, the 5x lens features a numerical aperture of 0.15, a working distance of 23.5 mm, a field of view of 3400 µm x 2837 µm, a spatial sampling of 2.76 µm, and an optical resolution of 0.93 µm. After scanning, the data acquisition percentage (the proportion of the mark captured by the profilometer) was verified to be at least 95%. If the percentage met or exceeded this threshold, the scan was saved. If not, the mark was re-scanned and saved once the threshold was met. When a scan generated multiple frames, they were combined before saving.

3.3.2 Processing the Human Tooth Marks

Before measuring the tooth marks, each human tooth mark required processing. This was done using Digital Surf's MountainsMap® software, a software that enables visualization, measurement, and analysis of mark surfaces and profiles (Digital Surf, 2025). Scans of the bite marks were initially uploaded into the MountainsMap® program as "unprocessed" marks (Figure 3.10A) and were later fully processed (Figure 3.10B) following the steps outlined below.

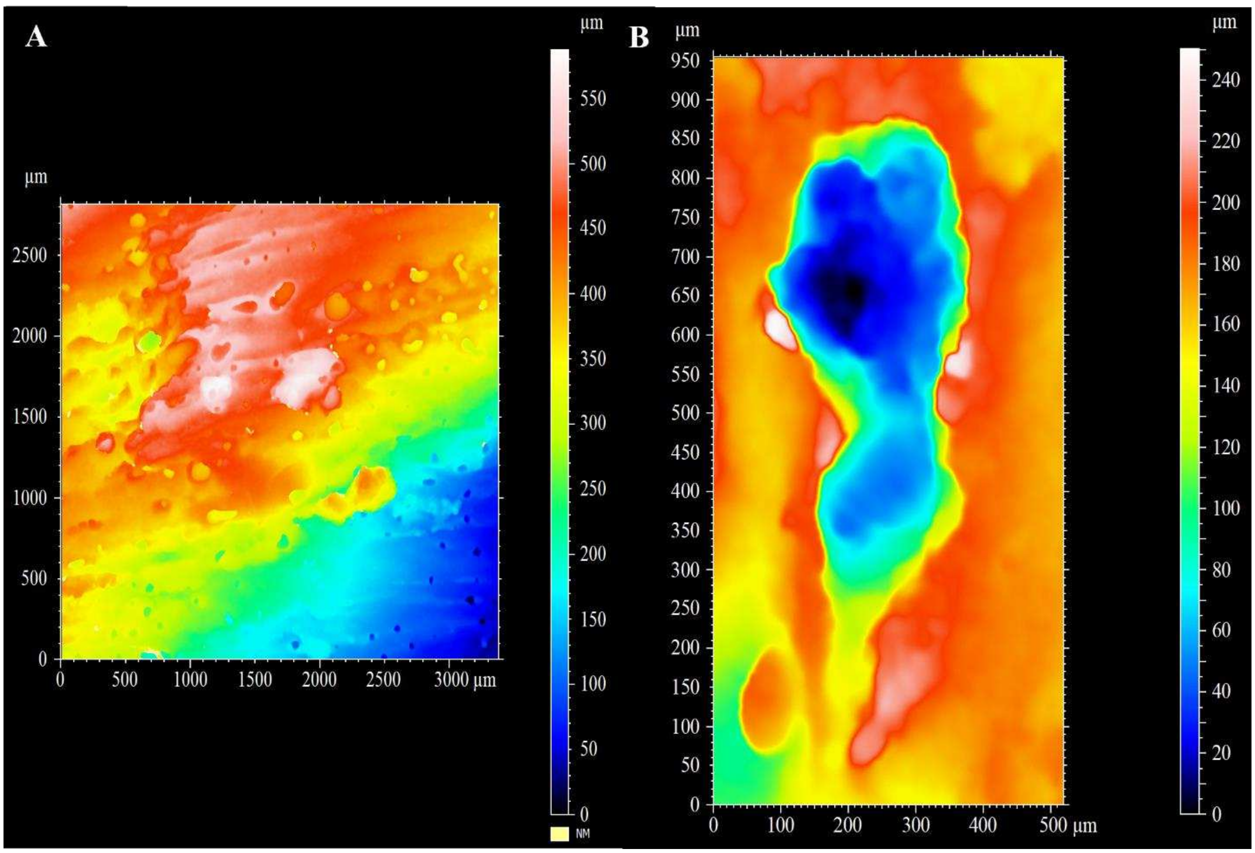


Figure 3.10) Image (A) shows the unprocessed version of mark 1.04a, while image (B) presents the processed version of mark 1.04a after applying several modifications: mirroring along the z-axis, outlier removal, rotation, form removal, mark area extraction, and peak retouching. The color scale beside each image indicates depth.

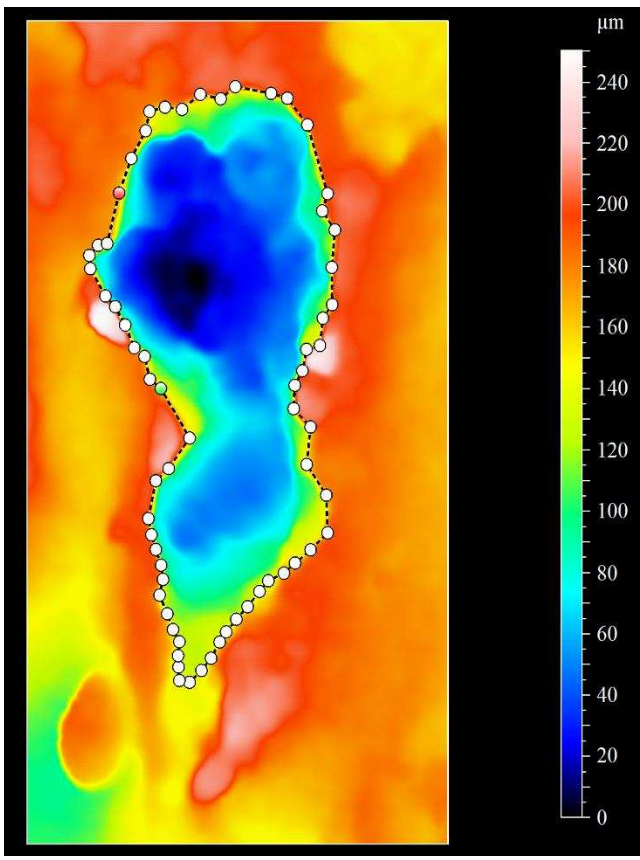
Processing each human tooth mark started with the mark being mirrored along the z-axis to correct for inversion, as the marks were derived from molds that produced inverted scans. Next, any outliers or non-measured data points were filled using the "remove outliers" function, which fills any non-measured data points by averaging the values of the surrounding measured data points. This adjustment was only applied to missing points outside of an actual tooth mark. Although the marks were already roughly perpendicular from manual adjustment of the mark molds prior to scanning, the "rotate" function was used to refine a marks alignment. The degree of rotation varied for each mark, yet this ensured accurate measurement of bite mark length.

Once rotated, the surrounding form of the bone was removed using the "remove form" function. This function levels the non-bite marked portions of the scan to be flat by applying a polynomial function set to a degree of three ($3 < 13$). This function excludes the bite mark itself, therefore resulting in a flat surface with an unmodified human bite mark. After removing the form, the "extract area" function was applied. This function crops the area being analyzed, allowing one to focus on the bite mark rather than the bite mark *and* the surrounding surface. Doing this fosters a more accurate measurement of a bite mark. For scans with multiple tooth marks, this function also enables one to divide the scan up so each tooth mark can be measured independently. Lastly, any large peaks were removed with the "retouch" function to prevent extreme or data-deficient points from affecting the tooth mark measurement data.

3.3.3 Measuring the Human Tooth Marks: 3-D Measurements

Once processed, 3-D measurements of each tooth mark were recorded. These included surface area (μm^2), volume (μm^3), maximum depth (µm), mean depth (µm), maximum length (µm), and maximum width (µm).

The surface area (μm^2), volume (μm^3), maximum depth (µm), and mean depth (µm) of the human tooth marks were measured using the "volume of a hole" tool with the "least squared planes" parameter applied. These measurements were obtained by manually defining the edges of the tooth mark using a series of connected points (Figure 3.11). These points define the boundary between the tooth mark and the unmodified bone surface, instructing the software to analyze only the data points within the defined boundary. The surface area represents all 3-D surfaces of the tooth mark within the defined boundary, while the volume represents the 3-D space displaced by the human tooth within the same boundary. The maximum depth measures the depth of the lowest point of the mark, while the mean depth calculates the average depth across the entire floor of the mark, both within the specified boundary.



Parameters	Unit	Hole
Surface area	μm^2	129107.000
Volume	μm^3	14394655.000
Maximum depth	µm	180.258
Mean depth	µm	111.949

Figure 3.11) Application of the "volume of a hole" tool to mark 1.04a, where the mark was outlined using multiple points. This tool generated the following metrics: surface area (μm^2), volume (μm^3), maximum depth (µm), and mean depth (µm).

The final 3-D measurements collected for each tooth mark were the maximum length (µm) and maximum width (µm). Both measurements were calculated using the "distance" tool. The maximum length is defined as the longest vertical distance from the top of the mark to the bottom, as determined by the researcher. Similarly, the maximum width is defined as the widest horizontal distance from the left side of the mark to the right, also determined by the researcher (Figure 3.12). Although not utilized as a metric in later analyses, the "distance" tool also pinpoints the deepest part of the mark, known as the "minimum point". This point will later assist in generating the 2-D profile view of the mark.

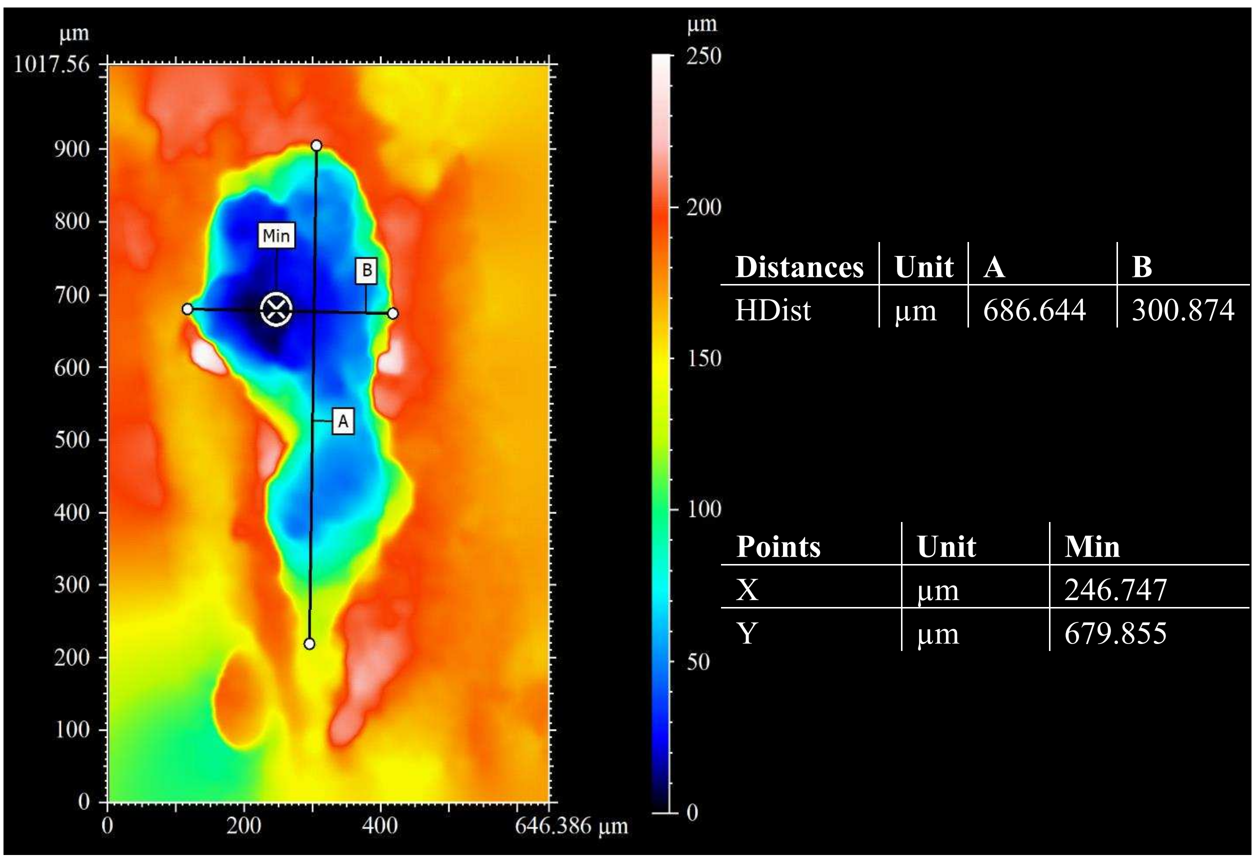


Figure 3.12) Application of the "distance" tool to mark 1.04a, where the mark was measured using a vertical and horizontal line. This tool generated the following metrics: maximum length ("A") (µm), maximum width ("B") (µm), and the X and Y coordinates of the marks deepest point ("Min") (µm).

3.3.4 Measuring the Human Tooth Marks: 2-D Measurements

Two dimensional (2-D) measurements of each tooth mark were also collected. These included maximum depth (µm), area (µm²), maximum width (µm), roughness (R_a), angle (x°), and radius (µm). These measurements were derived from a 2-D profile of each mark. Profile views were generated using the "extract profile" tool, a tool that generates a cross-sectional profile view of the mark through the marks deepest point (Figure 3.13). The MountainsMap® software does not generate mark profiles based on a marks' most central point because this point cannot be accurately identified by the software for all marks (Pante et al., 2017). Instead, MountainsMap® automatically detects the deepest point, thereby reducing user selection bias.

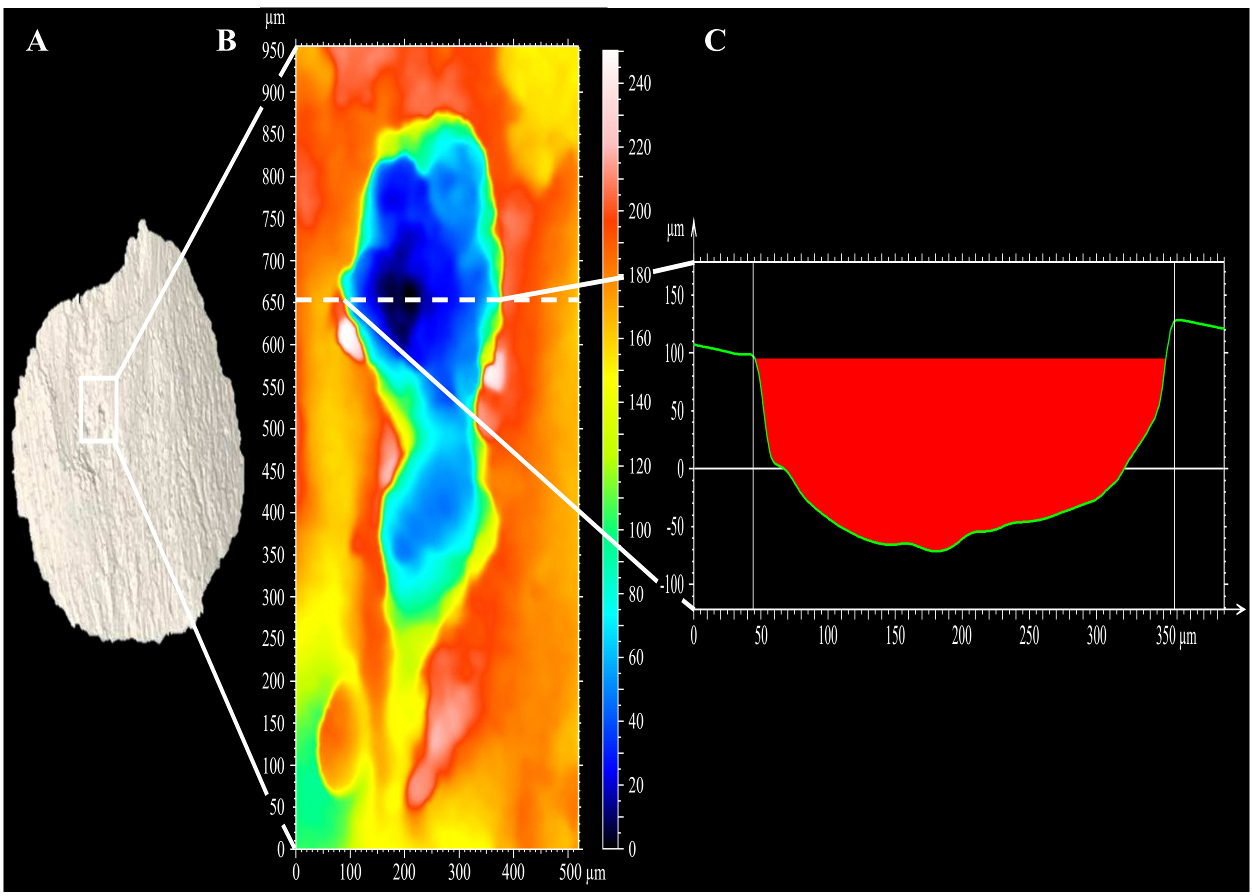
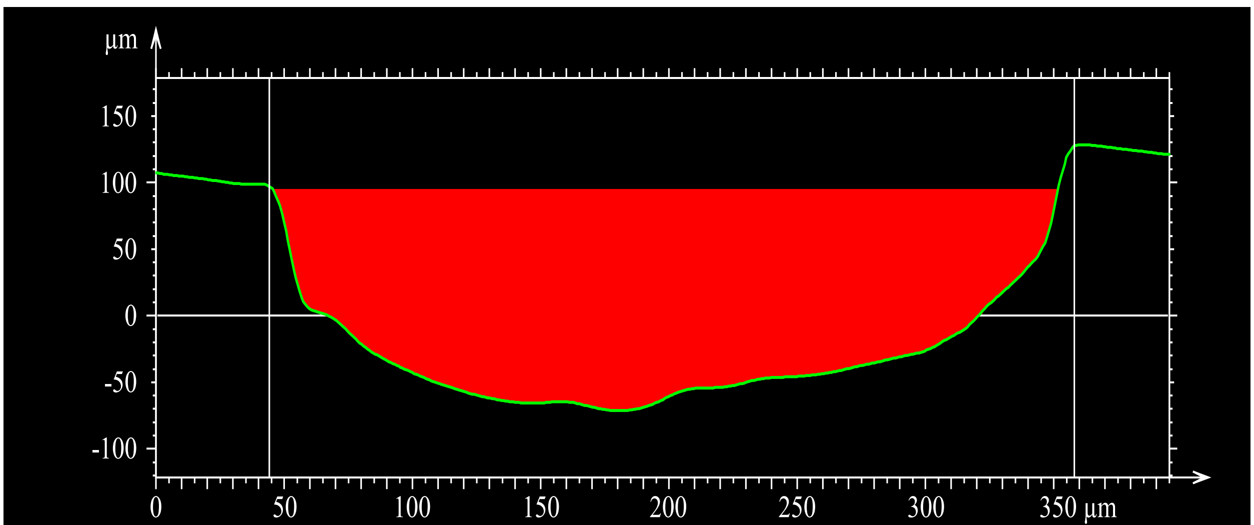


Figure 3.13) An example of the process for extracting a 2-D profile from a mark. (A) shows mark 1.04a on mold 1.04, (B) shows the location of the deepest point on mark 1.04a, and (C) displays the extracted profile of mark 1.04a with the "area of a hole" function applied.

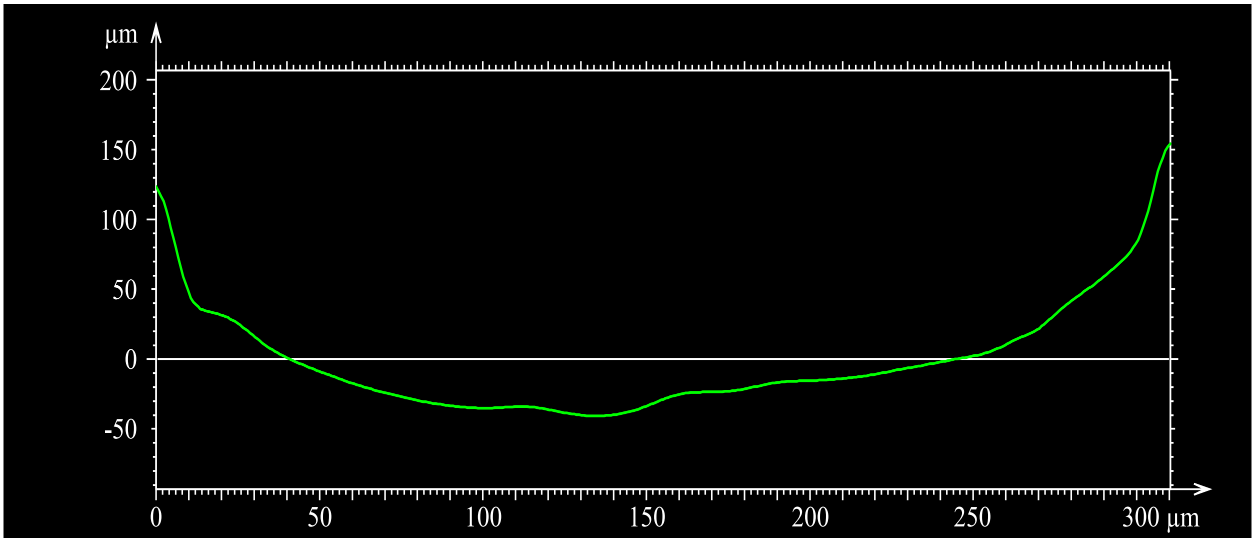
The maximum depth (µm) and area (µm²) of each mark were measured using the “area of a hole” tool with the “under the waterline” parameter applied. This setting limits the measured height of the mark by “filling” it to its lower edges, preventing the mark's shoulders from affecting depth and area calculations (Pante et al., 2017). These measurements were obtained by manually defining the edges of a tooth mark with two vertical white lines (Figure 3.14), which define the leftmost and rightmost boundaries between the tooth mark and the unmodified bone surface. This instructs the MountainsMap® software to analyze only the data points within the defined boundaries. The maximum depth metric represents the deepest point within the mark’s boundary, while the area metric represents all 2-D surfaces of the mark in the same boundary.



Parameters	Unit	Value
Maximum depth	µm	168.540
Area of a hole	µm²	39875.400

Figure 3.14) Application of the “area of a hole” tool to the profile view of mark 1.04a, where the edges of the mark were defined using two vertical white lines. This tool generated the following metrics: maximum depth (µm) and area of the hole (µm²). The green line represents the tooth mark, while the red shading represents the area where these metrics were obtained.

Next, the maximum width of a mark – referred to as “length” by the MountainsMap® software – was measured using the “extract area” tool. This tool isolates the mark profile by removing sections of the unmodified bone surface from the full 2-D profile, generating a new profile view that contains only the tooth mark. This approach allows for accurate measurement of the mark's width ("length") (Figure 3.15).



Parameters	Unit	Value
Length	µm	310.326

Figure 3.15) Application of the "extract area" tool to the profile view of mark 1.04a, where the section of the profile that contains only the mark was isolated. This tool generated the maximum width ("length") (µm) metric. The green line represents the tooth mark.

The final 2-D metrics collected from each tooth mark were roughness (R_a), angle (x°), and radius (µm). These metrics were collected from the profile view that focused solely on the mark itself. The roughness metric, derived from the "parameters table" tool, measures the average height of surface texture by calculating the arithmetic mean deviation across the mark's surface area (Pante et al., 2017). The "contour analysis" tool was used to determine the angle and radius, as it aids in capturing geometric features associated with a 2-D profile. The angle was measured by creating two best-fit lines on either side of the mark, extending to its deepest point (Figure 3.16). The radius was calculated by drawing an arc from the first to last point in the profile, generating a best-fit radius (Figure 3.17).

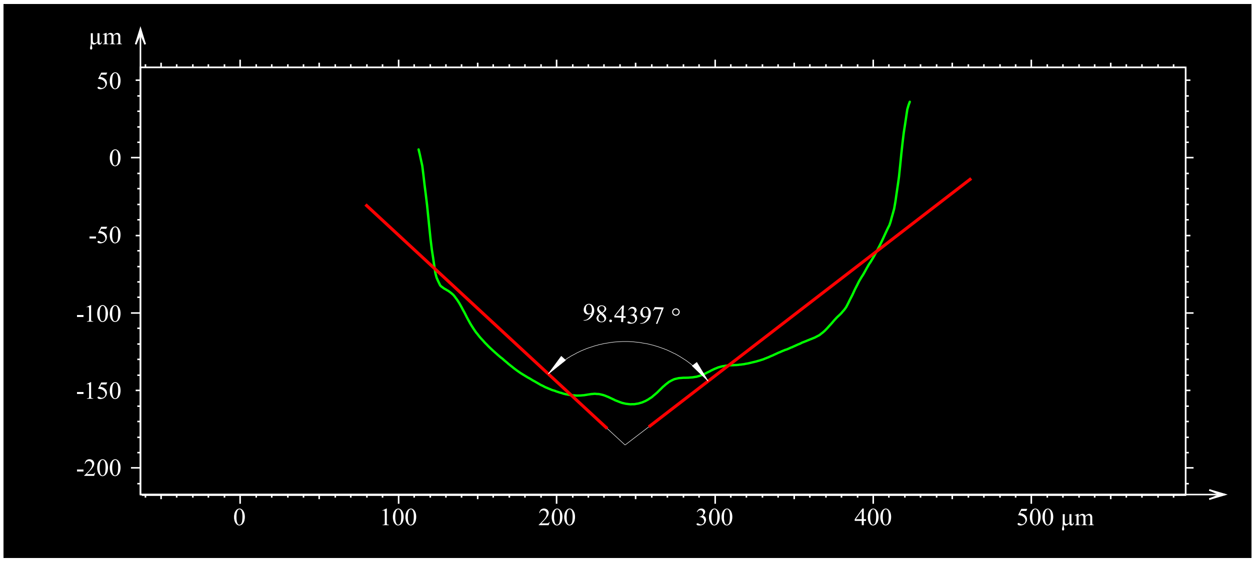


Figure 3.16) Application of the "angle" tool to the profile view of mark 1.04a, generating the angle (x°) metric. The green line indicates the tooth mark, while the red lines represent the best-fit lines extending from each shoulder the deepest part of the mark.

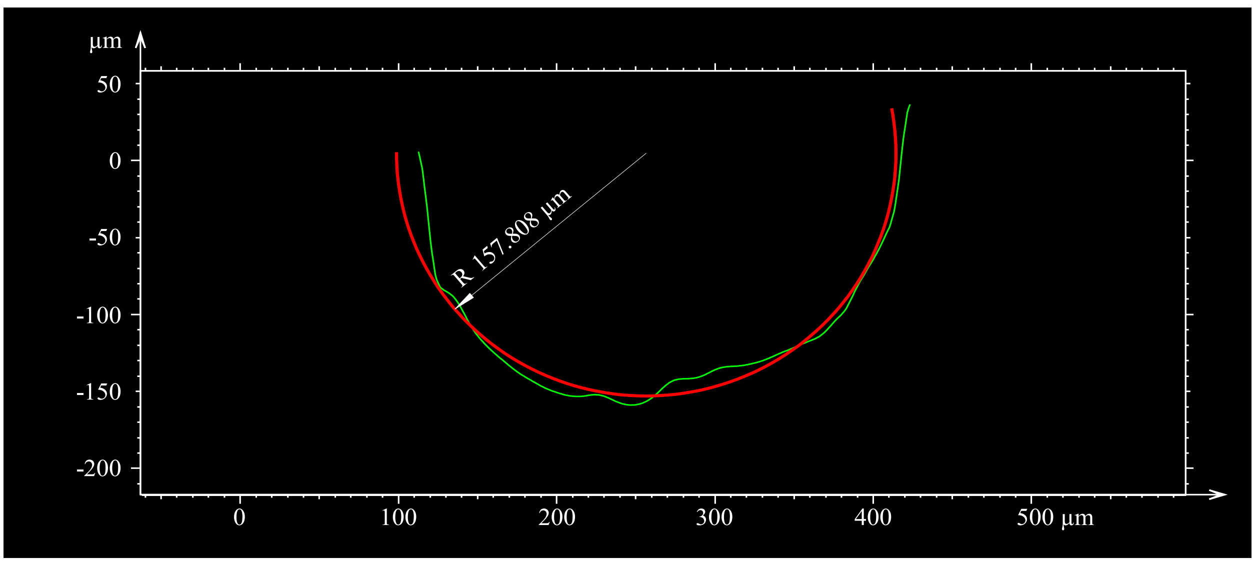


Figure 3.17) Application of the "radius" tool to the profile view of mark 1.04a, generating the radius (µm) metric. The green line indicates the tooth mark, while the red curve represents the best-fit arc extending from the first to the last point of the mark.

3.3.5 The Comparative Sample: 3-D Scanning & Analyses

The procedures for scanning, processing, and measuring the comparative sample of experimentally produced BSMs (n=898) are similar to those outlined in Sections 3.3.1 through 3.3.4. Yet there are slight variations among the marks regarding the technologies and software used. For explanations of these differences, refer to Keevil (2018), Muttart (2017), Pante et al. (2017), and Pobiner et al. (2023).

3.3.6 Methods of Analysis: BSMs

Next, the 3-D and 2-D data associated with each experimentally produced BSM – human tooth marks, carnivore tooth marks, stone tool cut marks, hammerstone percussion marks, and mammalian trample marks – were statistically analyzed using PAST 4.16c (Hammer et al., 2001) and JMP® Student Edition, version 18 (JMP®, 2023).

To ensure that all data from the experimental BSMs (n=1,024) followed a normal distribution, a Box-Cox transformation was applied to the data in PAST. This transformation was necessary, as the statistical tests used in this study assume the data are already normally distributed. Therefore, each data point for every experimental BSM was transformed accordingly, as Box-Cox transformations were applied separately to each metric class.

The normalized data were then imported into JMP® Student Edition to conduct multivariate discriminant analyses. While the data within each metric class were normalized, the covariance matrices for each class differed, necessitating the use of multivariate quadratic discriminant analyses (MQDA) (Lehman et al., 2014). Second, the metrics for 3-D surface area (μm^2) and 2-D maximum depth (µm) were excluded from each MQDA, as these metrics are highly correlated with the 3-D volume (μm^3) and 3-D maximum depth (µm), respectively. If left in the analyses, these variables could have caused data overfitting and therefore skewing the results (Montesinos López et al., 2022; Pobiner et al., 2023, p.10). Prior probability was set to "proportional occurrence" to account for the variable sample sizes for each mark class. Next, the canonical scores were saved to identify which variables had the most influence on a dataset (Lehman et al., 2014), and therefore, which quantitative features are most important for differentiating BSM types from one another.

3.3.7 Methods of Analysis: Tooth Types Utilized by Research Participants

In the final analysis, the frequency with which the research participants used different tooth types – front teeth (incisors and/or canines), middle teeth (canines and/or premolars), or back teeth (premolars and/or molars) (Figure 3.5) – to consume the pork meat and bite the bones was calculated. Data from each participant's tooth mark tally sheet (Figure 3.3) was compiled to create histograms comparing the most frequently used tooth types during the two experimental stages: meat removal and bone biting. This analysis aimed to determine which human tooth types contribute to bone damage and to identify which teeth are most commonly used in meat consumption and bone chewing.

A note regarding the tooth mark tally sheet; instead of identifying the specific tooth or teeth used in each interaction with the bones, research participants selected one of three predefined tooth groups (Figure 3.5). This approach was chosen for two key reasons. One, achieving 100% accuracy in self-reported tooth-use was unlikely, as research participants' knowledge of tooth types and names was unknown. Two, requiring participants to specify the individual tooth/teeth used would have caused unnecessary confusion. Therefore, having the research participants select from broad tooth groups was determined to be the most effective method of data collection for this portion of the research.

CHAPTER 4 RESULTS

4.1 Assessment of Carnivore Consumed Ribs

Of the 93 boxes containing carnivore-chewed remains from the SERS, NGOS, or OLDS experiments (Capaldo, 1995), 19 contained complete or mostly complete ribs. From these, 120 ribs were identified and analyzed (Appendix C). The ribs were examined for the following BSMs in the ventral and sternal regions: articular chop, fracture, peeling (classic and general), crenulation, midshaft incipient fractures, general butchery marks, and general tooth marks. Table 4.1 presents the data related to the carnivore-chewed ribs. Notably, 25.0% of the specimens showed peeling on the ventral portion, while 48.3% exhibited peeling on the sternal portion. Figure 4.1 demonstrates some of the peeling damage observed on the studied ribs.

Table 4.1) The count and percentage of carnivore-chewed ribs exhibiting specific BSMs. "V." denotes "vertebral", "M." denotes "midshaft", and "S." denotes "sternal". Peeling data is bolded.

Modification	**Capaldo (1995) Samples**			
	SERS (n = 88)	**NGOS (n = 28)**	**OLDS (n = 4)**	**Total (n = 120)**
V. Articular Chop	0 (0.00%)	0 (0.00%)	1 (25.0%)	1 (0.83%)
V. Fracture	51 (58.0%)	15 (53.6%)	0 (0.00%)	66 (55.0%)
V. Peel	**22 (25.0%)**	**7 (25.0%)**	**1 (25.0%)**	**30 (25.0%)**
V. Crenulation	15 (17.1%)	2 (7.14%)	1 (25.0%)	18 (15.0%)
M. Incipient Fracture	1 (1.14%)	0 (0.00%)	0 (0.00%)	1 (0.83%)
S. Fracture	38 (43.2%)	17 (60.7%)	0 (0.00%)	55 (45.8%)
S. Peel	**37 (42.1%)**	**20 (71.4%)**	**1 (25.0%)**	**58 (48.3%)**
S. Crenulation	32 (36.4%)	8 (28.6%)	1 (25.0%)	41 (34.2%)
Butchery Marks	47 (53.4%)	12 (42.9%)	2 (50.0%)	61 (50.8%)
Tooth Marks	53 (60.2%)	26 (92.9%)	2 (50.0%)	81 (67.5%)

Figure 4.1) Examples of rib bones peeled by carnivores. Classic peeling (white oval) observed on the dorsal (sternal) surface of rib specimen NGOS7-15 (A). General peeling observed dorsal on the dorsal (sternal) surface of rib specimen SERS526-75 (B).

Pickering et al. (2013) analyzed 192 ribs modified by human consumers. However, 163 ribs from the GOB sample may have also been consumed by carnivores, as no measures were taken to prevent carnivores from accessing the remains after human consumption. While the total dataset includes the GOB sample data, those seeking BSM data exclusively from human-altered remains should refer to the SV sample, which is confirmed to be modified only by humans. Because it is uncertain which tooth marks in the GOB sample were generated by humans or carnivores, their inclusion in Table 4.2 may inflate the overall total. Nonetheless, all the human-chewed ribs, whether from the SV or GOB sample, were examined for the same BSM types as the carnivore-chewed remains. Notably, 27.1% of the ribs analyzed by Pickering et al. (2013)

displayed peeling on the ventral portion, while 58.3% exhibited peeling on the sternal end. Figure 4.2 compares the data of the human-chewed and carnivore-chewed ribs, illustrating the similarities and differences between the two samples.

Table 4.2) The count and percentage of human-chewed ribs exhibiting specific BSMs. "V." denotes "vertebral", "M." denotes "midshaft", and "S." denotes "sternal". Peeling data is bolded.

Modification	**Pickering et al. (2013) Samples**		
	SV (n = 29)	**GOB (n = 163)**	**Total (n = 192)**
V. Articular Chop	18 (62.1%)	39 (23.9%)	57 (29.7%)
V. Fracture	5 (17.2%)	70 (42.9%)	75 (39.1%)
V. Peel	**4 (13.8%)**	**48 (29.4%)**	**52 (27.1%)**
V. Crenulation	0 (0.00%)	28 (17.2%)	28 (14.6%)
M. Incipient Fracture	0 (0.00%)	0 (0.00%)	0 (0.00%)
S. Fracture	4 (13.8%)	132 (80.9%)	136 (70.8%)
S. Peel	**7 (24.1%)**	**105 (64.4%)**	**112 (58.3%)**
S. Crenulation	0 (0.00%)	9 (5.50%)	9 (4.70%)
Butchery Marks	26 (89.7%)	75 (46.0%)	101 (52.6%)
Tooth Marks	7 (24.1%)	70 (42.9%)	77 (40.1%)

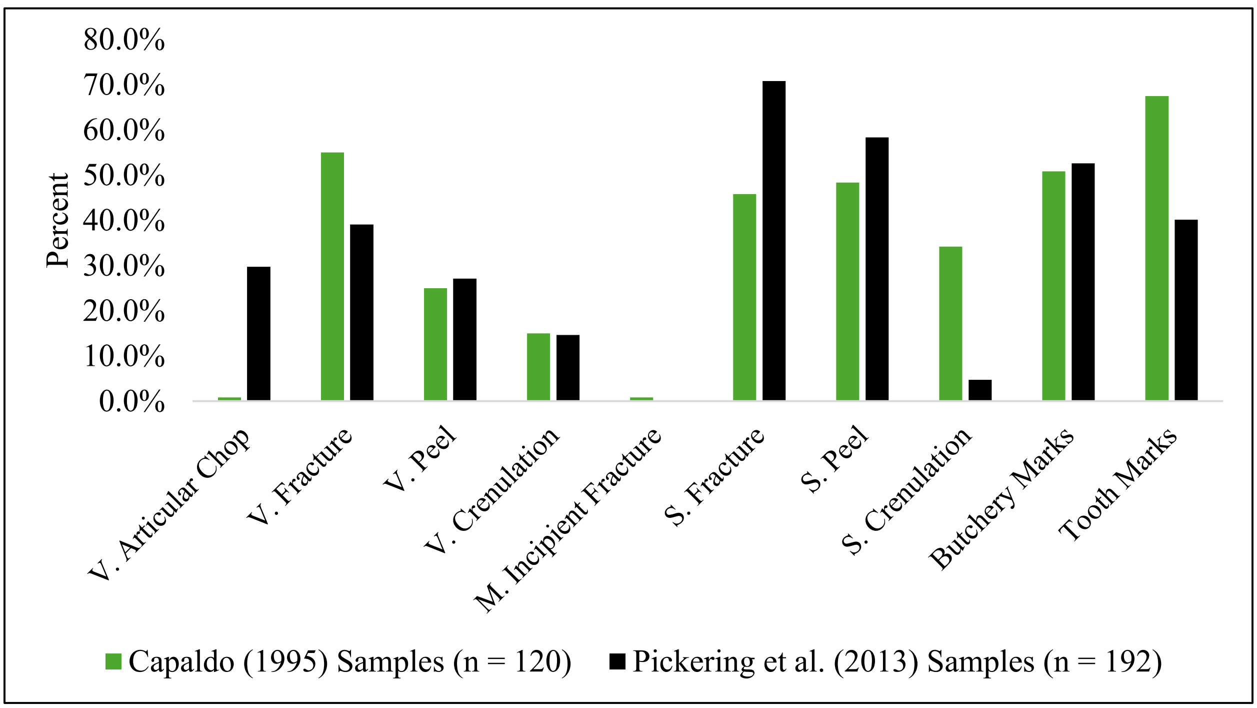


Figure 4.2) A comparison of the percentage of human- and carnivore-chewed ribs exhibiting specific BSMs. "V." denotes "vertebral", "M." denotes "midshaft", and "S." denotes "sternal".

4.2 Assessment of Univariate Normality

To assess whether human tooth marks are qualitatively distinct from other BSMs, specifically carnivore tooth marks, it was first necessary to determine whether the mark metrics followed a normal distribution. These metrics include the 3-D measurements of volume (μm^3), maximum depth (µm), mean depth (µm), maximum length (µm), and maximum width (µm), and 2-D measurements such as area (μm^2), maximum width (µm), roughness (R_a), angle (x°) and radius (µm). The 3-D surface area (μm^2) and the 2-D maximum depth (µm) metrics were excluded from analysis due to their strong correlation with volume and 3-D maximum depth, which can cause data overfitting (Montesinos López et al., 2022; Pobiner et al., 2023, p.10). Normality was assessed within two analysis groups. These groups were necessary, as different BSM types could influence the normality of the metrics. Table 4.3 outlines these groups and specifies the marks analyzed within each.

Table 4.3) The two analysis groups with their categories and the BSMs studied in each.

Group	Group Category	BSMs Compared
1	All Experimental BSMs	**Cut** vs. **percussion** vs. **trample** vs. **carnivore tooth** vs. **human tooth**
2	Tooth-retaining actors: Species Specific	**African wild dog** vs. **gray wolf** vs. **spotted hyena** vs. **striped hyena** vs. **African lion** vs. **Nile crocodile** vs. **brown bear** vs. **human**

Due to the non-normality observed in groups one (Appendix D) and two (Appendix E), Box-Cox transformations were applied to each metric using PAST 4.16c. This function automatically determined and applied optimal lambda values to normalize the data. The optimal lambda values for groups one and two are provided in Appendix F.

4.3 Assessment of Univariate Metrics

Once the datasets were found to be non-normally distributed, it was necessary to assess whether statistically significant differences existed among the univariate metrics. This analysis helps evaluate how effectively each metric distinguishes BSM types from one another. Kruskal-Wallis tests were applied to each metric within both groups, as this test is appropriate for comparing three or more independent categories (e.g., cut marks, human tooth marks, carnivore tooth marks) (Sheskin, 2003). Statistically significant differences were identified in the datasets when a p-value was less than or equal to 0.05. The results for analysis group one are provided in Table 4.4, while those for analysis group two are provided in Table 4.5. Furthermore, Tables 4.4 and 4.5 also provide the mean, median, and standard deviation of each metric for each mark type. This allows for a more detailed comparison of mark type data, thereby deepening our understanding of the quantitative differences that separate human tooth marks from others, specifically carnivore tooth marks.

Table 4.4) The mean, median, and standard deviation values, along with the Kruskal-Wallis test results for group one variables: cut, percussion, trample, carnivore tooth, and human tooth marks. Statistically significant *p*-values are bolded.

		3-D Measurements					2-D Measurements				
Mark Type		**Volume (µm³)**	**Maximum Depth (µm)**	**Mean Depth (µm)**	**Maximum Length (µm)**	**Maximum Width (µm)**	**Area (µm²)**	**Maximum Width (µm)**	**Roughness (Ra)**	**Angle (x°)**	**Radius (µm)**
Mean	Cut	2.0E+08	84.2	28.9	9201.1	431.9	24298.9	335.7	3.1	125.8	542.0
	Percussion	9.9E+08	422.7	155.4	3582.7	1566.3	830166.7	3012.1	12.5	146.4	8545.6
	Trample	1.4E+08	87.3	26.3	8079.1	724.9	24066.2	493.5	4.4	143.8	1962.7
	Carnivore Tooth	3.7E+09	192.6	74.1	4001.1	1439.4	181506.5	1462.7	7.2	150.8	2733.6
	Human Tooth	6.1E+07	144.2	70.4	1584.5	720.2	45818.9	625.8	5.7	129.3	2093.6
Median	Cut	1.6E+07	60.7	18.4	7980.3	313.5	5357.7	239.1	2.2	130.8	228.8
	Percussion	3.3E+08	312.7	131.7	2970.3	1311.1	308936.9	2198.0	10.2	149.6	3306.6
	Trample	3.0E+07	65.5	18.2	7327.7	479.8	7340.2	347.5	3.6	146.2	451.2
	Carnivore Tooth	1.4E+08	155.5	58.5	3027.1	1120.7	77763.2	1180.0	5.0	152.0	1529.9
	Human Tooth	3.7E+07	130.7	64.1	1458.5	653.9	30616.5	579.4	4.6	130.9	501.7
Standard Deviation	Cut	1.1E+09	84.1	36.8	5590.4	402.9	84066.1	358.7	3.6	25.2	1803.9
	Percussion	2.2E+09	316.0	96.9	2747.8	989.7	1763289.0	2722.2	9.2	20.8	13585.4
	Trample	2.8E+08	54.4	21.6	4874.3	672.8	41272.4	433.0	3.6	22.6	5971.7
	Carnivore Tooth	5.1E+10	147.6	58.2	3216.8	994.1	265750.1	999.0	9.4	14.0	3560.1
	Human Tooth	6.1E+07	56.0	30.7	841.1	374.3	45758.8	330.2	4.2	22.6	8283.8
Kruskal-Wallis *p*-values		**1.7E-54**	**6.3E-94**	**1.4E-108**	**1.4E-94**	**5.5E-90**	**2.7E-116**	**9.9E-120**	**4.4E-64**	**4.7E-49**	**1.4E-93**

Table 4.5) The mean, median, and standard deviation values, along with the Kruskal-Wallis test results for group two variables: African wild dog, gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth marks. Statistically significant *p*-values are bolded.

		3-D Measurements					2-D Measurements				
Mark Type		Volume (µm³)	Maximum Depth (µm)	Mean Depth (µm)	Maximum Length (µm)	Maximum Width (µm)	Area (µm²)	Maximum Width (µm)	Roughness (Ra)	Angle (x°)	Radius (µm)
Mean	African Wild Dog	7.3E+07	110.5	48.8	1705.2	728.7	46157.0	761.1	4.1	152.8	1477.5
	Gray Wolf	1.1E+08	143.1	56.7	1965.4	1071.3	96943.1	1174.8	5.3	152.5	1989.6
	Spotted Hyena	1.5E+10	223.8	87.4	3324.5	1581.6	206713.1	1625.5	9.1	147.2	2591.9
	Striped Hyena	7.6E+08	190.8	71.5	5384.2	1589.1	173820.8	1627.5	7.5	157.3	2929.9
	African Lion	1.5E+08	114.3	41.6	3632.0	770.3	52928.1	760.9	3.7	149.5	1374.0
	Nile Crocodile	9.4E+08	296.8	110.9	5004.7	1837.6	350792.7	1843.7	10.2	144.0	2639.4
	Brown Bear	2.4E+09	276.6	106.7	8097.8	3010.8	390783.5	2969.4	11.3	161.5	8292.7
	Human	6.1E+07	144.2	70.4	1584.5	720.2	45818.9	625.8	5.7	129.3	2093.6
Median	African Wild Dog	2.6E+07	105.4	44.8	1481.2	626.3	34507.7	685.0	3.6	153.9	925.2
	Gray Wolf	7.4E+07	137.8	51.2	1730.4	974.3	62171.3	1045.0	4.8	153.1	1403.3
	Spotted Hyena	2.4E+08	191.5	67.7	3288.0	1370.8	116810.0	1455.0	6.0	149.7	1655.6
	Striped Hyena	2.2E+08	172.7	64.2	3530.5	1354.7	101752.2	1405.0	6.2	158.1	2403.6
	African Lion	4.5E+07	78.6	28.7	3066.8	640.5	26706.5	700.0	3.1	149.5	893.4
	Nile Crocodile	3.0E+08	219.3	84.9	3609.6	1645.8	175344.9	1670.0	10.0	146.3	1890.1
	Brown Bear	1.9E+09	255.9	100.0	8425.7	3285.6	389636.1	3057.5	8.5	166.0	7590.6
	Human	3.7E+07	130.7	64.1	1458.5	653.9	30616.5	579.4	4.6	130.9	501.7
Standard Deviation	African Wild Dog	1.0E+08	51.7	27.4	1068.0	356.7	50338.8	381.4	3.0	11.0	1693.8
	Gray Wolf	1.4E+08	76.3	29.3	1096.3	482.4	90899.4	501.2	2.8	9.5	1819.3
	Spotted Hyena	1.1E+11	135.3	53.8	1946.1	766.8	220191.7	824.7	17.4	15.9	2808.7
	Striped Hyena	1.5E+09	101.6	43.0	4126.9	798.4	245191.4	831.6	4.1	8.7	1852.8
	African Lion	3.4E+08	74.8	33.6	2501.7	428.8	70639.0	386.4	2.9	12.2	2411.4
	Nile Crocodile	1.5E+09	237.4	89.9	3272.8	1050.1	457241.7	1056.5	6.9	15.3	3105.9
	Brown Bear	2.2E+09	118.2	54.4	3990.4	1153.1	227996.7	1165.2	6.7	14.1	6417.5
	Human	6.1E+07	56.0	30.7	841.1	374.3	45758.8	330.2	4.2	22.6	8283.8
Kruskal-Wallis *p*-values		**7.3E-30**	**1.4E-18**	**4.8E-15**	**1.3E-29**	**5.4E-34**	**6.0E-30**	**2.3E-38**	**1.9E-15**	**1.3E-21**	**3.5E-24**

As shown in Tables 4.4 and 4.5, all ten metrics for both analysis groups demonstrated statistically significant differences. In total, all 20 Kruskal-Wallis tests were rejected. As a result, *post hoc* Dunn's tests were conducted on each measurement for both groups to identify the specific pairwise relationships that were statistically different from one another (Sheskin, 2003). Pairwise relationships were deemed statistically significant when the *p*-value was less than or equal to 0.05. Dunn's tests were chosen over other multiple pairwise comparison methods due to the presence of non-normal data and the tests suitability for comparing three or more independent groups (Sheskin, 2003). In group one, every BSM pair exhibited at least one statistically significant difference (Appendix G). The same is true for group two (Appendix H). Overall, every BSM pair in both groups exhibited at least one statistically significant difference.

As shown in Table 4.4, the average values for human tooth marks are consistently lower than those of carnivore tooth marks across all metrics examined in this study. A similar pattern is observed for the median values, with the exception of the 3-D mean depth, where the human tooth mark value slightly exceeds that of carnivores. The standard deviation values further support this pattern – those for human tooth marks are consistently lower, suggesting that the data for human tooth marks is more uniform and predictable than that of carnivore tooth marks. Taken together, the mean, median, and standard deviation data indicate that human tooth marks are not only smaller but also consistently thinner and shallower than those produced by carnivores (Table 4.4). These distinctions are also evident in the metric-specific box plots for each mark type presented in Appendix D.

While the overall trend indicates that human tooth marks are generally smaller than those of carnivores, the data for analysis group two generally supports this, yet slightly diverges from this pattern (Table 4.5). This variation arises from the increased specificity of group two compared to the broader scope of group one. Consequently, subtler distinctions that were previously obscured become more apparent. For instance, although most average metric values for human tooth marks remain smaller, certain carnivore species exhibit lower averages than humans in metrics such as 3-D volume, 3-D maximum depth, 3-D mean depth, and 2-D roughness. A comparable pattern is observed in the median values for the human tooth marks as well. Despite these minor deviations, human tooth marks still generally remain smaller, thinner, and shallower than carnivore tooth marks (Table 4.5). These distinctions are also evident in the metric-specific box plots for each mark type presented in Appendix E.

Overall, the Kruskal-Wallis tests (Tables 4.4 and 4.5), the *post hoc* Dunn's tests (Appendices G and H), and the mark summary statistics (Tables 4.4 and 4.5) indicate that there are clear, measurable differences among the various mark types. However, these analyses evaluate each mark metric independently rather than collectively. This underscores the need for a statistical approach that simultaneously considers all variables to more accurately distinguish human tooth marks from other BSMs, particularly those made by carnivores.

4.4 Multivariate Quadratic Discriminant Analysis

To conduct more comprehensive statistical analyses, a multivariate quadratic discriminant analysis (MQDA) was selected. This analysis was chosen for its ability to compare multiple variables simultaneously and identify the most optimal combination of variables that maximize separation between predefined groups (Dixon & Brereton, 2009; Ghosh et al., 2021). In this study, the MQDAs were used to evaluate whether different BSMs types – specifically human tooth marks – could be distinguished from one another based on the 3-D and 2-D metrics provided. The results of both MQDAs are based on the data provided in Appendices I and J.

In MQDA one, 851 out of 1,024 BSMs (83.1%) were correctly classified into the correct BSM group. Human tooth marks were classified with moderate accuracy, with 109 out of 126 marks (86.5%) correctly classified. Stone tool cut marks had the highest accuracy, with 365 out of 405 marks (90.1%) correctly classified. Lastly, mammalian trample marks had the lowest accuracy, with only 71 out of 130 marks (54.6%) correctly classified (Table 4.6 and Figure 4.3).

Table 4.6) Confusion matrix for MQDA one. The prediction accuracy for human tooth marks is 86.5%. Bolded values represent the number of correctly classified BSMs in group one.

		Predicted Groups					
		Cut	Percussion	Trample	Carnivore Tooth	Human Tooth	**Total**
Given Groups	Cut	**365**	0	21	20	0	405
	Percussion	2	**64**	0	14	8	88
	Trample	43	0	**71**	13	3	130
	Carnivore Tooth	5	6	6	**242**	16	275
	Human Tooth	0	2	0	15	**109**	126
	Total	415	72	97	304	136	1,024

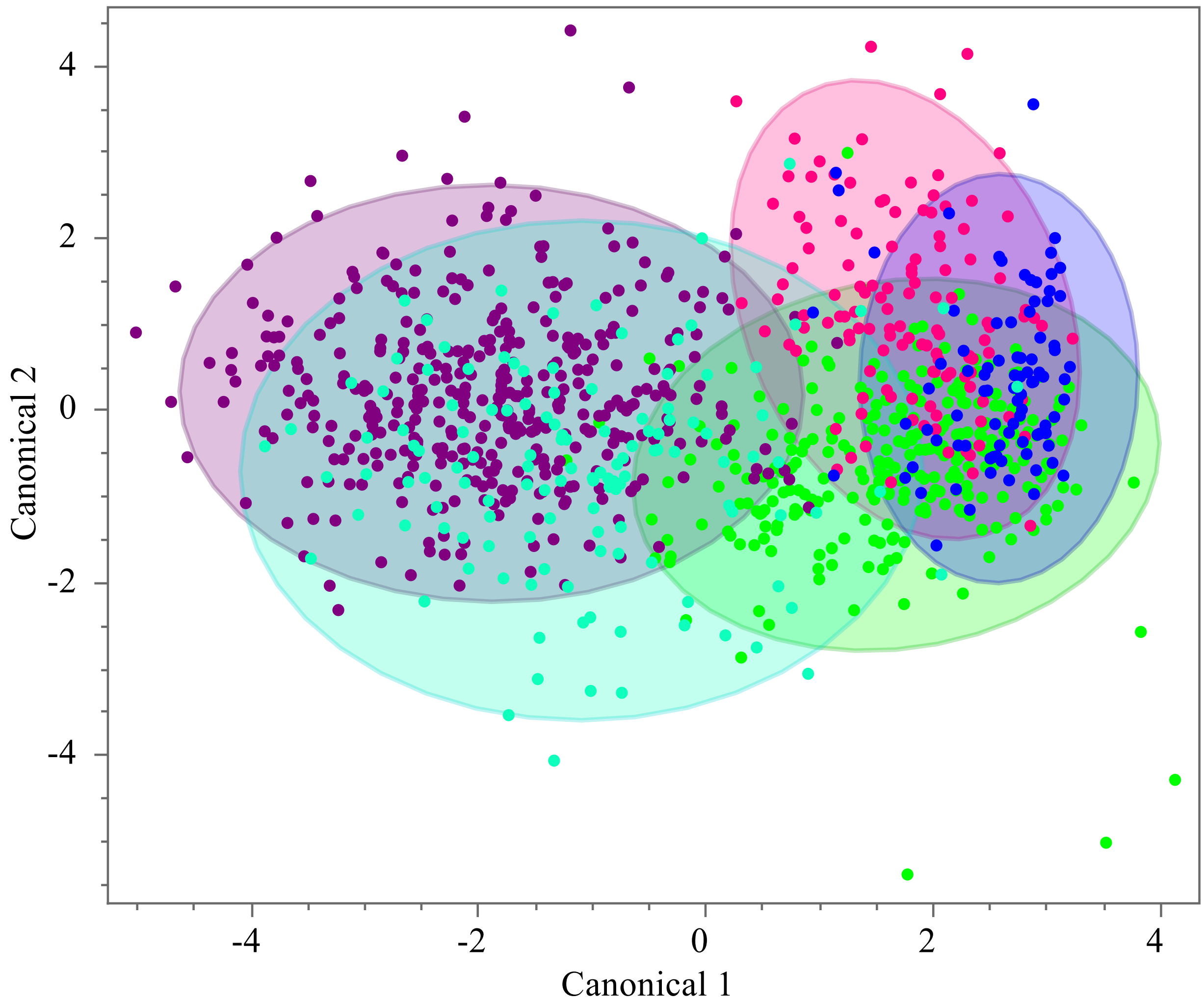


Figure 4.3) Canonical graph illustrating the results of MQDA one. Results are based on the raw data provided in Appendices I and J. Shaded ellipses represent 95% confidence intervals for the samples. Data-points are color-coded as follows: purple for cut marks, blue for percussion marks, teal for trample marks, green for carnivore tooth marks, and pink for human tooth marks.

In MQDA two, 273 out of 401 tooth marks (68.1%) were correctly classified into the correct species group. Human tooth marks had the highest classification accuracy, with 115 out of 126 marks (91.3%) correctly classified. Nile crocodile tooth marks were classified with moderate accuracy, with 30 out of 43 marks (69.8%) correctly classified. Lastly, spotted hyena tooth marks had the lowest accuracy, with only 19 out of 59 marks (32.2%) correctly classified. (Table 4.7 and Figure 4.4).

Table 4.7) Confusion matrix for MQDA two. The prediction accuracy for human tooth marks is 91.3%. Bolded values indicate the number of correctly classified tooth marks in group two. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

		Predicted Groups								
		A. Wild Dog	Gray Wolf	Spotted Hyena	Striped Hyena	A. Lion	Nile Crocodile	Brown Bear	Human	**Total**
Given Groups	A. Wild Dog	**18**	3	1	2	1	1	0	5	31
	Gray Wolf	1	**22**	0	2	0	3	0	1	29
	Spotted Hyena	1	11	**19**	6	3	12	5	2	59
	Striped Hyena	2	3	0	**19**	0	1	5	0	30
	A. Lion	3	5	5	4	**30**	9	1	0	57
	Nile Crocodile	1	1	2	3	3	**30**	2	1	43
	Brown Bear	0	0	0	2	0	3	**20**	1	26
	Human	5	2	0	2	2	0	0	**115**	126
	Total	31	47	27	40	39	59	63	125	401

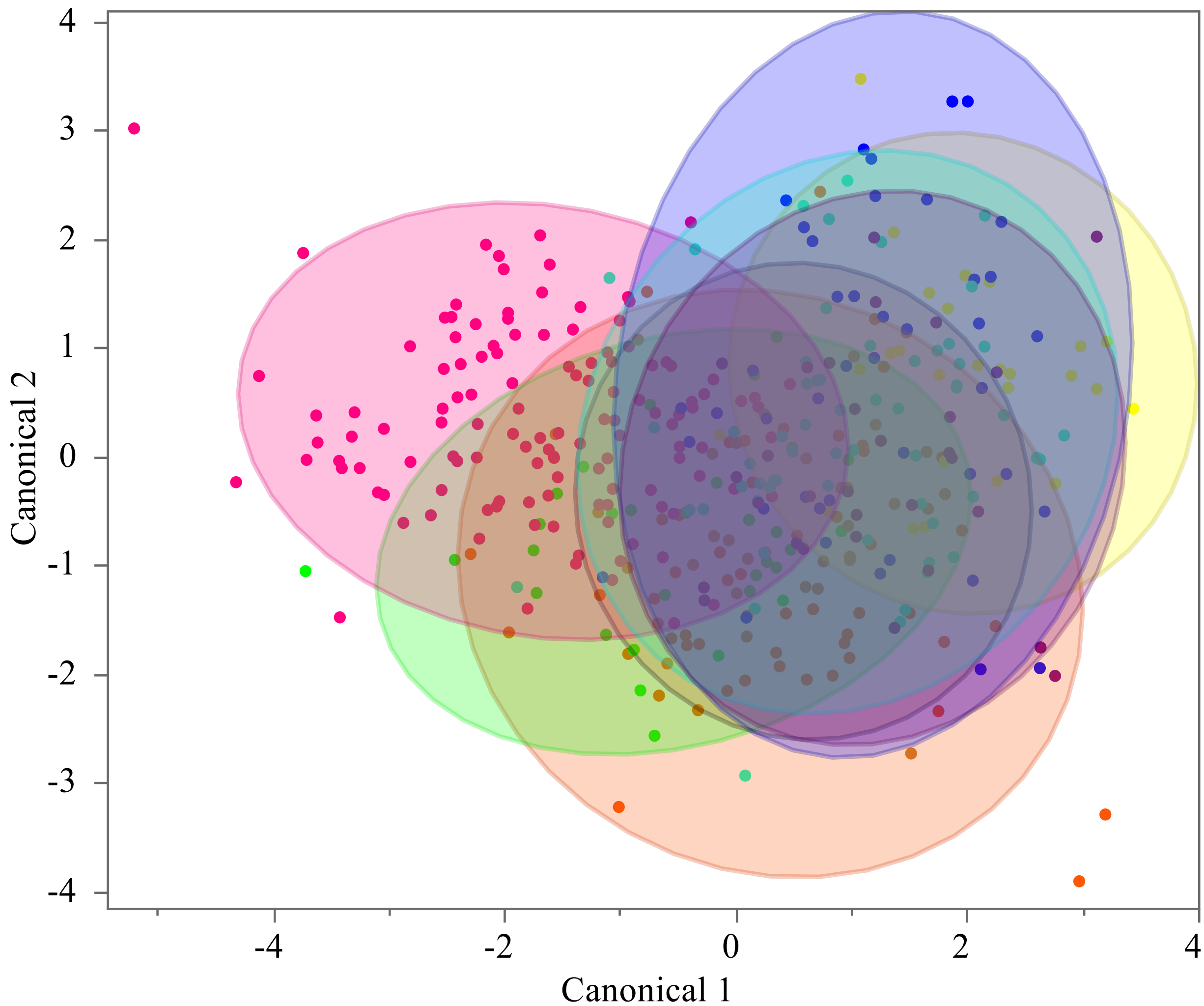


Figure 4.4) Canonical graph illustrating the results of MQDA two. Results are based on the raw data provided in Appendix J. Shaded ellipses represent 95% confidence intervals for the sample. Data-points are color-coded as follows: green for African wild dog tooth marks, black for gray wolf tooth marks, teal for spotted hyena tooth marks, purple for striped hyena tooth marks, orange for African lion tooth marks, blue for Nile crocodile tooth marks, yellow for brown bear tooth marks, and pink for human tooth marks.

4.5 Assessment of the Tooth Types Utilized by Research Participants

For the final analysis, the total number of interactions the research participants (n=10) had with the pig remains was compared. All comparisons were based on the data provided in Appendix K. These comparisons were made both with and without considering dietary behaviors – specifically, meat removal and bone biting. When dietary behavior was not considered, participants reported using their front teeth 318 out of 454 times (70.0%), their middle teeth 123 out of 454 times (27.1%), and their back teeth 13 out of 454 times (2.86%).

Yet when dietary behavior was considered, the tooth use pattern shifted slightly. In experimental stage one – meat removal – participants reported using their front teeth 223 out of 254 times (87.8%), their middle teeth 31 out of 254 times (12.2%), and their back teeth zero out of 254 times (0.00%). In experimental stage two – direct bone biting – participants reported using their front teeth 95 out of 200 times (47.5%), their middle teeth 92 out of 200 times (46.0%), and their back teeth 13 out of 200 times (6.50%). Figure 4.5 illustrates this data.

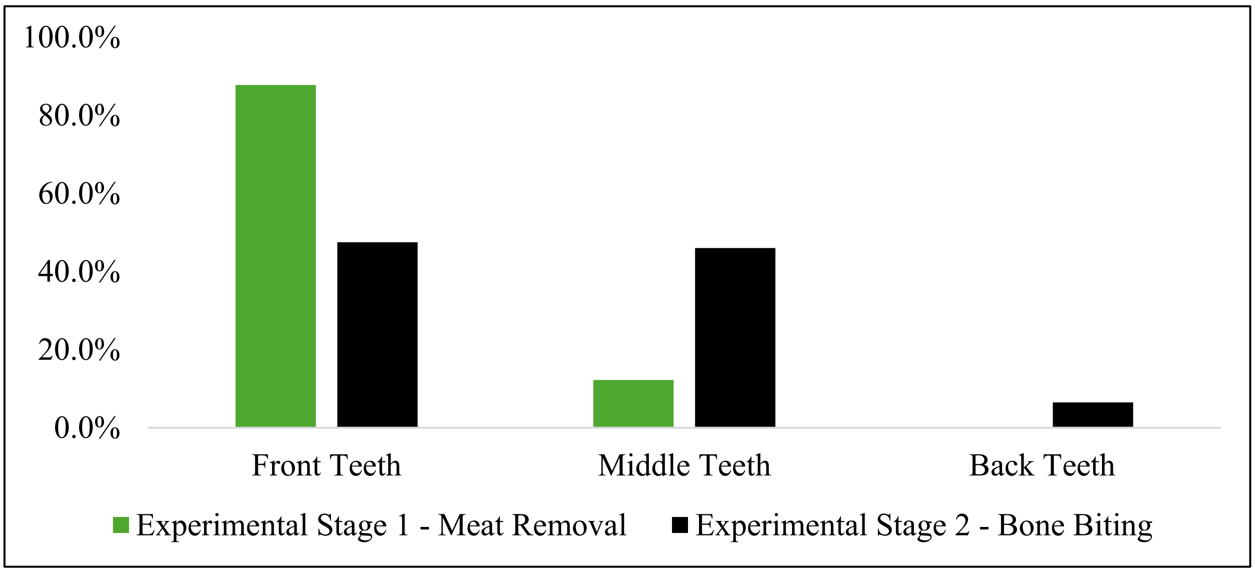


Figure 4.5) The total number of interactions per tooth group for both experimental stages. Results are based on the raw data provided in Appendix K.

It is important to note that the total number of interactions participants had with the pork remains (n=454) exceeds the total number of human tooth marks scanned and analyzed (n=126) for two reasons. One, not every interaction a research participant had with a rib or leg resulted in a visible tooth mark. And two, some tooth marks were excluded from analysis due to uncertainty as to where the mark edges were. Therefore, out of the 454 total interactions the research participants had with the 20 pork bones, 126 human tooth marks were suitable for analysis.

CHAPTER 5 DISCUSSION

To better understand ancient human subsistence patterns related to meat and bone consumption, researchers must prioritize evidence that confirms these behaviors rather than evidence that is suggestive of it. For instance, while cut and burn marks on bone may suggest meat and bone consumption by humans (Lloveras et al., 2009; Soulier & Costamango, 2017), these marks could result from other activities or natural processes such as symbolic modifications, funerary rituals, and wild fires (Bello et al., 2017; Carroll & Smith, 2018; Gonçalves et al., 2018; Lyman, 1994). A similar challenge arises when trying to identify ancient human cannibalism; while cut and burn marks on human bone may suggest human consumption (Turner & Turner, 1999; White, 1992) they do not provide definitive proof. Thus, the presence of human tooth marks on ancient bone provides the most direct evidence of meat and bone consumption, whether for cannibalistic purposes or not.

However, researchers have struggled to fully understand meat and bone consumption by ancient humans due to the morphological similarities between human and carnivore tooth marks (Arilla et al., 2023; Elkin & Mondini, 2001; Maguire et al., 1980; Rosell et al., 2019). To address this issue, 3-D scanning technologies were employed to differentiate human tooth marks from those of carnivores on a quantitative level, achieving a classification accuracy of 91.3%. While the accuracy is not 100%, this study significantly enhances researchers' ability to accurately differentiate the two by shifting from qualitative criteria to quantitative guidelines.

5.1 Interpretation of Results: Carnivore Consumed Ribs

A comparative analysis of carnivore-chewed ribs and human-chewed ribs revealed several similarities, with bone peeling and crenulation being the most notable. Pickering et al. (2013) claimed that rib peeling, both classic and general, "is a diagnostic signature of hominoid/hominin behavior" (p.1295); however, the data generated in this research does not support this assertion. The findings demonstrate that both actors are capable of peeling ribs on both the sternal and vertebral portions (Figure 4.2). Therefore, the claim that only hominids can peel ribs is incorrect, as it has been demonstrated here that carnivores are capable of peeling ribs. Although the specific carnivore species responsible for the rib peeling in Capaldo's (1995) experiments is uncertain, one conclusion remains clear: rib peeling is not exclusive to hominin-chewed bone.

It is important to recognize that others have also documented carnivores peeling rib bones, including bears (Arilla et al., 2014, 2023), foxes (Arilla et al., 2019), leopards (Pickering et al., 2011), and domestic dogs (Pickering & Wallis, 1997). These findings only further draw into question Pickering et al.'s (2013) assertion regarding peeled ribs. Rather than addressing the possibility that *both* humans and carnivores can peel ribs, Pickering et al. (2013) maintained a narrower set of identification criteria. This narrow criteria may have contributed to some of the current challenges associated with accurately identifying human tooth marks, which, in turn, may have affected interpretations of ancient human dietary behaviors (Konidaris et al., 2018; Rodríguez-Hidalgo et al., 2017; Romandini et al., 2018) and ancient human cannibalism (Bello et al., 2016; Sala & Conard, 2016; Saladié et al., 2014).

Another key finding from this comparison concerns crenulated bone. Current human tooth mark identification criteria suggests that crenulation on flat bones is a unique marker of human bone consumption (Fernández-Jalvo & Andrews, 2011; Romero et al., 2016a; Saladié et al., 2013, 2024). However, the results of the present study indicate otherwise. The carnivore-chewed ribs (which are considered flat bone) exhibited higher rates of crenulation than those chewed by humans for both the sternal and vertebral portions (Figure 4.2). This result not only confirms that humans are not the only species capable of producing crenulated edges on flat bones (Arilla et al., 2019, 2020; Errickson et al., 2024; Petersen, 2013; Rosell et al., 2019) but also suggests that such features may be more indicative of carnivore consumption than human consumption. However, further research is necessary in order to validate this claim.

In summary, while this comparison highlights several important points, its central message is clear: the current qualitative criteria used to identify human tooth damage are flawed, as they are based on criteria shared by both human- and carnivore-chewed bone. Although this study did not analyze all damage types associated with human and carnivore tooth marks, it effectively illustrates the limitations of relying on the existing qualitative identification criteria. Therefore, identifying quantitative differences between human and carnivore tooth marks is critical for improving the accuracy of interpretations related to ancient human subsistence strategies.

5.2 Interpretation of Results: Discriminating Actors Using BSM Micromorphology

5.2.1 MQDA One: All Experimental BSMs

Before conducting the assessments focused solely on the human and carnivore tooth marks, it was first necessary to assess whether human tooth marks could be reliably distinguished from other types of BSMs, particularly hammerstone percussion marks. This step was essential, as carnivore tooth marks and percussion marks often resemble one another in both qualitative and quantitative ways (Blumenschine & Selvaggio, 1988; Yravedra et al., 2018). Given the many similarities between human and carnivore tooth marks (see Chapter 2), and the various similarities between carnivore tooth marks and percussion marks, it was plausible that human tooth marks might also share similarities with percussion marks. Therefore, identifying potential relationships between human tooth marks and percussion marks was crucial, as their similarities could make it difficult to distinguish human tooth marks from those of carnivores.

Results from MQDA one indicated that human tooth marks are quantitatively distinct from the other tested BSMs, achieving a classification accuracy of 86.5%. Notably, human tooth marks were rarely misclassified as hammerstone percussion marks (Table 4.6 and Figure 4.3), suggesting that, despite potential qualitative similarities, the two are quantitatively distinct. Based on these findings, the overlap between human tooth marks and percussion marks was not significant enough to hinder differentiation of the two tooth mark types. As anticipated, subsequent analyses focused exclusively on comparing human and carnivore tooth marks.

MQDA one not only demonstrates that human tooth marks are quantitatively distinct from cut marks, percussion marks, and trampling marks, but from carnivore tooth marks as well (Table 4.6 and Figure 4.3). Although this finding is significant, MQDA one was limited to general BSM categories and did not account for tooth mark variations caused by different carnivorous species. As a result, the general scope of MQDA one limited insights into nuanced mark metric relationships. To address this limitation, MQDA two was conducted to evaluate the quantitative similarities and differences between human and carnivore tooth marks at the species level. This approach made it possible to identify which carnivore species included in the study produced tooth marks most similar to those made by humans.

5.2.2 MQDA Two: Tooth-Retaining Actors – Species Specific

In MQDA two, the classification accuracy for human tooth marks increased to 91.30% (Table 4.7 and Figure 4.4). Although this improvement may appear to be the result of the reduced sample size from MQDA one (n=1,024) to MQDA two (n=401), this is not the case. As previously mentioned, both analyses employed prior probabilities set to "proportional to occurrence", thereby effectively accounting for differences in sample sizes among the mark types. Instead, the high classification reflects the distinctiveness of human tooth marks, which are generally smaller than those of carnivores for nearly all metrics analyzed. In particular, 3-D maximum length, 3-D maximum width, and 2-D angle most clearly highlight this size difference. These differences are illustrated in the species-specific box-and-whisker plots (Appendix E), where the metric averages for human tooth marks generally fall below those of carnivores. Although less extensive, studies by Petrovic et al. (2019) and Stefanović et al. (2019) also support these findings, reporting that human tooth marks tend to be small.

MQDA two also revealed that, despite the extremely low misclassification rates, human tooth marks were most often misclassified as those made by African wild dogs, and vice versa (Table 4.7 and Figure 4.4). This misclassification stems from several shared metric characteristics – either occurring independently or in combination – including 3-D volume, 3-D maximum length, 3-D maximum width, 2-D area, and 2-D maximum width. Nevertheless, differences for the remaining five metrics allowed MQDA two to maintain a high classification accuracy for human tooth marks (Appendix E). Based on the results of MQDA two, African wild dog tooth marks quantitatively resemble human tooth marks more closely than those of any other species analyzed. Consequently, for practical research purposes, African wild dog tooth marks are the most likely – among the carnivores included in this study – to be misidentified as human due to their quantitative similarities.

Given the specificity of this comparison, few external studies have directly assessed the relationship between human and African wild dog tooth marks, whether qualitatively or quantitatively. Most research instead compares human tooth marks to those of other canid species, excluding African wild dogs. These studies have generally found that human tooth marks most closely resemble those of domestic dogs and foxes, both in qualitative appearance (Elkin & Mondini, 2001) and in quantitative metrics such as 3-D maximum length and 3-D maximum width (Andrés et al., 2012; Delaney-Rivera et al., 2009).

While the results of MQDA two differ from those of previous studies, this discrepancy may be due to the absence of fox and domestic dog tooth marks in the current carnivore tooth mark sample. Thus, it remains possible that human tooth marks more closely resemble those of foxes or domestic dogs, but this hypothesis can only be confirmed through future 3-D analyses that include a broader range of carnivore species. Another factor that may explain the differing results is the number and type of metrics studied. Earlier studies (Andrés et al., 2012; Delaney-Rivera et al., 2009) typically examined only two 2-D metrics, whereas the present study incorporated five 3-D metrics as well as five 2-D metrics, offering a more comprehensive analysis of tooth mark metrics. As a result, the limited scope of the previous analyses may have influenced their conclusions, potentially affecting which carnivore tooth marks appeared most similar to those of humans.

5.2.3 Quantitative Difference Between Human & Carnivore Tooth Marks

Since many simply wish to determine whether tooth marks were the result of a human or a carnivore without further classification (Bello et al., 2015, 2016; Saladié & Rodríguez-Hidalgo, 2017; Santana et al., 2019), it is important to understand their basic quantitative differences. As previously noted, human tooth marks are generally smaller, narrower, and shallower than those made by carnivores (Table 4.4). The most significant differences are found in 3-D measurements such as maximum depth, maximum length, and maximum width, as well as 2-D metrics such as maximum width and angle (Table 4.4 and Appendix D). Although the average values for all mark metrics are lower in human tooth marks compared to those made by carnivores, some metric averages are similar between the two. These metrics include 3-D mean depth and 2-D roughness (Table 4.4 and Appendix D). This highlights the need for further research to better define the quantitative differences between human and carnivore tooth marks for these particular variables.

Although establishing rigorous quantitative criteria to distinguish human tooth marks from those of carnivores would be ideal, achieving this level of precision is currently – and perhaps inherently – unrealistic. This limitation stems largely from the high variability in human and carnivore tooth mark morphology, which this study does not fully capture due to several constraints (detailed in Section 5.5). Numerous factors contribute to this variability, including tooth type (Kaitsas & Olivi, 2006; Mills et al., 2005; Murmann et al., 2006), bite force (Christiansen & Adolfssen, 2005; Edmonds & Glowacka, 2020; Różycka et al., 2024), resource availability (Blumenschine, 1986; Faith et al., 2007), tooth modifications (Barnes, 2010; Domett et al., 2013; Hedman et al., 2017), among others (Ashby et al., 1995; Gent, 2020; Lam & Pearson, 2005). As such, the development of fixed quantitative criteria to differentiate human from carnivore tooth marks remains unattainable until a broader dataset reflecting their variability is available.

Given these limitations, the quantitative differences presented in this research should be interpreted as general patterns rather than exact diagnostic criteria. The inherent variability of human tooth marks means that each mark will have different mark metrics. Because of this, some human tooth marks may even have dimensions that are more often associated with carnivore tooth marks. For instance, a confirmed human tooth mark may exhibit 3-D volume and 2-D maximum width values closer to that of a typical carnivore tooth mark, yet the remaining marks metrics align more closely with those of human teeth. This overlap does not necessarily indicate a carnivore produced tooth mark; rather, it underscores the importance of using a multivariate approach when attempting to identify a tooth mark as either “human” or “carnivore.”

Therefore, given the natural variability of human tooth marks, establishing a definitive set of identification criteria is currently unrealistic. Instead, the findings of this study should be regarded as general reference points that aid in quantitatively distinguishing human tooth marks from those of carnivores. Despite the lack of rigid identification criteria, the quantitative guidelines and analytical methods presented here offer a more precise approach to differentiating the two tooth mark types than the current qualitative criteria (Fernández-Jalvo & Andrews, 2011; Laroulandie, 2005; Petrovic et al., 2019; Pickering et al., 2013; Romero et al., 2016a, 2016b; Saladié et al., 2013, 2024).

5.3 Interpretation of Results: Tooth Types Utilized by Research Participants

The final analysis of this study aimed to determine which types of teeth humans most often use when interacting with bones. More specifically, it sought to identify which teeth are most likely responsible for producing tooth marks on both modern and fossil specimens, and whether different dietary behaviors – such as meat removal versus direct bone biting – influence the types of teeth involved. Ultimately, the goal of this analysis was to contribute a better understanding of ancient human subsistence strategies related to meat and bone consumption by examining patterns of tooth use.

When dietary behavior was not taken into account, humans most often used their front teeth to interact with meat and bone, followed by their middle teeth, and then their back teeth. However, when dietary behavior was taken into account, this pattern shifted slightly. In the first experimental stage, results revealed that only the front and middle teeth were used for meat removal – never the back teeth. Among these, the front teeth played the most significant role, accounting for over 80% of all meat removal interactions with the pig bones (Figure 4.5). This indicates that if tooth marks are created during meat removal, they are primarily the result of the front and, to a lesser extent, the middle teeth.

In the second experimental stage, although the front teeth remained the most commonly used, a pattern shift emerged. Specifically, the use of front and middle teeth was more evenly distributed compared to the first stage. Additionally, though rare, the back teeth were also used during this stage (Figure 4.5). Therefore, these results indicate that all tooth groups are capable of producing marks when biting directly into a bone. However, because the back teeth were only used during the second stage, it can be inferred that any marks attributed to them are the result of bone biting, not meat removal.

These results are further supported by previous research. For instance, studies by Romero et al. (2016a) and Saladié et al. (2013) also identified the front teeth as the most frequently used tooth group when interacting with bone, though they did not differentiate between meat removal and bone biting. In contrast, Landt (2007) provides behavior-based insight, noting through anecdotal observations that humans tend to increase the use of their premolars and molars when directly interacting with the bone – a pattern consistent with the findings from the second experimental stage.

In summary, this analysis, along with supporting literature, leads to the following conclusions: When dietary behaviors are not considered, the front teeth are used most often in interactions with meat and bone. However, when dietary behaviors are considered, only the front and middle teeth are involved in meat removal, whereas all tooth groups are utilized when directly biting bone. As a result, tooth marks left during meat removal can be attributed exclusively to the front and middle teeth. In contrast, tooth marks that result from bone biting could be the result of any tooth group, though they are most likely caused by the front and middle teeth due to their overall greater use.

5.4 Archaeological Implications

5.4.1 Research Focused on Ancient Human Cannibalism

As previously discussed, many studies on ancient human cannibalism rely on flawed qualitative criteria to identify human tooth marks. For example, Bello et al. (2015, 2016) and

Santana et al. (2019) base their identifications on problematic standards developed by Cáceres et al. (2007), Fernández-Jalvo and Andrews (2011), Landt (2007), Pickering et al. (2013), and Saladié et al. (2013). Not only are the criteria themselves flawed, but the methods used to establish them are also problematic (see Chapter 2). For example, Bello et al. (2015) utilizes the human tooth mark identification criteria developed by Cáceres et al. (2007), whose criteria were based on tooth marks presumed – rather than confirmed – to have been made by human teeth. As a result, the current standards for identifying human tooth marks are highly unreliable. Studies that depend on these flawed criteria risk developing inaccurate conclusions about ancient human cannibalism. While some archaeological sites argued to be "cannibalized" may indeed contain human skeletal remains bearing true human tooth marks, the weak evidentiary basis for these claims often render these conclusions uncertain.

Therefore, the purpose of this study is not to deny the occurrence of ancient human cannibalism, but rather to critically examine the limitations of the current criteria used to identify human tooth marks that support such conclusions. With these limitations recognized and the quantitative distinctions between human and carnivore tooth marks now clarified, researchers can begin integrating these findings into their analyses to more accurately determine whether a given tooth mark was made by a human or a carnivore. By extension, this data allows researchers to more accurately determine if a site was truly cannibalized. Ultimately, as more researchers shift towards a quantitative approach for identifying human tooth marks, the accuracy of interpretations regarding ancient cannibalism is likely to improve. Greater accuracy in these identifications may also clarify the underlying context of such behavior, whether driven by survival, dietary needs, or ritualistic purposes (Fernández-Jalvo & Andrews, 2021; Lindenbaum, 2004; Villa et al., 1986).

5.4.2 Applicability of Findings to Other *Homo* Species

Although the tooth marks analyzed in this study were produced by modern humans, the findings are applicable to *Homo neanderthalensis*. Despite differences in jaw structure (Harvati et al., 2011; Terhune et al., 2018; Trinkaus & Howells, 1979) and cranial muscle composition (Marom & Rak, 2018; Muscolino, 2016; Terhune et al., 2018), both humans and Neanderthals share similar jaw biomechanics and overall dental morphology. While Neanderthals were once thought to possess a stronger bite force than modern humans (Demes & Creel, 1988; Rak, 1986), more recent studies suggest their bite force is comparable to that of modern humans (Eng et al., 2013; O'Connor et al., 2005; Wroe et al., 2018). In addition, both species exhibit broadly similar tooth shapes and occlusal surface patterns (Garralda et al., 2020; Hlusko et al., 2013; Rusu & Cosmina, 2023).

Although numerous studies have documented specific morphological differences between Neanderthal and human dentition, such as differences in pulp chamber size, dentine-junction shape, and incisor morphology (e.g., shovel-shaped vs. non-shovel-shaped) (Bailey, 2002, 2006; Delgado, 2024; Krueger et al., 2017; McGrath et al., 2021), these differences were not considered critical to the present study. This is because many of these traits do not significantly affect the occlusal surfaces – the area of teeth that directly contact a bone – and are unlikely to significantly influence the dimensions of the resulting tooth marks. While shovel-shaped incisors are often cited as a distinctive Neanderthal trait (Bailey, 2006), this feature was also deemed unlikely to impact tooth mark dimensions in a significant way. Shoveling typically occurs on the lingual surface of the tooth, and only rarely is it pronounced enough to affect the occlusal surface of a tooth (Bailey, 2006; Denton, 2011). Therefore, given the general similarities in jaw mechanics and basic dental structure, human tooth marks are a reliable proxy for identifying Neanderthal tooth marks in the fossil record.

One factor that may affect Neanderthal tooth mark morphology, however, is the extensive wear often observed on their anterior teeth, both maxillary and mandibular (Clement, 2008; Hernaiz-García et al., 2024; Trinkaus, 2014). Yet previous studies suggests that tooth marks made by the Inuit may serve as a useful analog for those of Neanderthals, as the two are believed to have similar masticatory morphology (Clement et al., 2012; Harvati et al., 2011; Rak et al., 2002). Inuit populations are known to habitually use their anterior teeth to process tough meat, resulting in wear patterns closely resembling those seen in Neanderthals (Clement, 2008; Clement & Hillson, 2012; Schultz, 1945). Therefore, while extensive anterior wear may result in subtle differences in tooth marks left by Neanderthals, individuals with comparable wear patterns – such as the Inuit – may produce similar marks, offering as a more specific proxy for understanding Neanderthal tooth-induced damage.

It is important to note, however, that the applicability of this data does not extend to other archaic *Homo* species or earlier hominins. Modern human tooth marks are considered reliable proxies only for Neanderthals. Species such as *Homo heidelbergensis* (Godinho et al., 2018; Mounier et al., 2009), *Homo denisova* (Chen et al., 2019; Gokhman et al., 2019; Zubova et al., 2017), and other early *Homo* species (Davies et al., 2024; Eng et al., 2013; Ungar, 2012) differ significantly from modern humans in terms of jaw structure, biomechanics, and dental morphology. These differences extend beyond minor anatomical variations and would likely result in tooth marks that differ considerably from those left by modern humans. As a result, modern human tooth marks cannot be used to reliably infer the characteristics of tooth marks for *Homo* species that predate *Homo neanderthalensis*.

5.5 Future Work & Research Limitations

The data generated in this thesis offers a foundation upon which future researchers can use to address long-standing debates regarding ancient human cannibalism. For instance, researchers have questioned the nature of the BSMs found on the human remains at Gough's Cave and whether these marks are the result of human teeth (Andrews & Fernández-Jalvo, 2003; Bello et al., 2015; Cook, 1986; Lucas et al., 2019). Similar debates exist regarding Native American sites in the American Southwest (Hurlbut, 2000; Osterholtz, 2013; Turner & Turner, 1999; White, 1992).

Beyond human cases, this dataset also contributes to discussions about Neanderthal cannibalism. Scholars have long debated whether the remains at Krapina Cave reflect cannibalism and, if so, whether the behavior was ritualistic or driven by subsistence needs (Frayer et al., 2020; Gorjanović-Kramberger, 1901; Orschiedt, 2008; Russell, 1987; Trinkaus, 1985; Ullrich, 2005). A similar debate surrounds the site of Moula-Guercy (Defleur & Desclaux, 2019; Defleur et al., 1999, 2020; Slimak & Nicholson, 2020). Therefore, because this study clarified what quantitatively distinguishes human and carnivore tooth marks, the findings can be used to confirm or challenge interpretations of ancient cannibalism – whether that be for humans or Neanderthals.

However, before the data can be fully applied in archaeological contexts, additional research should be conducted to improve the accuracy of human tooth mark identification. This stems from several limitations of the present study. First, the comparative sample of carnivore tooth marks included those of only seven species, all of which are classified as size two animals or larger (Bunn, 1982). Although these species produce a variety of tooth mark morphologies, they do not capture the full spectrum of marks generated by all carnivores – particularly those of smaller carnivores. As a result, it remains possible that human tooth marks more closely resemble those of a carnivore not represented in this study. Yet this will remain unknown until tooth marks from a broader range of carnivores are quantitatively compared with those of humans.

Second, this study did not examine potential similarities between human tooth marks and those produced by non-carnivorous animals. It is well documented that animals such as rodents and ruminants gnaw on bones for nutrients like calcium and phosphorus, or to wear down their teeth (Cáceres et al., 2013; Froberg-Fejko, 2014; Klippel & Synstelien, 2007; Meckel et al., 2018; Potmesil, 2005, p. 28). Therefore, it is possible that human tooth marks closely resemble those of non-carnivorous animals. Yet, determining the validity of this claim will remain inconclusive until the tooth marks of non-carnivorous animals are quantitatively compared with those of humans.

A further limitation involves the exclusion of individuals with culturally modified teeth. Humans have historically altered their dentition through practices such as filing, notching, and sharpening (Barnes, 2010; Domett et al., 2013; Hedman et al., 2017). Depending on the nature of these modifications, the resulting tooth marks may differ from those produced by unmodified human dentition. To my knowledge, this study did not include participants with any culturally based dental modifications. Additionally, while not a cultural modification, individuals with shovel-shaped incisors – a morphological trait still found in some modern populations (Canger et al., 2014; Kimura et al., 2009) – were also not included. Future research would benefit by incorporating tooth marks from individuals with culturally modified teeth, as well as those with shovel-shaped incisors to better understand how these variations may affect human tooth mark morphology.

Participant demographics also represent a constraint. Only individuals aged 23 to 34 were included, excluding marks produced by both deciduous teeth and older, more worn permanent teeth. While both tooth types serve similar functions, differences in size and enamel wear (Syed Khaja, 2021) may result in distinct BSM patterns. Expanding future studies to include participants under 23 and over 34 would capture a more human dental variation.

Regarding the faunal material, this study used only pig ribs, femora, and tibiae. These elements offered a solid baseline, but broader experimentation using different species and skeletal elements would strengthen our understanding of human tooth mark variability. This is because bone density and structure affect how bone responds to applied force (Hodgskinson et al., 1989; Lam & Pearson, 2005; Selvaggio & Wilder, 2001), and as such, different bones are likely to yield varied mark morphologies.

The primary goal of this thesis was to establish a baseline understanding of what quantitatively distinguishes human and carnivore tooth marks from one another. To do so, experimental conditions – including the faunal elements used, participant age range, and exclusion of deciduous or culturally modified teeth – were deliberately controlled. With this baseline now established, future studies can systematically expand upon these parameters to better capture the variability of human tooth marks, as this study does not represent the full range of dental, demographic, and behavioral contexts found in modern humans. In short, a larger and more diverse human tooth mark sample is needed. Moreover, integrating data from other bone-chewing species will further clarify what features distinguish – or obscure – the differences between human and animal tooth marks. As this body of experimentally derived data continues to grow, its value to archaeological interpretation will become increasingly significant. Overall, it offers a more reliable framework for evaluating evidence of ancient cannibalism, enhancing our ability to discern not only whether such behavior occurred, but also its potential context – be it survival-driven, dietary, or ritualistic.

CHAPTER 6 CONCLUSION

While the field of taphonomy has advanced significantly since its inception, reliably distinguishing BSMs types from one another has remained a major challenge. This difficulty is due to the lack of standardized criteria to reliably identify BSMs. Accurate identifications are essential, as they are the key to reconstructing ancient human behaviors, especially those related to meat and bone consumption. However, interpretations often remain ambiguous due to the many morphological similarities between human and carnivore tooth marks. These similarities are often overlooked, as many human tooth mark studies either fail to systematically compare them to carnivore tooth marks, or neglect to validate their findings with experimental data. As a result, flawed identification criteria for human tooth marks have gained widespread acceptance. Without adopting more rigorous and comparative methods of analysis, distinguishing human tooth marks from those of carnivores will continue to be unreliable.

To address this issue, this thesis produced a sample of experimentally produced human tooth marks to determine if quantitative, rather than qualitative, traits can effectively differentiate the two from one another. Statistical analyses revealed that human tooth marks are, in fact, distinguishable from those of carnivores. When compared to a set of experimentally produced BSMs including stone tool cut marks, hammerstone percussion marks, mammalian trample marks, and carnivore tooth marks, 86.5% of human tooth marks were correctly identified. This accuracy rose to 91.3% when exclusively compared to carnivore tooth marks. The analysis also revealed that human tooth marks most closely resemble those created by African wild dogs, indicating a higher potential for misidentification between the two. Lastly, the results indicate that human tooth marks tend to be smaller, narrower, and shallower than those made by carnivores. However, additional research is necessary to confirm these findings, as the observed differences may be attributed to fundamental disparities in bite mechanics between humans and carnivores.

In the context of ancient cannibalism research, the goal of this study was not to refute the occurrence of such behavior, but rather to strengthen the evidentiary basis upon which such claims are made. By transitioning from qualitative descriptions to quantitative data to identify human tooth marks, researchers can more confidently interpret instances of ancient human cannibalism. Lastly, although this study focused on human tooth marks, the findings are applicable to *Homo neanderthalensis* given the broad similarities in jaw biomechanics and dental morphology between the two species. Yet the same cannot be said for earlier *Homo* species, as their anatomical differences prevent the use of human tooth marks as reliable proxies.

In summary, this study demonstrates that human tooth marks are quantitatively distinct from carnivore tooth marks, stone tool cut marks, hammerstone percussion marks, and mammalian trample marks. Applying these findings to the archaeological record will enhance our understanding of ancient human dietary practices, including those that may even be cannibalistic. Ultimately, the adoption of quantitative, experimentally validated methods of analysis for human tooth marks represents a crucial step forward in refining our interpretations of ancient subsistence patterns related to the consumption of meat and bone.

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APPENDIX A – IRB PROTOCOL #4958 RESEARCH APPROVAL

PROTOCOLS

kuali

COLORADO STATE UNIVERSITY

The protocol listed below has been approved by the CSU IRB Determinations Fort Collins on Wednesday, October 11th, 2023.

PI: Pante, Michael
Submission Type and ID: Initial 4958
Title: A 3-D Micromorphological Analysis of Human (*Homo sapiens*) Bite Mark Surface Modifications on Domestic Pig (*Sus scrofa domesticus*) Bones
Approval Date: Wednesday, October 11th, 2023
Expiration Date: Tuesday, October 10th, 2028

The CSU IRB (FWA0000647) has completed its review of protocol 4958 A 3-D Micromorphological Analysis of Human (*Homo sapiens*) Bite Mark Surface Modifications on Domestic Pig (*Sus scrofa domesticus*) Bones. In accordance with federal and state requirements, and policies established by the CSU IRB, the committee has approved this protocol under Exempt review.

Any additional comments regarding this approval are included below. If you have additional questions about this please contact IRB Staff.

The CSU IRB (FWA0000647) has completed its review of the above-referenced protocol. In accordance with federal and state requirements, and policies established by the CSU IRB, the designated reviewer has determined your project is exempt under 45CFR46.104(d). Although this research is considered exempt, CSU expects that researchers continue to follow moral and ethical obligations of research conduct, by honoring the principles in the Belmont Report.

Exempt 3 (i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and; (A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects.

Please note, any changes to the proposed research should be reported to the IRB via an amendment prior to implementation.

Thank you,

CSU_IRB@colostate.edu

Please note:

Any additional changes to this approved protocol must be obtained prior to implementation of those changes, by submitting an amendment request to the CSU IRB for review/approval.

Good luck in your research endeavors!

Attachments:

Recruitment Materials	IRB_Recruitment-Email-V.2 - E. M. Gniewek.pdf	Study Recruitment Email: A 3-D Micromorphological Analysis of Human (*Homo sapiens*) Bite Mark Surface Modifications on Domestic Pig (*Sus scrofa domesticus*) Bones
Recruitment Materials	IRB_Recruitment-Flyer-V.2 - E. M. Gniewek.png	Study Recruitment Flyer: A 3-D Micromorphological Analysis of Human (*Homo sapiens*) Bite Mark Surface Modifications on Domestic Pig (*Sus scrofa domesticus*) Bones
Other	IRB_ApplicationReferences - E. M. Gniewek.pdf	IRB Application References: A 3-D Micromorphological Analysis of Human (*Homo sapiens*) Bite Mark Surface Modifications on Domestic Pig (*Sus scrofa domesticus*) Bones
Consent	IRB_Signed-Consent-V.2 - E. M. Gniewek.pdf	Study Consent Form: A 3-D Micromorphological Analysis of Human (*Homo sapiens*) Bite Mark Surface Modications on Domestic Pig (*Sus scrofa domesticus*) Bones

APPENDIX B – RESEARCH PARTICIPANT INSTRUCTIONS FOR IRB PROTOCOL #4958

1. Write your age, date of birth (MM / DD / YYYY), and biological sex (F / M) on the two (2) plastic polyethylene storage bags with the black permanent marker.
2. Write "RIB BONE" on one (1) of the plastic polyethylene storage bags with the black permanent marker.
3. Write "LEG BONE" on the one (1) remaining plastic polyethylene storage bag with the black permanent marker.
4. Set the two (2) plastic polyethylene storage bags to the side until they are needed in the following steps.
5. Experimental Stage One – Consume the meat of one (1) cooked pork *rib* under the following guidelines (*read the entirety of these instructions before beginning*):
   a. Remove/consume the meat from the rib as normal as possible
   b. Use *only* your teeth to remove as much meat as possible
   c. *Do not gnaw* the rib when chewing
   d. *Only* chew on the midshaft/middle section of the rib
   e. *Always* hold the long axis of the rib perpendicular to your mouth when removing meat and/or biting the rib
   f. *After each bite*, note on the worksheet provided which teeth were used:
      i. Front teeth (incisors and/or canines) or
      ii. Middle teeth (canines and/or premolars) or
      iii. Back teeth (premolars and/or molars)

6. Experimental Stage Two – Once all or most of the meat from the midshaft/middle section of the rib has been removed, *intentionally* bite the *rib* ten (10) times under the following guidelines (*read the entirety of these instructions before beginning*):
    a. Use *only* your teeth to bite the rib
    b. *Do not gnaw* the rib when biting
    c. *Only* bite on the midshaft/middle section of the rib
    d. *Always* hold the long axis of the rib perpendicular to your mouth when biting the rib
    e. *After each bite*, note on the worksheet provided which teeth were used:
        i. Front teeth (incisors and/or canines) or
        ii. Middle teeth (canines and/or premolars) or
        iii. Back teeth (premolars and/or molars)
7. After intentionally biting the *rib* bone ten (10) times, put the remains of the rib specimen into your plastic polyethylene storage bag labeled "RIB BONE" and seal the bag shut. Set this bag to the side.
8. Repeat step 5, but this time using one (1) cooked pork *leg* bone – either a femur or a tibia – following the same guidelines as those provided in step 5.
9. Repeat step 6, but this time using one (1) cooked pork *leg* bone – either a femur or a tibia – following the same guidelines as those provided in step 6.
10. After intentionally biting the *leg* bone ten (10) times, put the remains of the leg specimen into your plastic polyethylene storage bag labeled "LEG BONE" and seal the bag shut.
11. Once both plastic polyethylene storage bags are securely sealed, give both bags (containing the remains) to Erin M. Gniewek.

APPENDIX C – BSM DATA OF CARNIVORE CHEWED RIBS FROM CAPALDO (1995)

	Vertebral BSMs				**Midshaft BSMs**	**Sternal BSMs**			**Mixed BSM Locations**	
Specimen	**Articular Chop**	**Fracture**	**Peel**	**Crenulation**	**Incipient Fracture**	**Fracture**	**Peel**	**Crenulation**	**Butchery Marks**	**Tooth Marks**
SERS4-77		X							X	X
SERS4-78		X	X							X
SERS4-87		X		X						X
SERS4-88		X							X	X
SERS4-90		X								
SERS4-96		X		X		X				X
SERS4-97		X				X	X			X
SERS4-102		X				X				X
SERS4-103		X	X			X	X		X	
SERS4-104		X				X	X			
SERS4-108		X				X			X	
SERS4-109						X	X		X	
SERS4-110							X	X	X	X
SERS4-111		X				X	X		X	X
SERS9-48		X							X	
SERS9-49				X					X	X
SERS9-50							X			
SERS9-52			X				X		X	
SERS9-501							X			X
SERS10-57		X		X					X	X
SERS10-58			X							
SERS10-59		X				X				X
SERS10-60			X						X	
SERS10-61			X							X

SERS10-62		X					X			X
SERS10-63		X							X	
SERS10-64			X						X	
SERS13-53			X				X	X	X	
SERS17-30		X	X	X				X		X
SERS17-31			X	X		X	X			X
SERS17-32		X	X					X		X
SERS18-36		X					X	X		X
SERS18-40			X	X						X
SERS18-41		X	X							X
SERS20-20								X		X
SERS24-89		X						X	X	X
SERS24-92		X	X					X	X	
SERS24-93		X		X		X			X	
SERS24-94		X						X	X	
SERS24-95		X						X	X	
SERS25-1		X				X		X	X	
SERS25-2		X				X			X	X
SERS25-3		X					X		X	
SERS25-4						X	X		X	
SERS26-66							X	X		X
SERS42-53		X							X	X
SERS42-54		X				X	X			X
SERS42-59		X	X			X		X		X
SERS42-60		X						X	X	
SERS520						X				X
SERS520-21						X				X
SERS520-22		X		X		X	X			X

SERS520-23		X	X			X				X
SERS520-24		X				X			X	X
SERS520-26		X				X				X
SERS520-28				X			X	X		X
SERS520-29		X				X	X			X
SERS520-30				X				X		X
SERS520-31		X	X			X				X
SERS523-12		X	X				X	X		
SERS524-88		X						X	X	
SERS524-91		X						X	X	
SERS524-96							X	X	X	
SERS524-97							X	X	X	
SERS524-98						X	X		X	
SERS524-99							X	X	X	X
SERS526-67						X	X			
SERS526-68						X	X			X
SERS526-69			X				X	X	X	
SERS526-73						X				
SERS526-75		X				X	X		X	
SERS526-77		X						X	X	
SERS526-79						X	X		X	
SERS526-80					X	X	X			X
SERS526-88							X	X	X	
SERS542-46		X						X	X	
SERS542-47						X	X		X	X
SERS542-48				X			X	X	X	X
SERS542-49			X	X		X		X	X	X
SERS542-52								X	X	X

SERS542-55			X	X		X	X			X
SERS542-56		X	X			X	X		X	X
SERS542-57		X				X	X			X
SERS542-58		X		X		X		X	X	X
SERS542-61						X		X	X	X
SERS555-17		X								X
SERS555-18		X							X	X
SERS555-19		X						X		X
NGOS6-34		X					X	X	X	X
NGOS6-37			X							X
NGOS6-38		X						X		X
NGOS6-40		X				X	X			X
NGOS7-13						X	X			X
NGOS7-14		X	X				X			X
NGOS7-15							X	X		X
NGOS7-16		X	X			X				X
NGOS7-17						X	X			X
NGOS7-18						X			X	X
NGOS7-19		X				X	X		X	X
NGOS7-20						X	X		X	X
NGOS7-21		X	X			X	X			X
NGOS20-34						X	X		X	X
NGOS20-35						X	X		X	X
NGOS20-36							X	X	X	X
NGOS20-37							X	X	X	X
NGOS20-38						X	X		X	
NGOS20-39							X	X		X
NGOS20-40		X	X						X	

NGOS20-41		X	X						X	X
NGOS20-46		X		X		X	X			X
NGOS20-47		X				X	X			X
NGOS20-48		X					X	X		X
NGOS21-7						X		X		X
NGOS21-8		X	X			X	X		X	X
NGOS21-9		X				X	X			X
NGOS21-10		X		X		X				X
OLDS2-1				X			X	X		X
OLDS3-4			X							
OLDS3-19									X	
OLDS3-20	X								X	X

Note: "X" indicates the specified BSM was present on the rib specimen.

APPENDIX D – BOX PLOT DISTRIBUTIONS OF UNTRANSFORMED UNIVARIATE EXPERIMENTAL MARK DATA: ALL EXPERIMENTAL BSMS

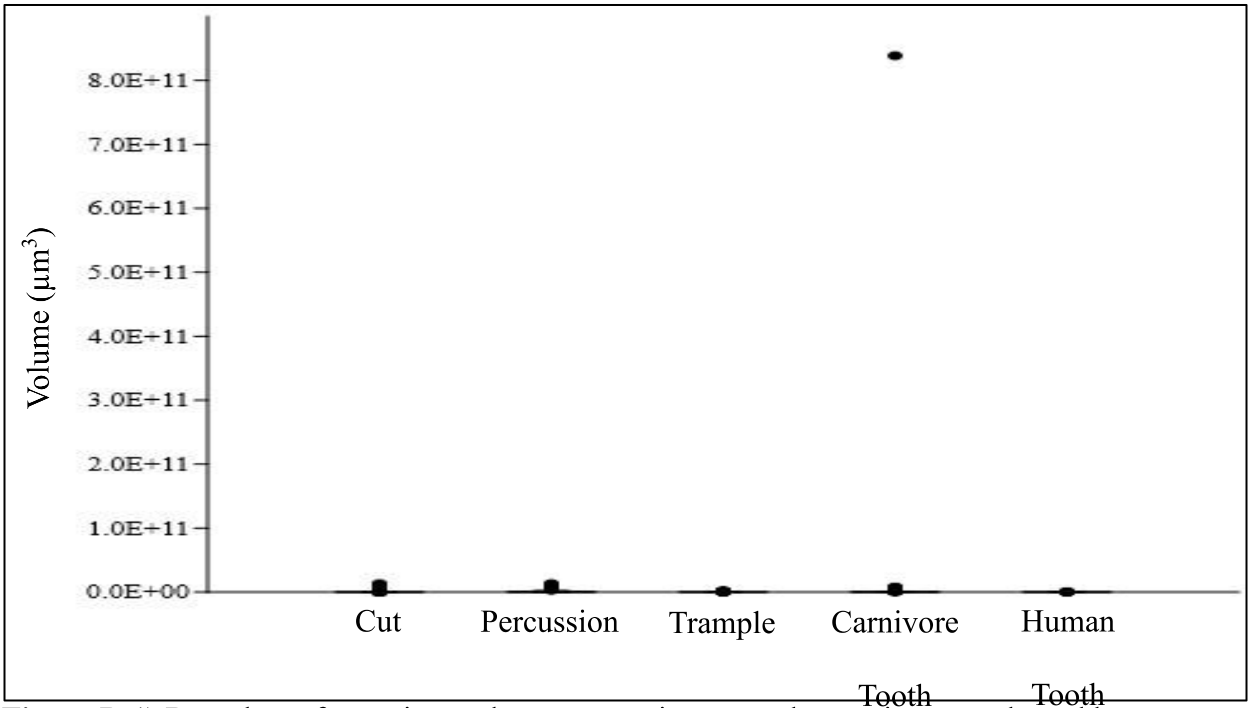

Figure D.1) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark volume (3-D) measurements. Outliers are shown as black dots.

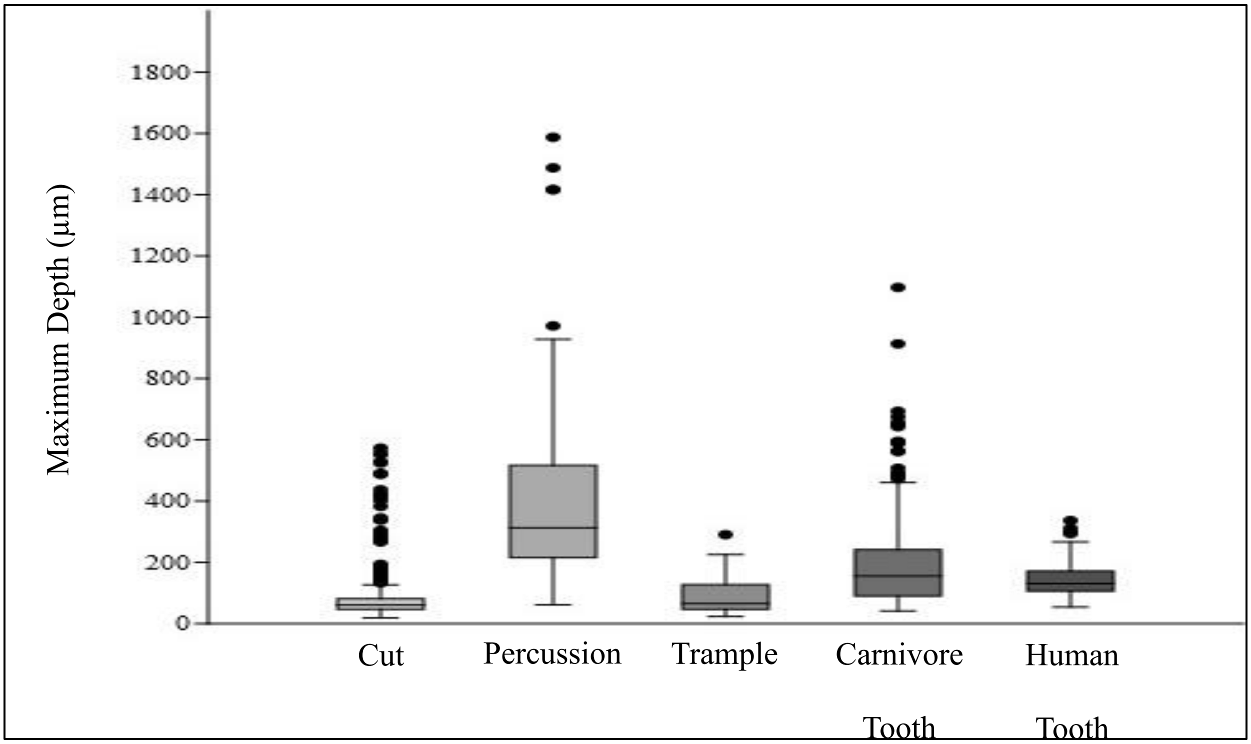

Figure D.2) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark maximum depth (3-D) measurements. Outliers are shown as black dots.

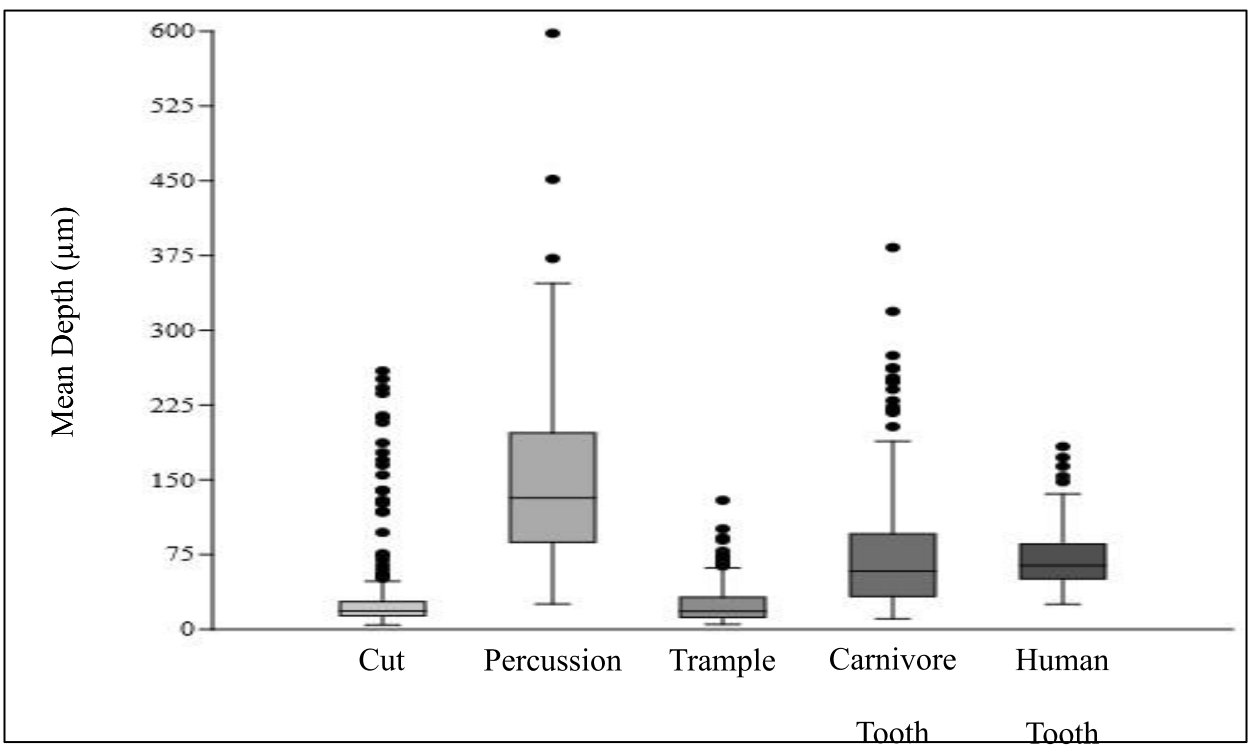

Figure D.3) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark mean depth (3-D) measurements. Outliers are shown as black dots.

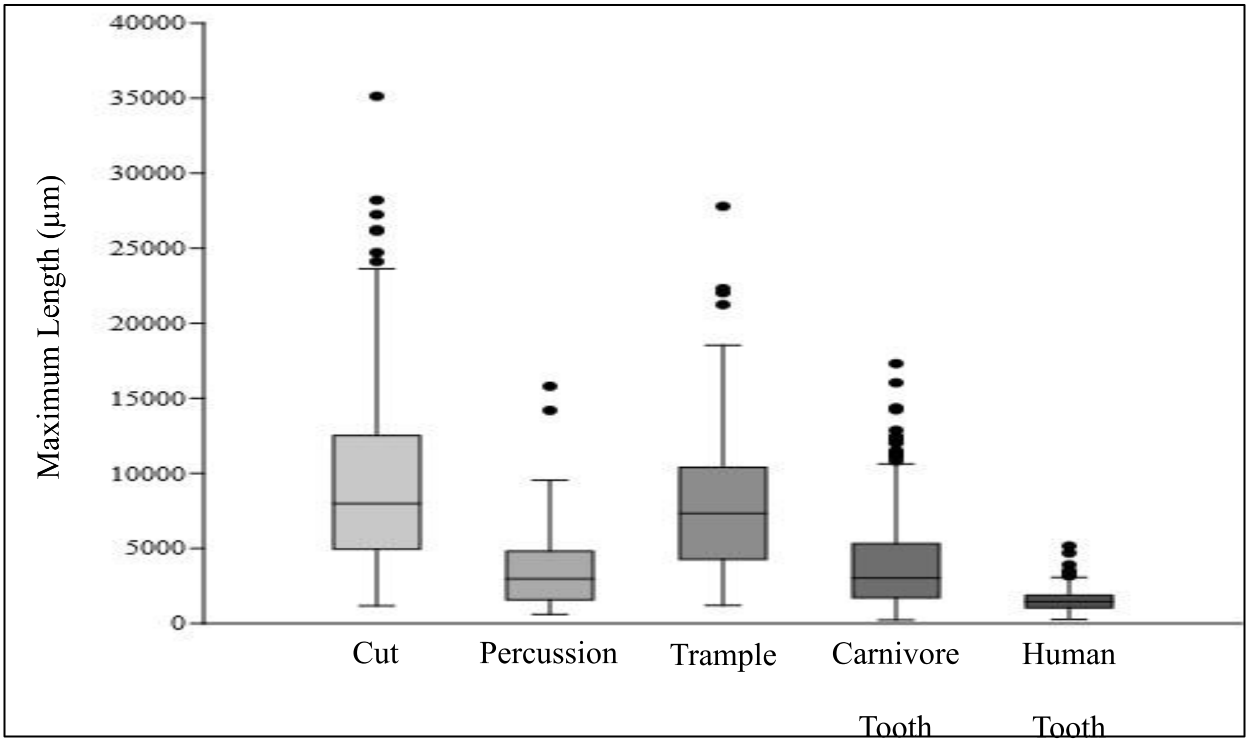

Figure D.4) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark maximum length (3-D) measurements. Outliers are shown as black dots.

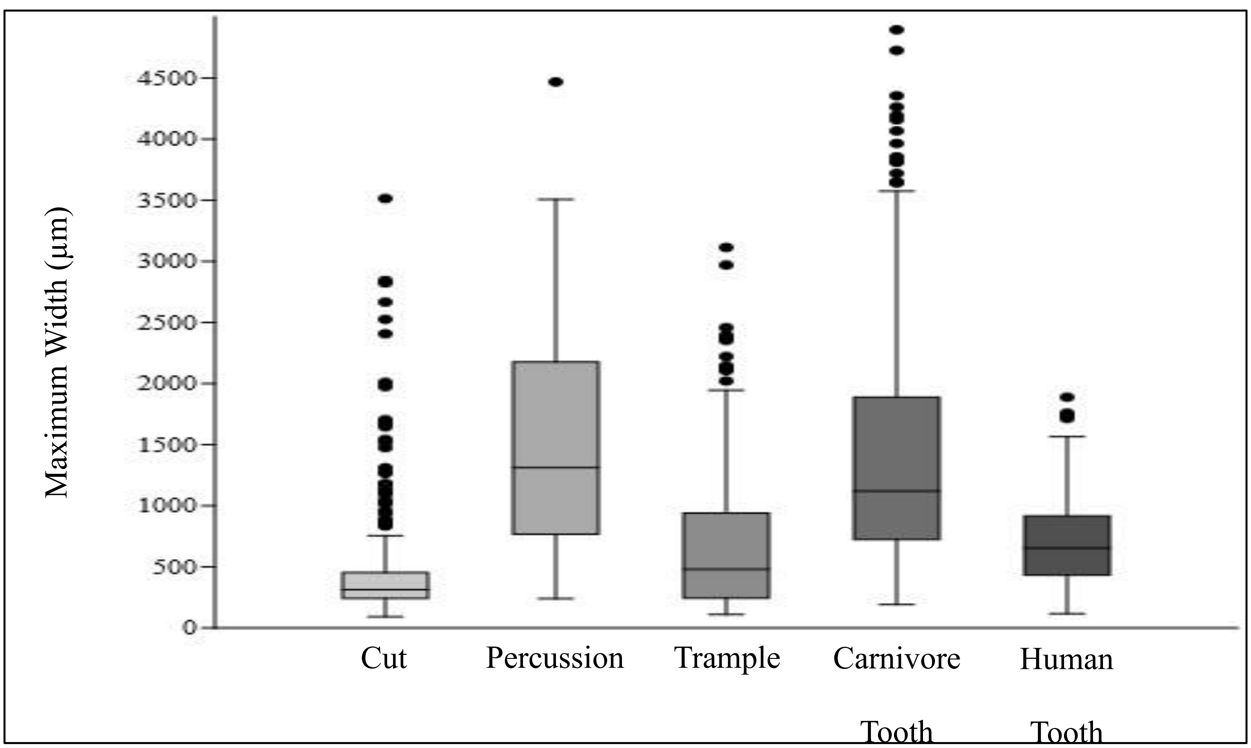

Figure D.5) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark maximum width (3-D) measurements. Outliers are shown as black dots.

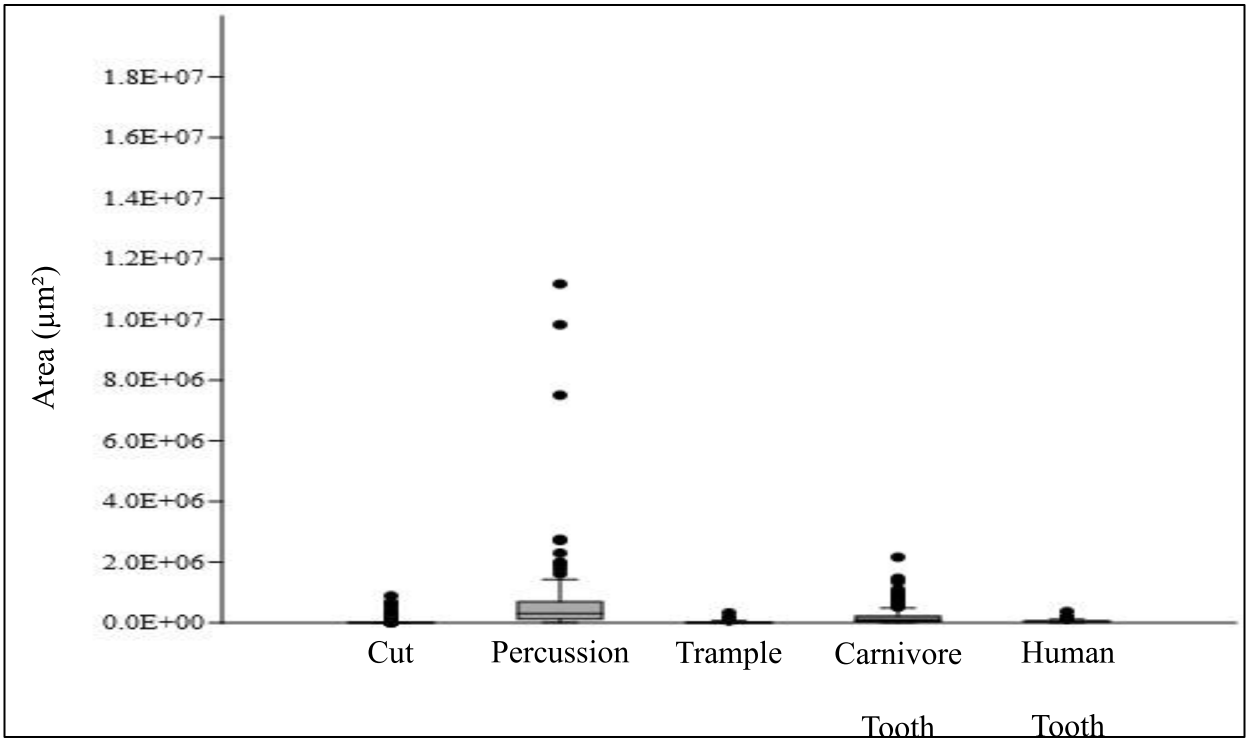

Figure D.6) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark area (2-D) measurements. Outliers are shown as black dots.

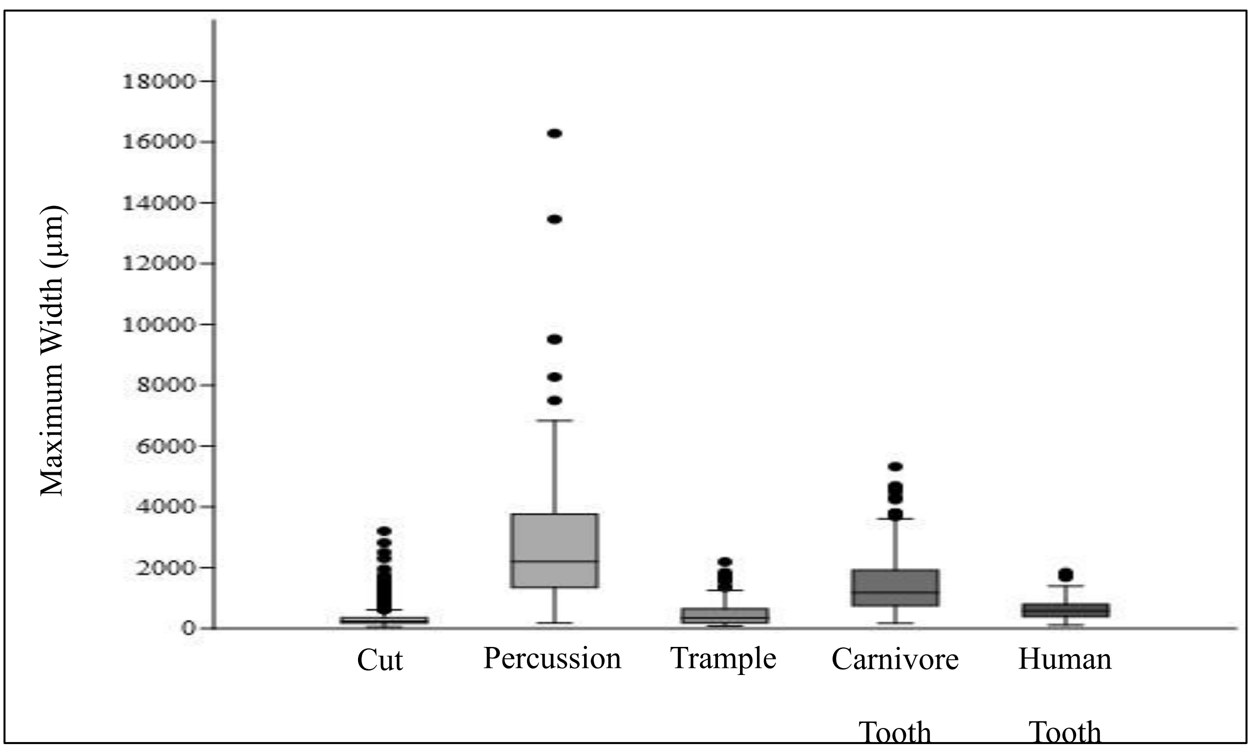

Figure D.7) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark maximum width (2-D) measurements. Outliers are shown as black dots.

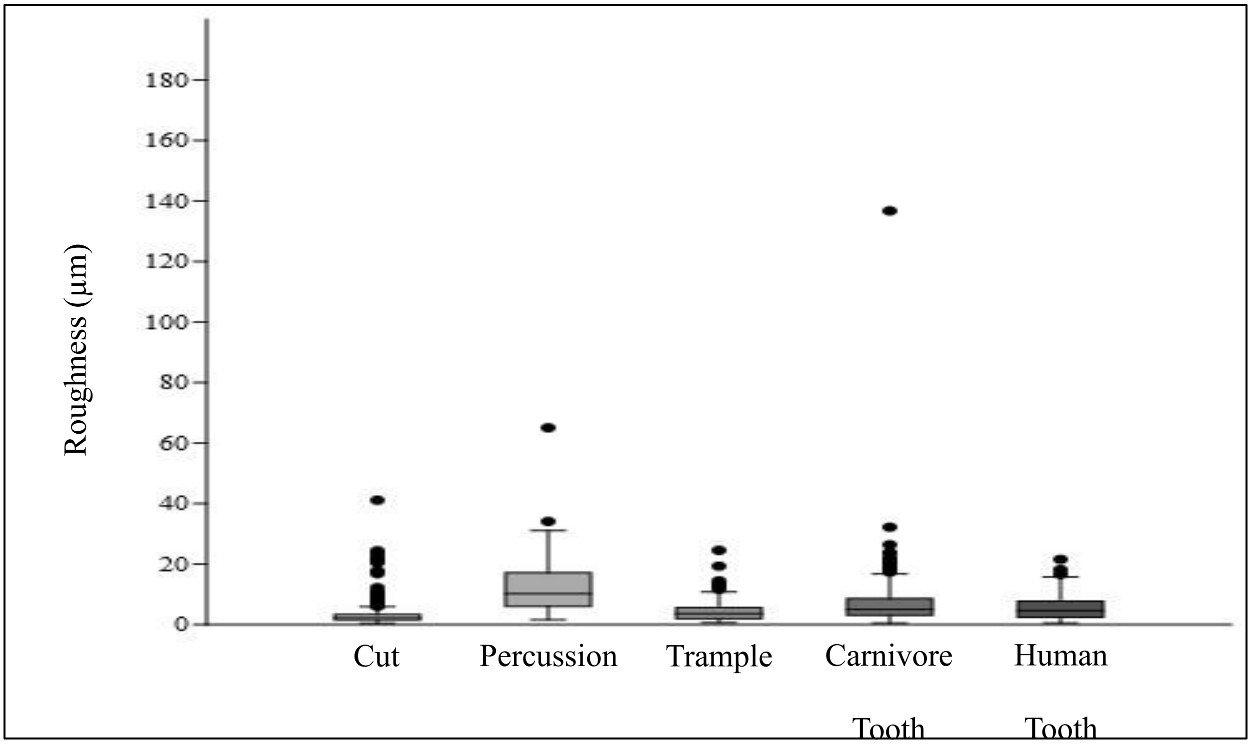

Figure D.8) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark roughness (2-D) measurements. Outliers are shown as black dots.

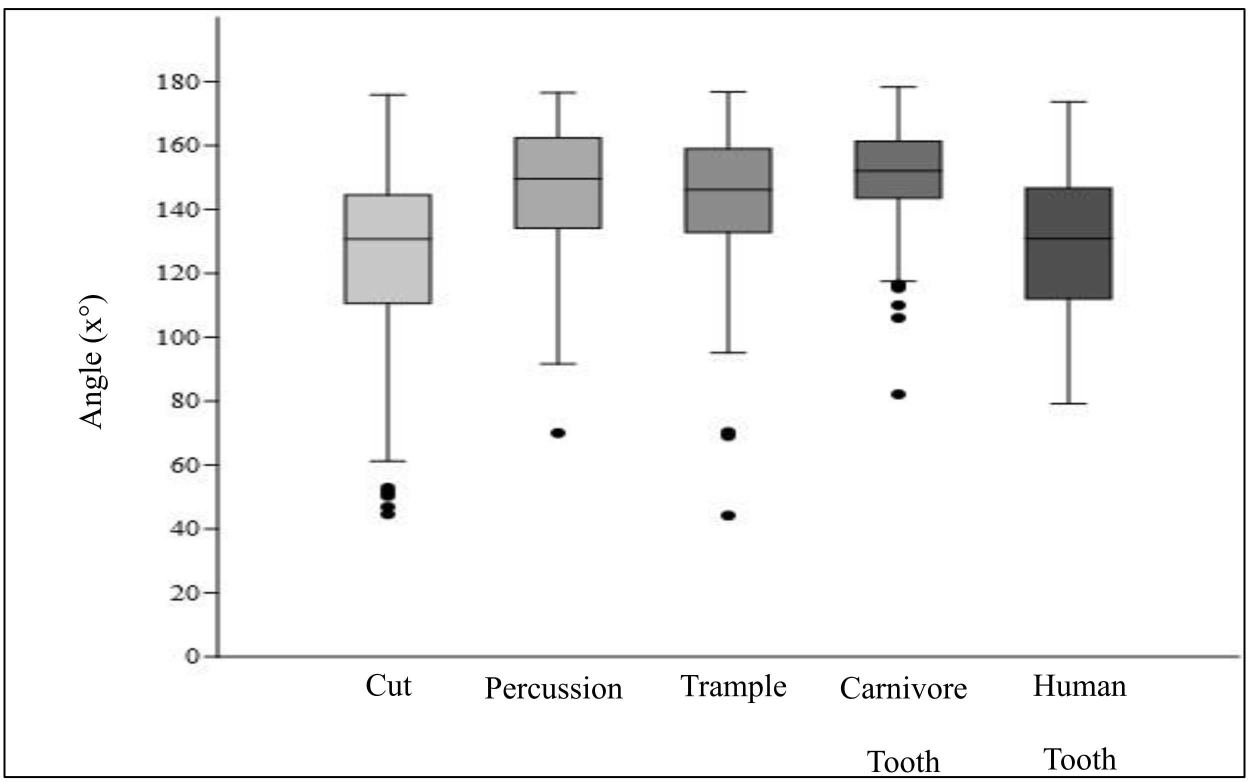

Figure D.9) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark angle (2-D) measurements. Outliers are shown as black dots.

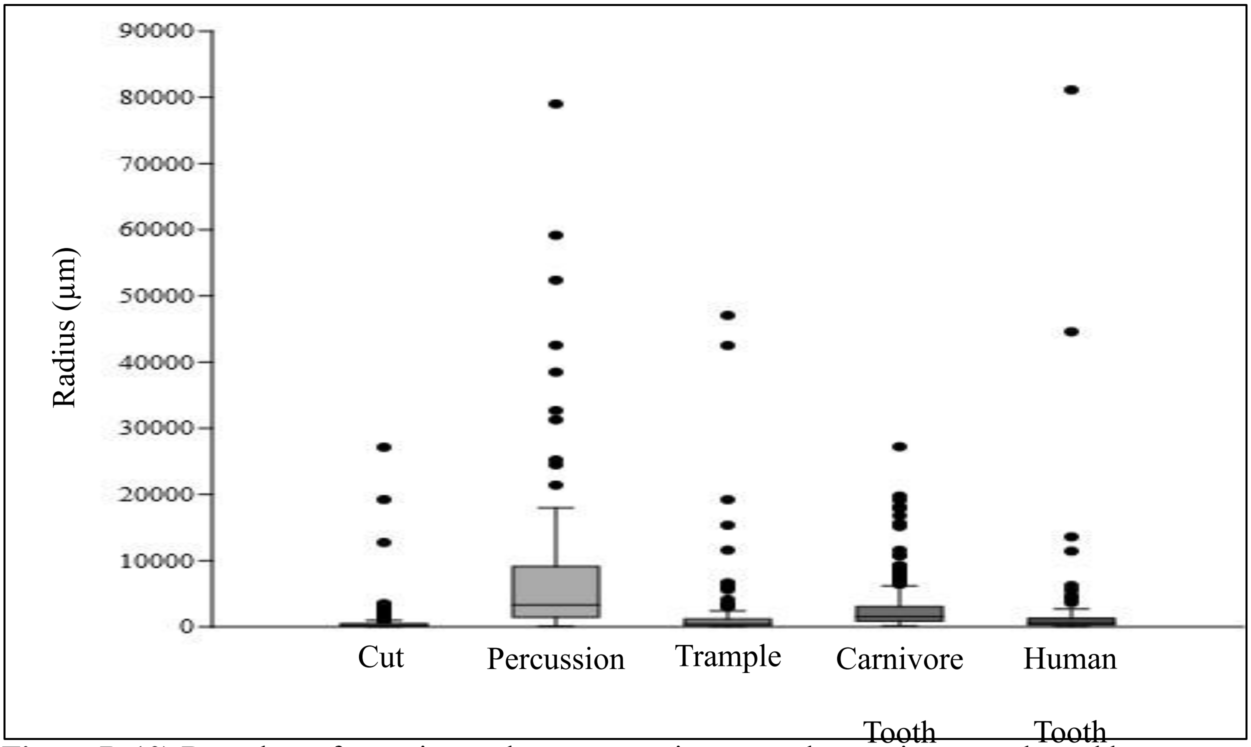

Figure D.10) Box plots of experimental cut, percussion, trample, carnivore tooth, and human tooth mark radius (2-D) measurements. Outliers are shown as black dots.

APPENDIX E – BOX PLOT DISTRIBUTIONS OF UNTRANSFORMED UNIVARIATE EXPERIMENTAL MARK DATA: TOOTH-RETAINING ACTORS – SPECIES SPECIFIC

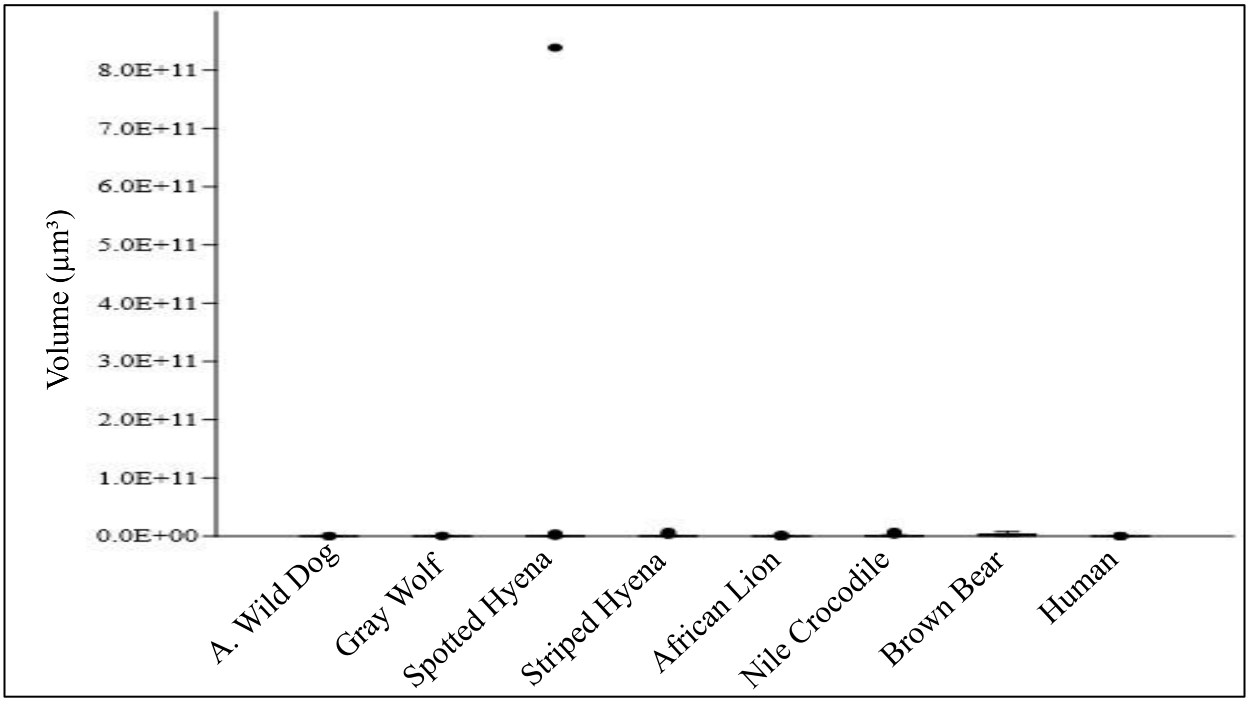

Figure E.1) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark volume (3-D) measurements. Outliers are shown as black dots.

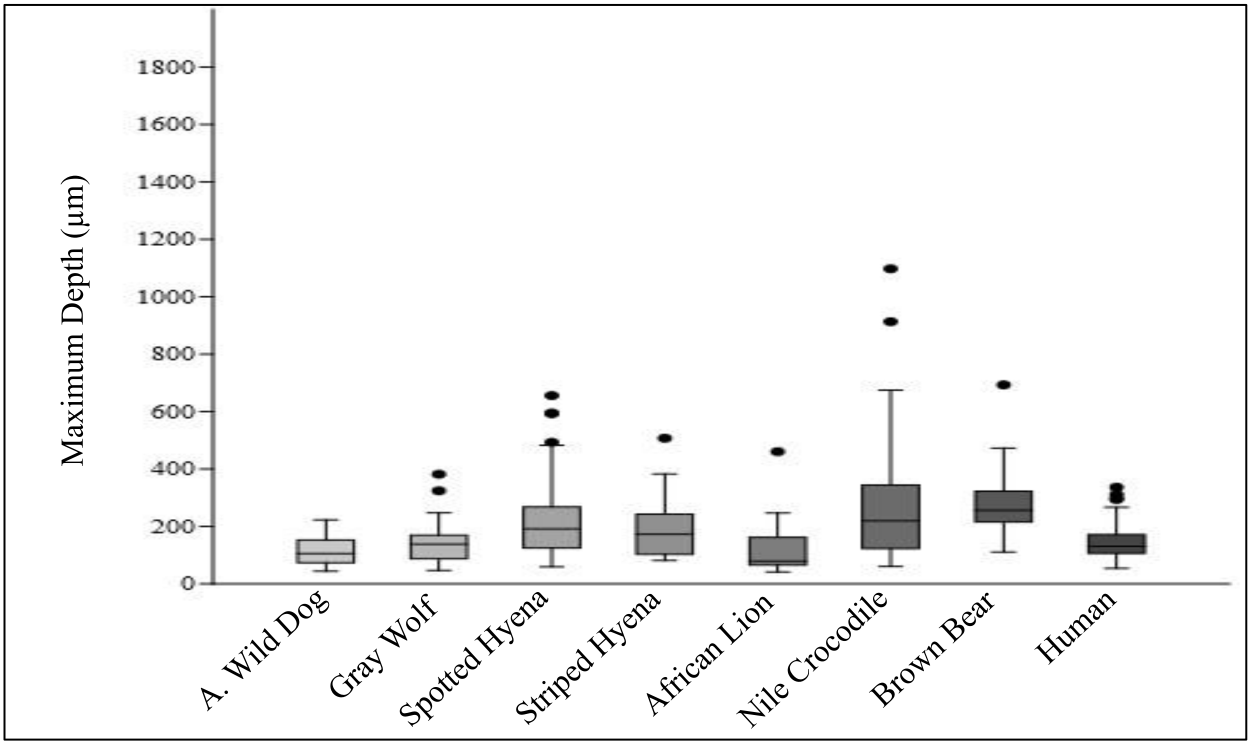

Figure E.2) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark maximum depth (3-D) measurements. Outliers are shown as black dots.

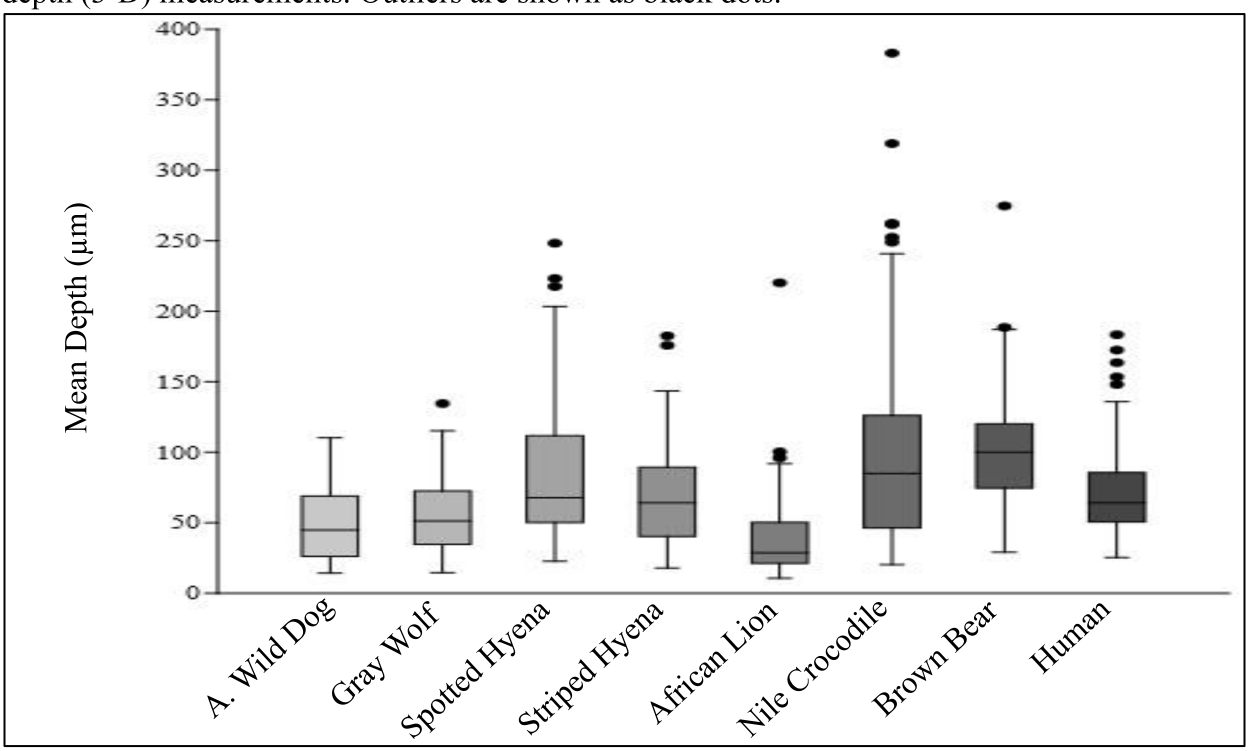

Figure E.3) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark mean depth (3-D) measurements. Outliers are shown as black dots.

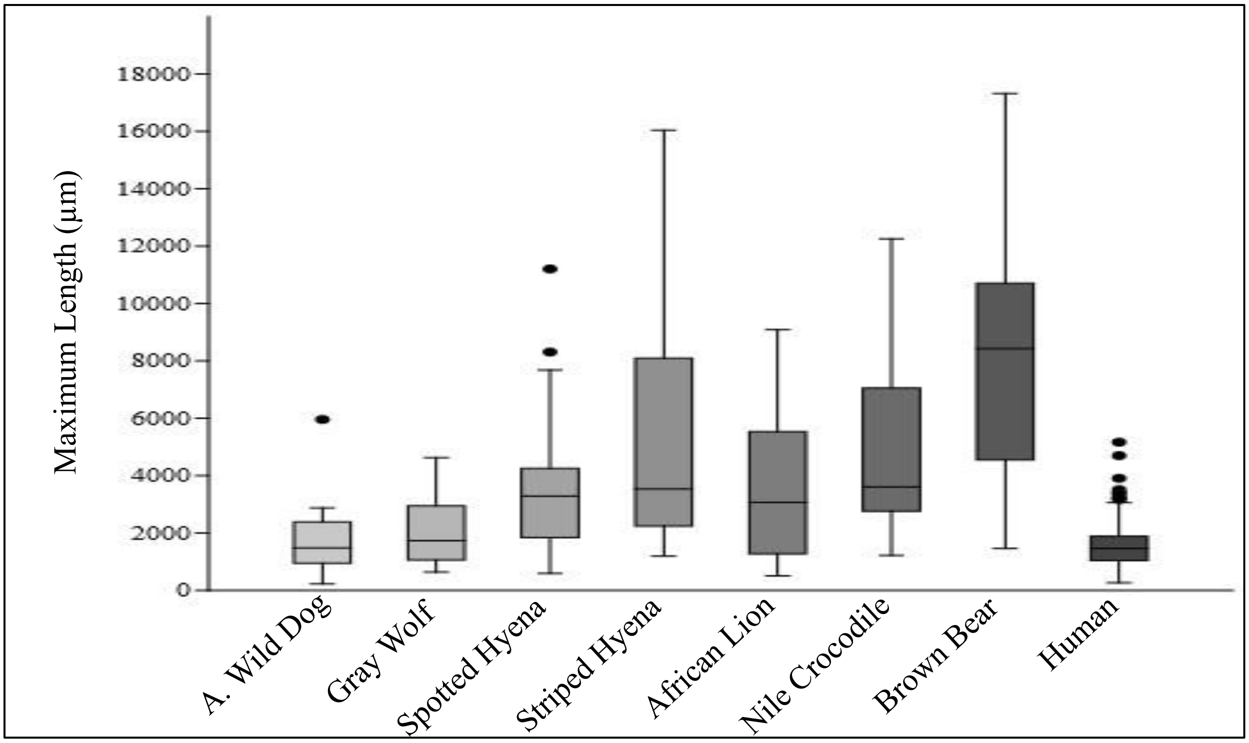

Figure E.4) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark maximum length (3-D) measurements. Outliers are shown as black dots.

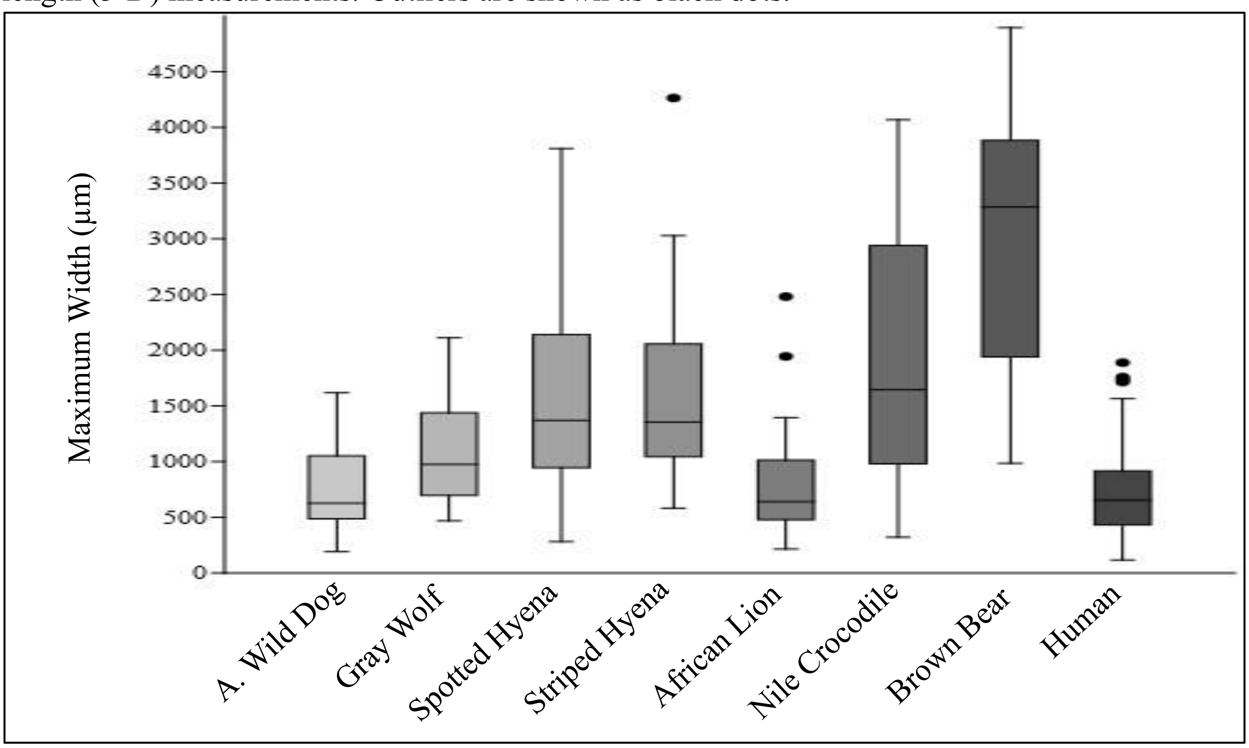

Figure E.5) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark maximum width (3-D) measurements. Outliers are shown as black dots.

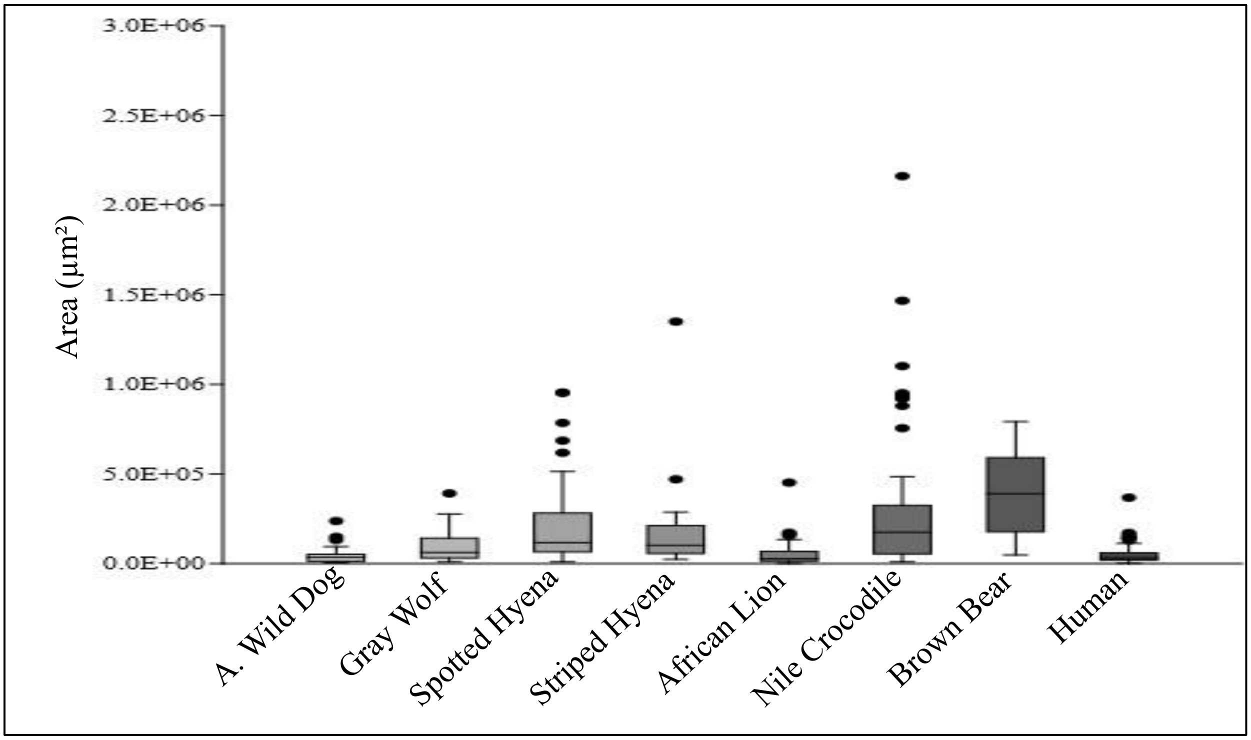

Figure E.6) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark area (2-D) measurements. Outliers are shown as black dots.

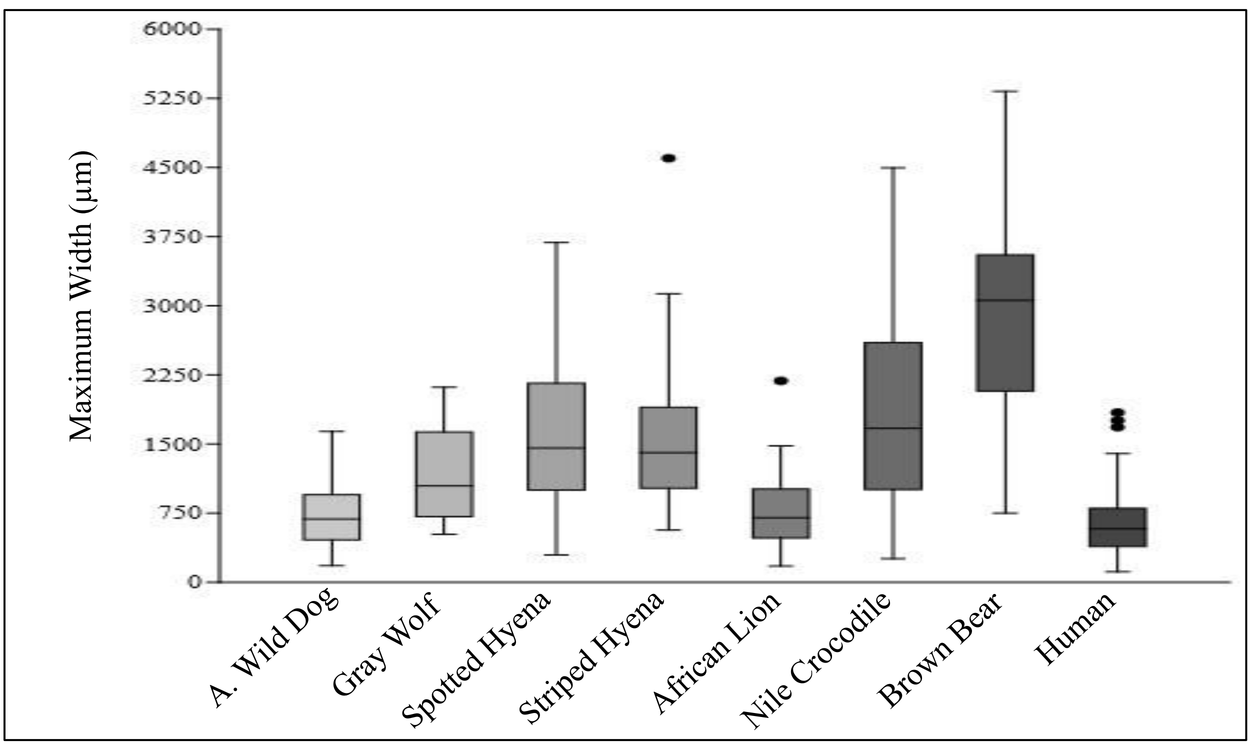

Figure E.7) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark maximum width (2-D) measurements. Outliers are shown as black dots.

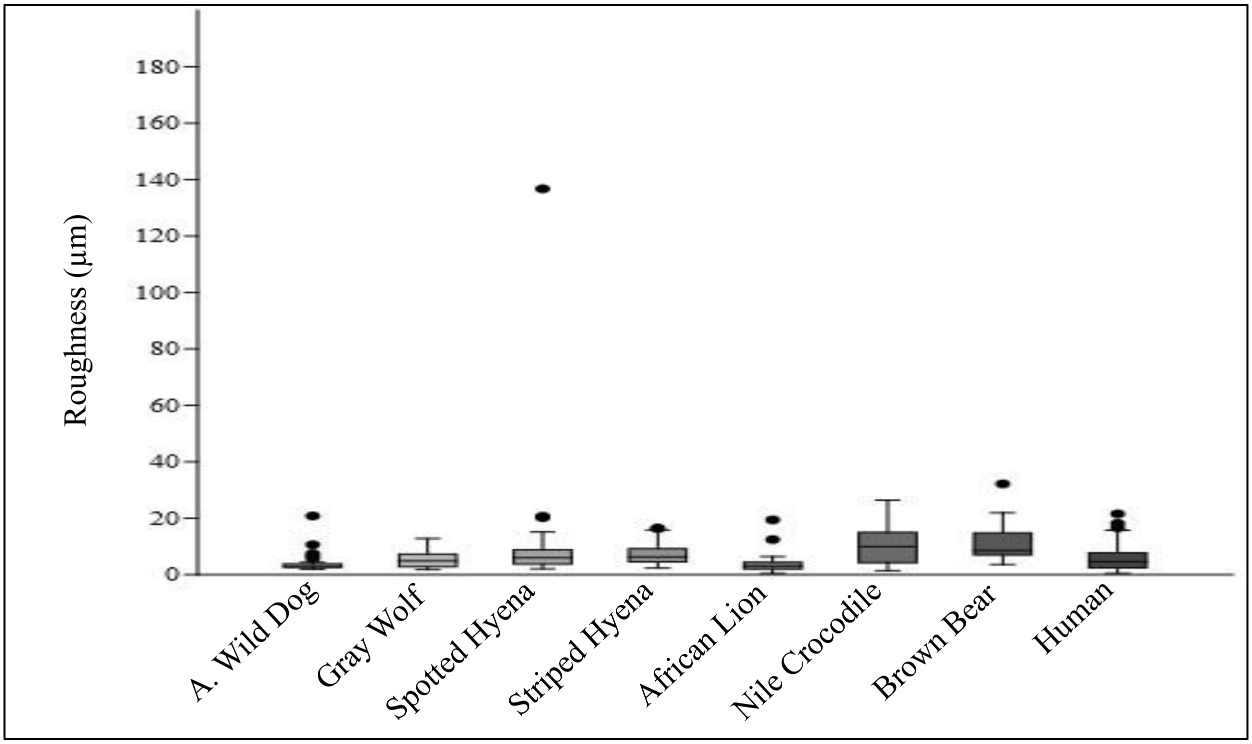

Figure E.8) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark roughness (2-D) measurements. Outliers are shown as black dots.

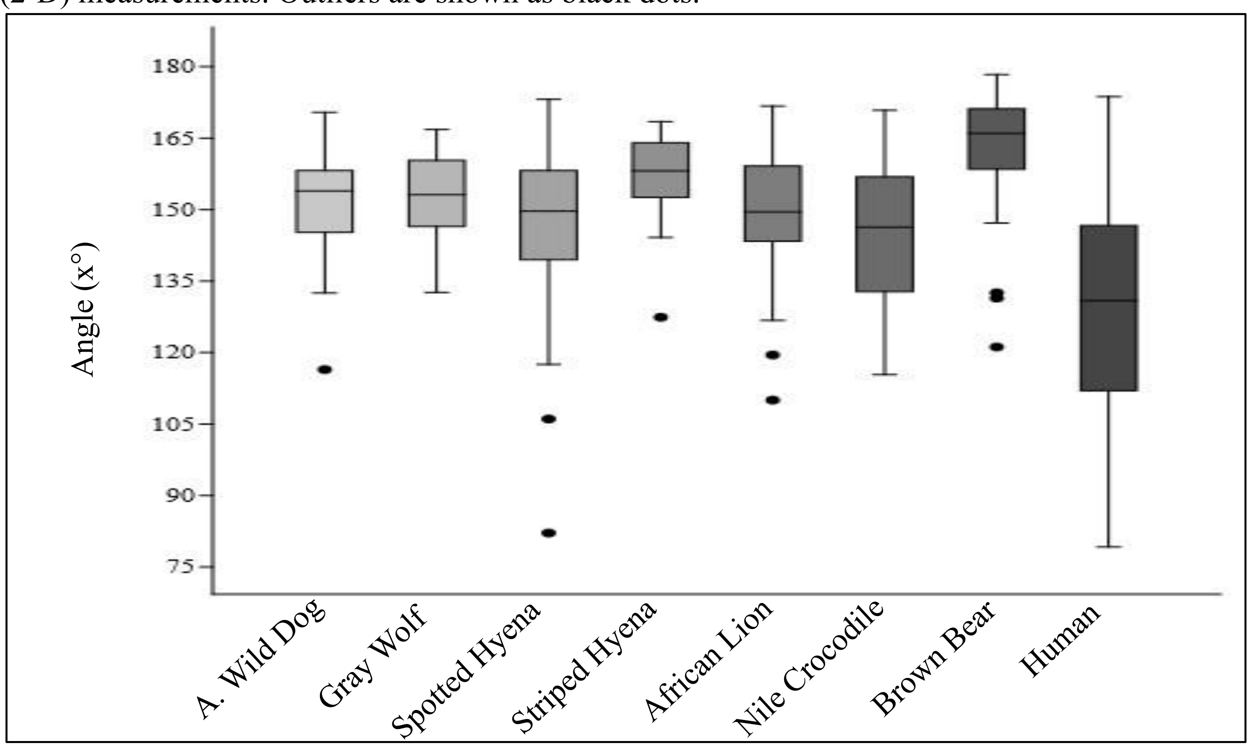

Figure E.9) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark angle (2-D) measurements. Outliers are shown as black dots.

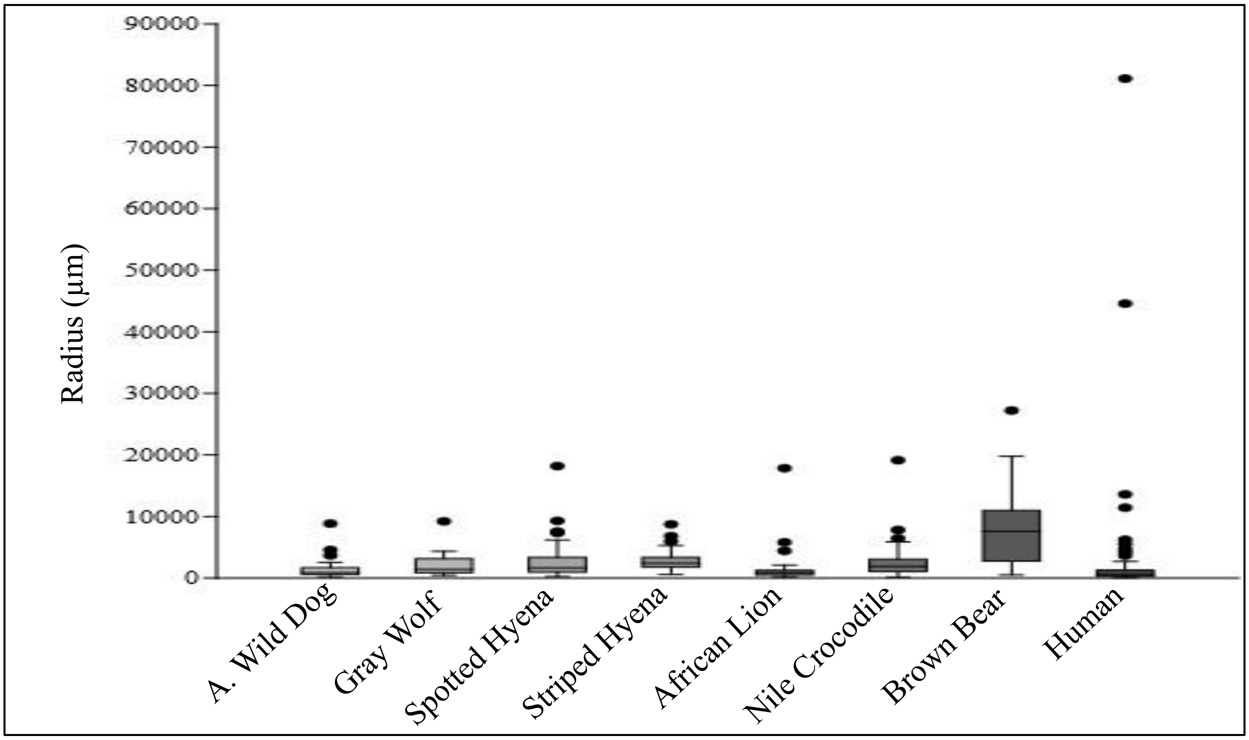

Figure E.10) Box plots of experimental African wild dog ("A. Wild Dog"), gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth mark radius (2-D) measurements. Outliers are shown as black dots.

APPENDIX F – OPTIMAL LAMBDA VALUES FOR ANALYSIS GROUPS ONE AND TWO

Table F.1) The optimal lambda values used in the Box-Cox transformations for group one, which includes cut, percussion, trample, carnivore tooth, and human tooth marks.

	Measurement	**Optimal Lambda**
3-D Measurements	Volume (µm³)	-0.127768
	Maximum Depth (µm)	-0.322713
	Mean Depth (µm)	-0.166305
	Maximum Length (µm)	0.141974
	Maximum Width (µm)	-0.196475
2-D Measurements	Area (µm²)	-0.0984367
	Maximum Width (µm)	-0.166827
	Roughness (R_a)	-0.133934
	Angle (x°)	2.71729
	Radius (µm)	-0.114626

Table F.2) The optimal lambda values used in the Box-Cox transformations for group two, which includes African wild dog, gray wolf, spotted hyena, striped hyena, African lion, Nile crocodile, brown bear, and human tooth marks.

	Measurement	**Optimal Lambda**
3-D Measurements	Volume (µm³)	-0.0863021
	Maximum Depth (µm)	-0.239834
	Mean Depth (µm)	0.00697894
	Maximum Length (µm)	-0.0877812
	Maximum Width (µm)	-0.0425244
2-D Measurements	Area (µm²)	-0.0503902
	Maximum Width (µm)	-0.0396221
	Roughness (R_a)	-0.0196433
	Angle (x°)	3.57358
	Radius (µm)	-0.0655979

APPENDIX G – *POST HOC* DUNN'S TEST RESULTS FOR GROUP ONE VARIABLES

Table G.1) Dunn's Multiple Comparison test results for group one volume (3-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**4.32E-05**			
Percussion	**1.34E-11**	**8.55E-31**		
Trample	2.13E-01	**9.48E-03**	**2.10E-15**	
Carnivore Tooth	**3.84E-09**	**3.08E-41**	**1.25E-02**	**1.20E-13**

Table G.2) Dunn's Multiple Comparison test results for group one maximum depth (3-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**6.23E-27**			
Percussion	**5.10E-09**	**3.50E-59**		
Trample	**1.07E-13**	9.77E-02	**1.81E-36**	
Carnivore Tooth	4.90E-01	**1.01E-50**	**1.72E-09**	**4.18E-21**

Table G.3) Dunn's Multiple Comparison test results for group one mean depth (3-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**4.56E-40**			
Percussion	**3.05E-05**	**1.45E-60**		
Trample	**1.61E-27**	9.42E-01	**8.85E-45**	
Carnivore Tooth	8.99E-02	**1.30E-50**	**4.98E-10**	**2.13E-28**

Table G.4) Dunn's Multiple Comparison test results for group one maximum length (3-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**3.78E-71**			
Percussion	**1.00E-06**	**3.28E-22**		
Trample	**2.05E-41**	1.83E-01	**3.20E-13**	
Carnivore Tooth	**1.10E-12**	**1.92E-41**	4.82E-01	**5.64E-18**

Table G.5) Dunn's Multiple Comparison test results for group one maximum width (3-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**1.94E-15**			
Percussion	**2.34E-07**	**1.26E-38**		
Trample	**4.98E-03**	**5.18E-06**	**9.47E-15**	
Carnivore Tooth	**2.92E-09**	**8.97E-77**	5.15E-01	**1.43E-20**

Table G.6) Dunn's Multiple Comparison test results for group one area (2-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**2.71E-23**			
Percussion	**8.23E-12**	**1.38E-62**		
Trample	**1.68E-11**	8.67E-02	**1.71E-38**	
Carnivore Tooth	**4.57E-05**	**3.65E-77**	**3.02E-05**	**2.56E-33**

Table G.7) Dunn's Multiple Comparison test results for group one maximum width (2-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**1.98E-17**			
Percussion	**4.86E-15**	**5.22E-62**		
Trample	**5.90E-05**	**3.00E-04**	**1.07E-30**	
Carnivore Tooth	**8.19E-11**	**2.71E-89**	**1.50E-03**	**1.56E-29**

Table G.8) Dunn's Multiple Comparison test results for group one roughness (2-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**3.47E-15**			
Percussion	**4.54E-10**	**1.03E-45**		
Trample	**1.85E-02**	**4.52E-07**	**4.20E-17**	
Carnivore Tooth	**3.98E-02**	**2.96E-39**	**1.40E-07**	**1.27E-06**

Table G.9) Dunn's Multiple Comparison test results for group one angle (2-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	3.95E-01			
Percussion	**1.30E-08**	**8.99E-14**		
Trample	**7.37E-08**	**4.86E-14**	3.96E-01	
Carnivore Tooth	**6.90E-20**	**1.34E-42**	1.17E-01	**3.66E-03**

Table G.10) Dunn's Multiple Comparison test results for group one radius (2-D) measurements. Statistically significant relationships (*p*-values) are bolded.

	Human Tooth	**Cut**	**Percussion**	**Trample**
Cut	**2.97E-11**			
Percussion	**3.90E-15**	**3.57E-51**		
Trample	3.12E-01	**4.39E-08**	**1.11E-18**	
Carnivore Tooth	**1.43E-11**	**2.87E-72**	**2.88E-03**	**1.11E-15**

APPENDIX H – *POST HOC* DUNN'S TEST RESULTS FOR GROUP TWO VARIABLES

Table H.1) Dunn's Multiple Comparison test results for group two volume (3-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	**A. Wild Dog**	**Gray Wolf**	**Spotted Hyena**	**Striped Hyena**	**A. Lion**	**Nile Crocodile**
A. Wild Dog	6.46E-01						
Gray Wolf	1.43E-01	1.28E-01					
Spotted Hyena	**3.54E-12**	**8.29E-08**	**4.51E-04**				
Striped Hyena	**7.48E-09**	**7.65E-07**	**8.04E-04**	7.31E-01			
A. Lion	3.20E-01	2.61E-01	5.32E-01	**4.36E-07**	**6.74E-06**		
Nile Crocodile	**1.35E-11**	**4.75E-08**	**2.02E-04**	6.27E-01	9.32E-01	**2.93E-07**	
Brown Bear	**4.68E-18**	**1.82E-13**	**6.98E-09**	**1.10E-03**	**9.87E-03**	**5.50E-13**	**6.91E-03**

Table H.2) Dunn's Multiple Comparison test results for group two maximum depth (3-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	**A. Wild Dog**	**Gray Wolf**	**Spotted Hyena**	**Striped Hyena**	**A. Lion**	**Nile Crocodile**
A. Wild Dog	**9.30E-03**						
Gray Wolf	6.07E-01	1.08E-01					
Spotted Hyena	**1.65E-04**	**4.91E-07**	**2.01E-03**				
Striped Hyena	**4.97E-02**	**3.27E-04**	5.26E-02	3.83E-01			
A. Lion	**4.57E-04**	8.65E-01	**4.68E-02**	**5.22E-10**	**2.16E-05**		
Nile Crocodile	**1.03E-04**	**3.00E-07**	**9.83E-04**	6.48E-01	2.28E-01	**7.06E-10**	
Brown Bear	**8.24E-08**	**2.90E-10**	**3.03E-06**	**1.72E-02**	**4.77E-03**	**4.34E-13**	5.89E-02

Table H.3) Dunn's Multiple Comparison test results for group two mean depth (3-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	A. Wild Dog	Gray Wolf	Spotted Hyena	Striped Hyena	A. Lion	Nile Crocodile
A. Wild Dog	**8.66E-04**						
Gray Wolf	**4.37E-02**	3.29E-01					
Spotted Hyena	2.59E-01	**1.38E-04**	**8.88E-03**				
Striped Hyena	5.65E-01	**3.15E-02**	2.52E-01	1.88E-01			
A. Lion	**9.22E-10**	1.66E-01	**1.38E-02**	**4.97E-10**	**1.37E-04**		
Nile Crocodile	1.37E-01	**7.81E-05**	**4.75E-03**	6.72E-01	1.10E-01	**8.24E-10**	
Brown Bear	**2.73E-03**	**7.90E-07**	**8.57E-05**	**4.71E-02**	**4.44E-03**	**7.05E-12**	1.24E-01

Table H.4) Dunn's Multiple Comparison test results for group two maximum length (3-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	A. Wild Dog	Gray Wolf	Spotted Hyena	Striped Hyena	A. Lion	Nile Crocodile
A. Wild Dog	7.29E-01						
Gray Wolf	2.20E-01	4.79E-01					
Spotted Hyena	**1.04E-09**	**5.64E-05**	**1.74E-03**				
Striped Hyena	**5.46E-11**	**8.20E-07**	**3.39E-05**	9.95E-02			
A. Lion	**3.79E-08**	**2.91E-04**	**6.11E-03**	6.48E-01	**4.40E-02**		
Nile Crocodile	**6.30E-15**	**2.85E-08**	**2.86E-06**	**3.88E-02**	8.50E-01	**1.35E-02**	
Brown Bear	**3.98E-18**	**1.30E-11**	**2.14E-09**	**1.17E-04**	**4.49E-02**	**2.79E-05**	**4.75E-02**

Table H.5) Dunn's Multiple Comparison test results for group two maximum width (3-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	**A. Wild Dog**	**Gray Wolf**	**Spotted Hyena**	**Striped Hyena**	**A. Lion**	**Nile Crocodile**
A. Wild Dog	9.00E-01						
Gray Wolf	**1.60E-03**	**1.56E-02**					
Spotted Hyena	**1.04E-14**	**7.19E-08**	**1.20E-02**				
Striped Hyena	**7.67E-10**	**1.74E-06**	**2.13E-02**	8.95E-01			
A. Lion	5.79E-01	7.76E-01	**1.38E-02**	**1.12E-09**	**2.64E-07**		
Nile Crocodile	**5.06E-13**	**1.11E-07**	**9.21E-03**	7.81E-01	9.13E-01	**4.17E-09**	
Brown Bear	**1.23E-19**	**4.20E-13**	**1.41E-06**	**1.85E-03**	**8.68E-03**	**3.34E-15**	**6.42E-03**

Table H.6) Dunn's Multiple Comparison test results for group two area (2-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	**A. Wild Dog**	**Gray Wolf**	**Spotted Hyena**	**Striped Hyena**	**A. Lion**	**Nile Crocodile**
A. Wild Dog	7.12E-01						
Gray Wolf	**2.89E-03**	**7.78E-03**					
Spotted Hyena	**3.69E-13**	**3.78E-08**	**1.89E-02**				
Striped Hyena	**3.12E-07**	**1.38E-05**	1.02E-01	6.34E-01			
A. Lion	7.72E-01	9.02E-01	**3.81E-03**	**1.35E-10**	**1.48E-06**		
Nile Crocodile	**8.99E-12**	**5.72E-08**	**1.39E-02**	7.70E-01	4.87E-01	**5.85E-10**	
Brown Bear	**5.45E-16**	**7.93E-12**	**2.80E-05**	**1.10E-02**	**8.45E-03**	**3.75E-14**	**2.97E-02**

Table H.7) Dunn's Multiple Comparison test results for group two maximum width (2-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	A. Wild Dog	Gray Wolf	Spotted Hyena	Striped Hyena	A. Lion	Nile Crocodile
A. Wild Dog	1.46E-01						
Gray Wolf	**1.74E-06**	**7.28E-03**					
Spotted Hyena	**3.85E-18**	**1.17E-06**	8.95E-02				
Striped Hyena	**1.16E-12**	**6.74E-06**	7.76E-02	7.39E-01			
A. Lion	7.45E-02	9.76E-01	**2.15E-03**	**5.15E-09**	**2.73E-07**		
Nile Crocodile	**2.53E-16**	**9.33E-07**	5.43E-02	7.00E-01	9.91E-01	**8.67E-09**	
Brown Bear	**1.14E-21**	**2.93E-11**	**6.86E-05**	**3.37E-03**	**2.16E-02**	**6.32E-14**	**1.36E-02**

Table H.8) Dunn's Multiple Comparison test results for group two roughness (2-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	A. Wild Dog	Gray Wolf	Spotted Hyena	Striped Hyena	A. Lion	Nile Crocodile
A. Wild Dog	**2.15E-02**						
Gray Wolf	7.94E-01	**4.63E-02**					
Spotted Hyena	**1.21E-02**	**1.12E-04**	1.31E-01				
Striped Hyena	**7.89E-03**	**9.33E-05**	6.21E-02	5.22E-01			
A. Lion	**7.58E-04**	7.31E-01	**9.52E-03**	**4.99E-07**	**1.79E-06**		
Nile Crocodile	**6.55E-05**	**7.47E-07**	**6.73E-03**	1.23E-01	4.87E-01	**7.66E-10**	
Brown Bear	**9.73E-07**	**1.20E-08**	**2.10E-04**	**5.13E-03**	5.45E-02	**1.71E-11**	1.59E-01

Table H.9) Dunn's Multiple Comparison test results for group two angle (2-D). Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	**A. Wild Dog**	**Gray Wolf**	**Spotted Hyena**	**Striped Hyena**	**A. Lion**	**Nile Crocodile**
A. Wild Dog	**3.88E-08**						
Gray Wolf	**3.81E-07**	8.28E-01					
Spotted Hyena	**9.01E-07**	1.40E-01	2.32E-01				
Striped Hyena	**2.68E-12**	2.13E-01	1.50E-01	**3.98E-03**			
A. Lion	**5.26E-08**	2.96E-01	4.37E-01	6.13E-01	**1.44E-02**		
Nile Crocodile	**1.73E-03**	**1.99E-02**	**4.04E-02**	2.69E-01	**2.66E-04**	1.18E-01	
Brown Bear	**3.56E-15**	**2.57E-02**	**1.62E-02**	**9.26E-05**	3.06E-01	**4.80E-04**	**4.30E-06**

Table H.10) Dunn's Multiple Comparison test results for group two radius (2-D) measurements. Statistically significant relationships (*p*-values) are bolded. "A. Wild Dog" denotes "African wild dog" and "A. Lion" denotes "African lion".

	Human	**A. Wild Dog**	**Gray Wolf**	**Spotted Hyena**	**Striped Hyena**	**A. Lion**	**Nile Crocodile**
A. Wild Dog	**4.73E-02**						
Gray Wolf	**1.24E-04**	1.28E-01					
Spotted Hyena	**9.11E-10**	**1.04E-02**	4.39E-01				
Striped Hyena	**3.11E-11**	**2.03E-04**	**3.20E-02**	8.76E-02			
A. Lion	1.18E-01	5.06E-01	**1.76E-02**	**1.14E-04**	**1.08E-06**		
Nile Crocodile	**2.63E-08**	**1.30E-02**	4.24E-01	9.34E-01	1.24E-01	**2.82E-04**	
Brown Bear	**8.15E-18**	**4.54E-08**	**8.52E-05**	**1.68E-04**	6.06E-02	**1.27E-11**	**4.68E-04**

APPENDIX I – RAW DATA FROM THE EXPERIMENTALLY PRODUCED CUT, PERCUSSION, AND TRAMPLE MARKS

	Three Dimensional Measurements						**Two Dimensional Measurements**					
BSM	**Surface Area**	**Volume**	**Maximum Depth**	**Mean Depth**	**Maximum Length**	**Maximum Width**	**Maximum Depth**	**Area**	**Width**	**Roughness**	**Angle**	**Radius**
Cut	2.26E+05	1.10E+06	20.2	4.9	1909.4	477.3	21.5	5.69E+02	43.3	0.7	79.7	19.5
Cut	5.03E+05	8.26E+06	64.6	16.4	6905.2	168.6	77.8	4.07E+03	115.0	1.6	62.5	21.1
Cut	1.20E+06	1.25E+07	43.6	10.4	13595.4	272.3	33.3	9.51E+02	52.4	1.7	62.2	22.9
Cut	5.27E+05	1.95E+07	70.4	37.0	8674.3	137.6	44.3	1.42E+03	70.0	3.3	44.6	25.8
Cut	6.02E+05	8.67E+06	47.1	14.4	12447.4	293.5	46.3	1.09E+03	70.0	2.0	78.0	34.2
Cut	5.22E+05	8.18E+06	51.5	15.7	6364.7	229.6	51.8	2.08E+03	90.0	3.4	82.6	36.2
Cut	4.81E+05	7.52E+06	47.0	15.6	8291.6	303.0	37.0	9.29E+02	80.0	2.5	89.3	36.9
Cut	1.10E+05	1.72E+06	62.8	15.7	3023.3	91.3	56.0	2.19E+03	85.0	2.3	67.6	37.0
Cut	8.58E+04	3.43E+06	88.7	39.9	1713.0	148.6	88.8	3.82E+03	90.0	4.5	46.9	43.2
Cut	4.01E+05	3.08E+06	27.2	7.7	6033.8	104.5	23.3	9.76E+02	77.3	0.4	115.0	43.2
Cut	1.77E+05	1.36E+06	25.7	7.7	3245.7	158.4	26.8	1.27E+03	82.8	0.7	112.6	43.5
Cut	1.21E+06	1.74E+07	86.5	14.4	17011.6	202.7	90.8	3.80E+03	110.0	10.4	61.2	45.4
Cut	9.43E+05	1.27E+07	38.2	13.4	12075.8	168.4	36.3	1.65E+03	95.0	1.2	99.5	45.8
Cut	1.37E+05	2.31E+06	69.4	16.8	1789.8	206.6	68.9	1.72E+03	100.0	4.4	73.1	46.5
Cut	3.84E+05	9.46E+06	70.4	24.7	2745.0	228.0	66.4	3.63E+03	110.0	3.2	74.6	48.1
Cut	4.04E+05	6.82E+06	55.7	16.9	8763.9	247.8	38.0	8.16E+02	70.0	1.1	77.6	49.7
Cut	1.42E+06	2.79E+07	46.6	19.7	9450.5	283.9	50.1	2.82E+03	110.0	1.8	94.6	50.1
Cut	6.86E+05	1.87E+07	62.0	27.2	5992.8	245.0	60.8	4.01E+03	120.0	4.6	83.1	50.7
Cut	6.90E+05	6.88E+06	40.8	10.0	14450.6	275.5	30.6	1.08E+03	90.0	1.9	104.4	50.8
Cut	1.95E+05	4.20E+06	59.0	21.5	2346.2	138.4	55.2	2.71E+03	110.0	4.1	96.6	51.2
Cut	2.14E+05	5.49E+06	64.3	25.7	4261.5	182.9	45.2	2.03E+03	110.0	1.5	82.3	53.5
Cut	8.99E+05	9.23E+06	69.7	10.3	10620.5	203.3	52.3	2.54E+03	110.0	2.4	90.0	54.2
Cut	1.60E+05	2.06E+06	35.4	12.9	1689.5	200.0	34.5	1.38E+03	85.0	0.5	82.9	54.6
Cut	4.45E+05	9.40E+06	62.2	21.1	6543.2	170.6	53.3	2.65E+03	105.0	3.6	80.9	55.4
Cut	2.24E+06	6.53E+07	103.0	29.1	14950.9	335.0	94.9	6.05E+03	105.0	1.5	51.5	59.5
Cut	4.56E+05	9.92E+06	59.8	21.8	6403.6	159.9	63.7	4.19E+03	140.0	2.7	89.7	59.6
Cut	4.01E+05	7.50E+06	52.1	18.7	6913.4	177.7	45.7	1.71E+03	100.0	3.3	100.3	60.3
Cut	4.54E+05	5.41E+06	40.8	11.9	9547.3	173.7	31.6	1.44E+03	100.0	1.3	109.5	61.3
Cut	5.94E+05	1.50E+07	70.6	25.2	5270.6	275.4	49.7	3.07E+03	140.0	1.9	104.4	66.0
Cut	2.18E+05	4.86E+06	49.8	22.2	2474.1	172.0	61.0	4.21E+03	145.0	1.9	101.4	69.1
Cut	6.87E+05	1.56E+07	69.8	22.7	6522.7	251.2	46.9	3.33E+03	140.0	2.6	110.7	70.4
Cut	4.94E+05	6.87E+06	69.6	13.9	8222.7	211.2	66.3	3.41E+03	115.9	1.4	62.0	71.1
Cut	1.56E+06	5.29E+07	81.3	33.9	20252.5	319.4	66.4	4.51E+03	150.0	5.9	98.9	71.3
Cut	1.85E+06	6.26E+07	100.2	33.8	15995.9	439.1	91.6	5.73E+03	160.0	3.0	87.5	71.4

Cut	3.93E+05	7.38E+06	58.2	18.8	4824.2	152.0	50.5	3.13E+03	145.0	1.8	109.0	71.9
Cut	9.17E+05	4.00E+07	123.2	43.6	13559.3	201.8	90.6	6.44E+03	160.0	4.6	88.9	72.5
Cut	1.17E+05	2.10E+06	46.1	18.0	1834.3	180.5	33.3	1.68E+03	100.0	1.8	115.0	73.2
Cut	2.59E+06	2.73E+07	50.0	10.5	17067.8	254.1	53.0	2.18E+03	125.0	2.4	104.4	74.0
Cut	2.29E+05	4.68E+06	66.0	20.4	2031.6	144.5	60.5	5.28E+03	157.0	2.9	98.8	74.6
Cut	3.10E+05	2.50E+06	29.2	8.1	3884.3	208.9	27.1	1.60E+03	118.7	0.4	129.5	75.0
Cut	3.40E+05	4.10E+06	41.3	12.1	4423.3	140.0	39.6	1.95E+03	110.0	1.3	110.8	76.1
Cut	6.70E+05	2.35E+07	94.8	35.1	3074.6	362.5	78.3	4.67E+03	160.0	8.0	94.8	78.9
Cut	1.89E+05	5.57E+06	78.8	29.4	1387.2	299.2	78.8	4.86E+03	180.0	4.2	95.7	79.9
Cut	2.42E+06	1.03E+08	102.9	42.4	12533.9	405.2	93.6	9.08E+03	190.4	4.1	87.2	80.3
Cut	5.10E+05	6.78E+06	52.0	13.3	9128.9	167.9	42.1	2.54E+03	130.0	1.9	106.4	81.1
Cut	5.27E+05	1.79E+07	88.4	33.9	3818.4	302.2	83.8	7.44E+03	180.0	4.9	83.7	82.0
Cut	9.28E+05	1.10E+07	46.2	11.9	10104.9	277.7	39.4	1.51E+03	124.2	1.0	96.8	83.2
Cut	1.61E+05	2.65E+06	41.7	16.5	1245.6	222.0	31.7	1.35E+03	120.0	3.0	127.7	83.5
Cut	1.18E+06	1.36E+07	79.4	11.5	15460.4	215.9	81.9	3.02E+03	150.0	3.5	97.8	84.0
Cut	2.64E+06	4.61E+07	75.1	17.4	20222.6	239.6	66.6	2.76E+03	140.0	3.2	92.3	85.2
Cut	5.03E+05	5.04E+06	37.4	10.0	4176.9	265.2	26.0	1.35E+03	100.0	2.3	123.2	86.4
Cut	2.59E+06	3.80E+07	53.3	14.7	24114.3	366.4	47.3	2.44E+03	150.0	1.8	102.4	87.8
Cut	1.47E+05	2.02E+06	35.8	13.7	1623.2	153.5	21.3	8.76E+02	112.1	1.6	135.8	89.3
Cut	9.18E+05	2.31E+07	71.8	25.1	5324.5	294.7	77.1	6.70E+03	195.0	1.2	67.3	89.8
Cut	7.12E+05	1.43E+07	59.6	20.1	7922.5	199.8	51.0	4.32E+03	160.0	2.3	121.5	90.3
Cut	1.02E+06	1.88E+07	65.0	18.4	10093.0	263.2	41.8	2.47E+03	150.0	2.6	120.2	91.1
Cut	6.75E+05	2.69E+07	124.1	39.9	3751.9	342.1	130.5	1.46E+04	196.0	3.0	63.8	91.2
Cut	2.92E+06	1.62E+08	162.1	55.6	12080.5	459.6	140.6	1.20E+04	180.0	3.4	52.9	92.2
Cut	3.95E+05	6.65E+06	45.4	16.8	3894.2	258.2	40.9	3.13E+03	138.0	1.0	133.1	92.3
Cut	4.71E+05	1.08E+07	62.2	22.8	4635.7	394.6	53.8	5.31E+03	176.6	1.7	113.5	93.2
Cut	1.12E+06	3.35E+07	85.9	29.9	8527.2	324.2	82.7	7.09E+03	209.8	5.0	101.9	94.5
Cut	4.94E+05	5.25E+06	51.9	10.6	12577.4	223.3	47.8	1.73E+03	140.0	3.5	116.2	94.7
Cut	1.60E+06	2.29E+07	52.0	14.3	16219.5	187.5	48.7	3.38E+03	130.0	1.3	104.8	95.0
Cut	1.07E+06	2.19E+07	68.2	20.6	7455.3	258.5	52.0	4.48E+03	168.4	4.3	119.1	96.0
Cut	7.93E+05	5.11E+07	146.4	64.5	4103.6	470.3	108.3	1.09E+04	200.0	4.0	88.1	96.6
Cut	8.37E+05	3.12E+07	94.0	37.3	5609.6	331.9	77.8	6.62E+03	195.0	3.0	103.1	97.8
Cut	1.47E+06	2.84E+07	65.9	19.3	7544.3	382.9	66.1	5.78E+03	190.4	4.1	104.1	98.2
Cut	7.97E+05	1.49E+07	57.8	18.7	3815.6	386.8	51.8	4.10E+03	179.4	3.5	114.2	98.7
Cut	3.15E+06	8.17E+07	87.4	26.0	21300.2	389.6	88.3	8.50E+03	205.0	1.4	97.8	98.9
Cut	2.92E+05	2.72E+06	29.2	9.3	3368.0	135.1	25.8	1.19E+03	115.9	1.1	134.8	98.9
Cut	6.46E+05	1.16E+07	62.6	20.0	8212.9	155.6	60.8	4.65E+03	150.0	4.7	107.1	100.9
Cut	1.18E+06	3.94E+07	90.9	33.4	7719.3	283.3	94.6	1.04E+04	215.3	3.3	102.8	101.7
Cut	1.83E+05	1.90E+06	31.5	10.4	2223.7	184.3	27.4	1.35E+03	105.0	1.7	117.5	101.8

Cut	6.26E+05	1.34E+07	52.5	21.4	5046.1	196.1	43.9	3.08E+03	170.0	3.3	123.4	102.0
Cut	1.11E+06	1.84E+07	75.9	16.6	17207.7	276.3	80.2	7.32E+03	210.0	2.2	111.7	102.3
Cut	1.63E+05	4.41E+06	69.9	27.0	1616.6	218.2	65.1	5.61E+03	190.0	5.4	114.7	102.7
Cut	6.20E+05	1.12E+07	52.1	18.0	9638.8	186.0	41.6	3.04E+03	155.0	1.3	125.4	103.0
Cut	8.26E+05	9.90E+06	52.4	12.0	13821.1	189.8	54.5	4.01E+03	170.0	3.0	107.4	104.0
Cut	8.47E+05	1.21E+07	47.2	14.3	9156.8	228.3	35.1	2.15E+03	146.3	1.4	124.4	104.3
Cut	5.81E+05	9.99E+06	75.3	17.2	5295.0	346.3	75.2	5.36E+03	200.0	3.8	101.0	104.4
Cut	9.75E+05	1.87E+07	51.7	19.2	15709.7	249.6	37.0	1.66E+03	130.0	2.4	128.5	104.5
Cut	1.57E+06	3.41E+07	97.6	21.7	10854.1	364.7	79.9	4.26E+03	150.0	2.4	76.7	106.1
Cut	5.47E+05	5.57E+06	30.8	10.2	4958.8	254.4	17.2	9.14E+02	105.0	0.7	142.7	106.2
Cut	2.60E+06	1.92E+08	165.0	74.0	9941.8	531.5	173.3	2.26E+04	205.0	2.2	50.3	106.5
Cut	2.39E+05	3.85E+06	52.7	16.1	3277.3	186.7	43.9	1.85E+03	140.0	4.3	114.3	107.4
Cut	1.36E+05	4.02E+06	94.7	29.6	1398.0	231.3	83.1	8.33E+03	220.0	2.2	101.1	108.1
Cut	6.63E+05	2.71E+07	126.0	40.9	3059.6	285.7	95.0	9.45E+03	226.3	5.7	90.8	108.3
Cut	3.65E+06	1.18E+08	106.1	32.4	20416.5	447.3	99.2	7.57E+03	210.0	1.4	96.8	108.7
Cut	1.21E+05	2.24E+06	53.7	18.4	1195.2	171.6	54.6	3.86E+03	170.0	2.0	115.1	108.8
Cut	2.84E+06	8.20E+07	98.4	28.9	19176.8	393.8	99.5	1.24E+04	245.0	2.4	94.0	108.9
Cut	2.69E+06	1.38E+08	156.5	51.4	14101.0	406.2	144.1	1.98E+04	250.0	3.0	67.4	109.4
Cut	5.46E+05	7.26E+06	44.3	13.3	3812.7	272.0	40.1	3.25E+03	160.0	4.8	132.2	109.8
Cut	7.14E+05	1.93E+07	61.9	27.0	5134.8	321.5	62.9	6.67E+03	210.0	2.4	112.0	110.3
Cut	6.11E+05	1.23E+07	66.9	20.2	6930.3	240.7	67.8	5.36E+03	200.0	2.1	114.1	110.4
Cut	9.69E+05	8.36E+06	73.5	8.6	13529.5	290.0	77.5	2.97E+03	190.0	9.3	111.5	112.4
Cut	7.72E+05	1.15E+07	56.0	14.9	6969.7	274.4	52.8	1.62E+03	120.0	4.4	122.3	114.3
Cut	5.81E+05	6.19E+06	34.4	10.6	5229.9	293.7	33.9	1.76E+03	150.0	3.2	132.0	116.4
Cut	8.84E+05	1.15E+07	48.6	13.0	8980.2	232.0	47.2	4.77E+03	180.0	2.8	107.5	118.1
Cut	1.67E+06	3.28E+07	70.7	19.6	14787.0	204.4	53.8	5.95E+03	195.0	2.2	123.4	118.2
Cut	1.89E+06	6.52E+07	117.9	34.6	9453.0	444.7	122.2	1.42E+04	265.0	5.7	101.6	118.7
Cut	8.62E+05	1.12E+07	40.2	13.0	13151.3	207.4	43.6	3.34E+03	150.0	1.5	123.7	119.2
Cut	9.36E+05	1.54E+07	37.4	16.5	7967.9	214.9	32.1	2.74E+03	165.6	1.6	135.0	119.4
Cut	7.87E+05	1.09E+07	69.3	13.8	5320.1	286.7	53.2	5.87E+03	200.0	2.1	121.1	120.2
Cut	4.52E+05	6.76E+06	45.4	14.9	4333.2	190.6	50.5	3.78E+03	170.0	3.3	131.7	120.4
Cut	6.04E+05	1.03E+07	68.1	17.0	6062.7	233.4	64.2	7.15E+03	220.0	2.3	112.2	120.8
Cut	1.19E+06	7.17E+07	182.3	60.4	5581.4	506.0	141.3	2.01E+04	290.0	4.0	85.2	122.5
Cut	8.77E+05	2.12E+07	100.2	24.2	11693.9	218.8	82.4	4.97E+03	190.0	5.0	110.6	122.9
Cut	7.59E+05	1.39E+07	52.5	18.3	5516.0	244.0	52.0	5.69E+03	209.8	1.4	119.9	125.3
Cut	9.21E+05	2.52E+07	59.3	27.3	6084.1	253.5	64.1	6.27E+03	220.0	1.7	110.1	126.7
Cut	8.91E+05	1.35E+07	75.1	15.2	5616.1	352.3	76.5	8.98E+03	210.0	3.7	96.3	127.5
Cut	5.48E+05	7.13E+06	134.8	13.0	15151.0	283.9	131.6	1.81E+04	280.0	2.6	89.9	127.6
Cut	3.30E+06	5.66E+07	76.5	17.1	20371.4	231.1	57.2	4.43E+03	195.0	2.0	116.0	128.0

Cut	1.06E+06	2.27E+07	76.4	21.3	11405.0	235.6	49.1	5.26E+03	180.0	1.6	108.7	129.0
Cut	9.40E+05	1.85E+07	51.2	19.7	10024.0	280.5	49.0	6.51E+03	160.0	2.9	110.9	129.1
Cut	8.06E+05	1.50E+07	59.7	18.6	12890.1	206.6	48.2	3.00E+03	180.0	1.1	126.6	132.1
Cut	3.17E+05	4.10E+06	33.7	12.9	2799.6	161.7	33.8	2.14E+03	145.0	4.0	135.0	132.4
Cut	1.26E+06	5.78E+07	114.3	45.7	6237.8	435.6	114.3	1.07E+04	260.0	6.4	106.8	134.2
Cut	2.74E+05	4.64E+06	45.6	16.9	2752.3	192.4	39.6	3.42E+03	179.4	2.9	135.2	134.8
Cut	5.57E+05	1.32E+07	68.0	23.7	6519.7	235.8	55.1	4.33E+03	200.0	2.3	116.9	135.0
Cut	8.28E+05	1.43E+07	54.3	17.2	8839.4	225.8	57.7	7.00E+03	200.0	1.1	119.6	136.7
Cut	8.45E+05	2.37E+07	71.5	28.1	6521.3	251.8	58.5	5.26E+03	223.1	2.6	123.7	139.2
Cut	2.83E+05	6.36E+06	54.0	22.5	2114.5	228.5	50.7	5.62E+03	200.0	0.9	116.2	140.0
Cut	6.43E+05	2.49E+07	140.3	38.7	2298.9	466.9	116.5	1.28E+04	235.0	4.3	87.3	140.5
Cut	8.42E+05	4.61E+07	160.5	54.8	8254.4	455.5	140.9	1.88E+04	360.0	4.8	91.8	141.8
Cut	3.81E+05	3.25E+06	31.6	8.5	3233.6	278.6	28.6	1.21E+03	110.4	0.5	113.6	142.3
Cut	5.48E+05	7.76E+06	46.4	14.2	4240.3	204.3	42.6	4.21E+03	190.0	2.2	131.7	145.7
Cut	1.39E+06	3.27E+07	85.4	23.6	9332.3	330.9	81.3	6.36E+03	224.2	4.8	114.6	146.1
Cut	6.70E+05	7.50E+06	78.1	11.2	13621.2	217.6	79.2	3.78E+03	205.0	5.3	115.9	147.5
Cut	5.88E+05	1.24E+07	55.8	21.0	3835.5	300.7	55.9	6.90E+03	220.8	2.4	130.5	148.9
Cut	5.79E+05	7.62E+06	42.3	13.1	7787.9	223.3	35.3	2.23E+03	170.0	2.2	146.7	149.4
Cut	6.33E+05	4.83E+06	32.4	7.6	6411.9	294.9	33.5	1.30E+03	130.0	2.6	117.6	150.0
Cut	4.48E+05	4.98E+06	44.6	11.1	7435.7	218.9	33.5	2.62E+03	180.0	1.8	140.8	150.2
Cut	2.36E+06	4.23E+07	52.3	17.9	7267.8	449.2	52.5	5.27E+03	230.0	1.0	128.3	150.5
Cut	1.16E+06	3.40E+07	85.2	29.4	6097.4	363.2	84.6	1.03E+04	260.0	2.3	112.2	150.5
Cut	1.24E+06	2.23E+07	53.3	17.9	9059.0	306.3	47.7	4.19E+03	185.0	1.5	122.7	152.1
Cut	8.07E+05	1.29E+07	45.3	16.0	5606.2	269.1	43.0	3.51E+03	170.0	1.5	142.5	152.7
Cut	2.99E+06	1.42E+08	146.8	47.6	15944.9	376.8	140.4	1.71E+04	340.0	5.4	104.5	153.5
Cut	1.17E+06	4.49E+07	83.5	38.4	6105.1	301.2	88.0	1.30E+04	285.0	3.5	115.6	153.6
Cut	9.36E+05	2.39E+07	79.9	25.5	4673.1	333.3	66.4	6.57E+03	240.0	2.5	124.3	154.4
Cut	4.58E+05	4.54E+06	34.1	9.9	5048.8	189.9	21.3	1.21E+03	140.8	0.5	138.3	156.1
Cut	4.24E+05	1.14E+07	69.2	26.8	6371.2	255.4	55.3	3.44E+03	190.0	2.6	126.2	159.2
Cut	5.34E+05	7.93E+06	63.7	14.8	8369.3	199.8	55.3	3.31E+03	180.0	3.7	111.1	159.5
Cut	2.22E+06	8.25E+07	94.5	37.2	15185.8	584.2	37.3	3.17E+03	196.0	1.9	138.5	159.6
Cut	6.69E+05	2.34E+07	72.7	35.0	4696.4	272.6	63.5	6.15E+03	250.0	2.4	117.9	160.0
Cut	1.13E+06	3.00E+07	51.8	26.5	6584.5	272.2	54.8	6.03E+03	240.0	1.7	127.6	160.1
Cut	5.13E+05	1.05E+07	56.1	20.4	2607.0	282.4	37.6	3.41E+03	180.0	2.3	141.0	160.3
Cut	6.65E+05	7.92E+06	38.1	11.9	8816.3	299.5	37.2	2.74E+03	170.0	2.1	146.0	160.9
Cut	2.09E+05	2.78E+06	46.2	13.3	3122.7	164.7	24.8	1.39E+03	120.0	2.2	107.5	161.3
Cut	1.71E+06	5.84E+07	68.4	34.1	10273.8	273.0	73.9	9.93E+03	270.5	3.3	121.9	162.5
Cut	5.14E+05	7.78E+06	49.1	15.1	5073.4	212.0	48.1	5.66E+03	210.0	2.0	125.1	162.8
Cut	1.19E+06	1.86E+07	47.2	15.6	14777.1	370.4	46.5	4.13E+03	190.0	3.4	133.1	163.2

Cut	2.55E+06	3.15E+07	57.3	12.4	11936.2	266.4	49.3	5.02E+03	230.0	1.0	128.1	163.3
Cut	1.07E+06	4.99E+07	123.3	46.7	4357.0	339.5	116.9	2.08E+04	320.0	4.7	109.8	163.4
Cut	6.99E+05	2.43E+07	76.1	34.8	4924.4	293.6	70.0	8.17E+03	225.0	2.4	110.7	164.3
Cut	2.69E+06	2.04E+08	182.4	75.9	11432.0	502.2	187.6	3.36E+04	285.0	3.2	64.6	164.7
Cut	2.02E+05	2.07E+06	29.3	10.3	3178.6	119.6	25.8	1.72E+03	99.4	1.0	96.9	165.8
Cut	1.54E+06	4.03E+07	79.2	26.2	9426.7	429.3	68.4	1.07E+04	278.8	1.9	127.0	167.5
Cut	6.49E+05	1.29E+07	56.2	19.9	5520.0	251.9	47.4	5.18E+03	239.1	2.5	131.4	168.9
Cut	2.59E+05	4.69E+06	44.6	18.1	2539.2	235.5	35.7	3.36E+03	196.8	1.3	139.7	169.3
Cut	4.01E+05	1.15E+07	69.5	28.6	4653.8	230.8	57.9	4.57E+03	230.0	3.1	130.9	173.8
Cut	2.72E+06	9.31E+07	154.5	34.3	15468.0	405.3	115.6	1.13E+04	240.1	4.9	82.2	174.4
Cut	6.21E+05	5.44E+06	27.9	8.8	5595.6	308.9	26.0	1.82E+03	160.1	1.4	136.1	175.5
Cut	2.25E+05	9.78E+05	38.2	4.3	5378.8	158.0	42.0	2.07E+03	190.0	3.4	141.1	175.8
Cut	4.17E+05	6.98E+06	52.1	16.7	4373.0	233.0	46.2	3.22E+03	170.0	2.6	122.1	176.0
Cut	1.02E+06	1.87E+07	47.8	18.4	13226.1	280.3	46.8	4.28E+03	210.0	1.5	139.0	176.1
Cut	1.38E+06	3.77E+07	64.3	27.4	12900.3	280.9	52.4	5.75E+03	250.0	1.7	132.9	177.2
Cut	4.22E+06	1.07E+08	70.7	25.4	10816.8	594.1	61.6	8.08E+03	260.0	1.9	114.8	179.2
Cut	1.18E+06	2.18E+07	42.7	18.4	20541.7	295.6	38.4	2.20E+03	170.0	1.9	138.0	179.3
Cut	4.42E+05	7.98E+06	45.3	18.1	3216.9	219.5	44.2	5.69E+03	209.8	1.7	131.1	179.4
Cut	2.03E+06	3.94E+07	49.3	19.4	9634.6	566.6	42.6	2.77E+03	180.0	2.5	134.8	180.8
Cut	1.02E+06	4.33E+07	118.4	42.4	12950.7	266.3	91.8	7.82E+03	255.0	1.8	106.9	181.2
Cut	8.37E+05	1.56E+07	40.6	18.6	7938.7	205.5	33.7	2.57E+03	149.0	0.4	107.5	182.4
Cut	4.04E+05	4.03E+06	46.5	10.0	7561.6	279.2	39.4	5.14E+03	220.0	0.5	142.5	182.6
Cut	9.64E+05	1.56E+07	48.2	16.2	11909.3	271.3	50.6	5.30E+03	220.0	1.7	130.0	182.9
Cut	4.32E+05	4.88E+06	44.8	11.3	12246.2	234.6	45.1	3.91E+03	210.0	2.4	135.3	185.0
Cut	1.34E+06	3.45E+07	82.0	25.7	8458.8	315.8	74.7	1.05E+04	290.0	2.5	129.0	186.1
Cut	1.36E+06	2.35E+07	74.6	17.3	11477.5	427.0	70.4	1.02E+04	284.3	2.9	129.8	186.3
Cut	5.29E+05	7.18E+06	58.6	13.6	6291.8	256.9	39.0	3.47E+03	190.0	2.5	116.4	188.9
Cut	7.06E+05	4.62E+06	33.9	6.5	5183.7	222.8	38.3	2.19E+03	190.0	2.8	141.8	189.1
Cut	1.27E+06	4.05E+07	105.2	31.9	3683.2	482.3	94.4	1.25E+04	318.7	3.6	126.0	192.8
Cut	4.68E+05	3.53E+06	32.0	7.5	4619.1	198.2	36.7	2.36E+03	185.0	3.1	141.7	196.8
Cut	4.99E+05	4.68E+06	38.1	9.4	4103.5	298.7	42.2	3.54E+03	210.0	2.6	143.8	197.1
Cut	1.23E+06	2.41E+07	62.8	19.6	5448.4	407.1	59.4	6.07E+03	276.0	2.8	132.5	197.4
Cut	1.38E+06	1.85E+07	67.1	13.5	11649.0	273.2	67.5	5.44E+03	240.0	5.1	112.1	198.0
Cut	7.03E+05	1.60E+07	58.2	22.8	4053.2	275.3	46.8	5.61E+03	245.0	2.3	139.8	199.1
Cut	1.58E+06	2.12E+07	57.3	13.4	18489.4	434.8	57.2	4.56E+03	250.0	3.5	139.0	200.0
Cut	1.37E+06	2.49E+07	69.2	18.1	15391.7	284.7	54.9	3.02E+03	200.0	3.2	139.4	200.1
Cut	1.86E+05	2.44E+06	32.3	13.1	3470.7	175.0	32.1	2.10E+03	170.0	1.5	149.2	201.6
Cut	5.79E+05	3.07E+07	149.0	52.9	3339.8	383.6	133.3	1.94E+04	335.0	3.7	108.7	202.1
Cut	7.11E+05	9.32E+06	37.4	13.1	5534.3	208.1	27.4	2.29E+03	204.2	2.1	146.2	202.4

Cut	5.78E+05	1.22E+07	86.4	21.1	9476.8	310.9	70.0	1.03E+04	280.0	1.4	125.6	208.6
Cut	1.09E+06	1.06E+07	66.6	9.7	6522.5	355.6	56.9	5.53E+03	240.0	4.1	138.8	209.0
Cut	7.58E+05	1.66E+07	66.0	21.9	6279.3	382.6	56.6	4.85E+03	215.0	5.1	125.9	213.9
Cut	6.55E+05	7.21E+06	40.6	11.0	9507.6	230.8	34.5	1.64E+03	160.0	1.5	141.4	214.8
Cut	3.71E+05	1.12E+07	64.7	16.6	7685.2	235.1	49.2	4.33E+03	235.0	2.6	140.6	215.2
Cut	2.35E+06	7.41E+07	80.9	31.6	10219.4	511.1	88.1	1.59E+04	340.0	1.0	125.9	218.0
Cut	1.32E+06	4.84E+07	93.3	36.7	6756.5	379.8	98.0	1.88E+04	375.4	2.0	113.6	221.3
Cut	1.27E+06	2.32E+07	73.3	18.3	16258.5	270.7	68.4	3.88E+03	240.0	3.5	136.9	222.0
Cut	9.00E+05	1.30E+07	69.6	14.5	9668.3	360.9	57.8	5.11E+03	230.0	3.2	136.1	222.3
Cut	3.14E+06	5.27E+07	58.8	16.8	19082.0	300.9	54.7	3.91E+03	200.0	2.6	137.8	222.6
Cut	4.97E+05	5.15E+06	42.8	10.4	8994.1	251.0	38.8	4.88E+03	240.0	0.6	140.0	225.0
Cut	6.18E+05	1.17E+07	42.2	18.9	3802.8	251.7	32.7	3.56E+03	210.0	1.5	150.3	227.2
Cut	1.53E+06	3.53E+07	58.1	23.1	6059.7	395.2	57.5	8.82E+03	294.1	1.7	135.5	228.8
Cut	5.84E+05	8.47E+06	45.7	14.5	6981.0	208.5	37.9	2.60E+03	170.0	1.4	112.3	230.0
Cut	2.15E+06	8.75E+07	110.6	40.8	5464.5	483.7	103.4	1.75E+04	365.0	3.2	126.6	232.8
Cut	3.12E+05	5.25E+06	60.6	16.8	2200.0	261.1	61.4	5.81E+03	260.0	2.5	127.8	233.3
Cut	5.58E+05	1.28E+07	87.3	22.9	3750.7	356.0	89.3	8.52E+03	300.0	4.5	114.7	233.4
Cut	2.21E+05	1.85E+06	36.2	8.4	3091.8	209.8	42.6	4.02E+03	225.0	3.6	140.3	235.8
Cut	1.17E+06	3.02E+07	71.4	25.8	10589.0	516.9	55.7	5.88E+03	255.0	2.1	127.6	236.9
Cut	1.07E+06	1.44E+07	51.8	13.5	13613.8	208.6	55.7	1.63E+03	130.0	2.3	94.6	238.4
Cut	1.02E+06	1.41E+07	43.0	13.9	6259.0	550.1	39.9	2.75E+03	220.8	2.3	145.1	239.4
Cut	5.29E+05	1.08E+07	57.8	20.4	7064.1	301.1	40.2	5.22E+03	265.0	1.5	144.4	243.1
Cut	1.46E+06	2.34E+07	58.4	16.0	11771.3	282.2	52.6	8.32E+03	270.0	1.6	142.2	244.1
Cut	8.95E+05	1.13E+07	46.5	12.6	7032.7	257.9	45.0	4.34E+03	250.0	2.7	147.2	245.0
Cut	1.48E+06	1.90E+07	40.0	12.8	13288.7	218.8	38.4	1.47E+03	130.0	1.1	98.8	246.0
Cut	1.23E+06	1.92E+07	56.7	15.6	10612.6	314.4	40.6	3.52E+03	210.0	1.7	142.9	246.1
Cut	2.49E+06	5.90E+07	65.3	23.6	12202.6	399.1	64.9	1.07E+04	320.0	1.9	137.6	246.6
Cut	1.38E+07	4.33E+08	135.6	31.4	21623.9	933.5	130.4	2.55E+04	470.0	3.0	114.9	247.8
Cut	6.04E+05	1.85E+07	59.5	30.6	4645.8	359.9	48.9	5.24E+03	270.0	1.8	139.7	248.1
Cut	5.90E+05	8.28E+06	40.9	14.1	8539.8	227.5	40.9	3.00E+03	200.0	3.2	151.8	248.5
Cut	1.20E+06	1.09E+07	43.8	9.1	10561.7	536.5	38.4	2.69E+03	150.0	2.3	103.8	250.8
Cut	1.56E+06	3.17E+07	52.2	20.4	11151.0	282.1	55.0	6.85E+03	260.0	1.4	139.1	252.1
Cut	4.74E+05	3.51E+06	30.0	7.4	6401.7	186.2	31.4	2.25E+03	170.0	2.3	138.1	253.3
Cut	1.60E+06	3.33E+08	414.9	207.6	6221.7	492.4	378.3	1.15E+05	640.0	12.2	75.0	254.0
Cut	5.20E+05	6.59E+06	67.8	12.7	2879.0	267.9	68.4	6.17E+03	240.0	2.7	119.1	258.3
Cut	1.63E+06	5.79E+07	86.7	35.4	8891.1	435.9	81.8	1.73E+04	395.0	1.7	133.3	258.4
Cut	4.47E+05	8.18E+06	63.6	18.3	7852.0	267.0	41.6	4.44E+03	255.0	2.2	148.2	258.5
Cut	1.70E+05	1.15E+06	26.0	6.8	2258.2	149.6	21.5	8.57E+02	132.5	0.8	117.8	263.1
Cut	7.66E+05	1.59E+07	56.7	20.7	4561.0	282.4	73.0	9.83E+03	275.0	1.3	112.5	263.6

Cut	7.46E+05	6.86E+06	51.9	9.2	11641.5	260.7	35.6	6.54E+03	210.0	2.2	136.6	264.3
Cut	4.89E+05	4.38E+06	44.5	9.0	17103.2	283.9	47.2	3.68E+03	200.0	2.2	110.1	265.9
Cut	5.88E+06	9.99E+08	382.8	169.9	10784.2	878.0	325.0	1.28E+05	580.0	9.3	89.0	267.0
Cut	1.84E+06	2.34E+07	60.3	12.7	16731.5	263.9	52.4	3.90E+03	162.8	3.9	109.5	268.0
Cut	6.04E+06	1.09E+08	59.9	18.0	26133.8	1035.1	50.7	6.15E+03	275.0	3.3	144.4	268.7
Cut	1.57E+06	1.56E+07	53.1	10.0	14174.9	425.4	55.8	1.04E+04	280.0	0.7	148.7	269.9
Cut	1.20E+06	1.30E+07	72.5	10.8	13485.6	253.4	64.2	2.80E+03	200.0	5.1	106.8	271.2
Cut	1.43E+06	3.34E+07	69.4	23.3	10606.2	624.7	51.1	3.92E+03	260.0	4.3	143.2	275.4
Cut	4.72E+05	1.20E+07	58.4	25.4	2895.0	332.9	56.7	8.01E+03	304.9	2.2	140.1	276.9
Cut	1.31E+05	1.73E+06	38.4	13.3	1180.3	220.8	41.0	5.25E+03	275.0	1.7	144.6	278.2
Cut	2.31E+05	2.99E+06	60.0	12.9	4699.7	319.9	50.4	9.49E+03	310.0	1.1	147.7	279.3
Cut	1.37E+06	2.67E+07	62.9	19.6	9390.4	285.3	65.1	7.50E+03	270.0	1.4	146.0	280.7
Cut	6.34E+06	8.22E+08	304.8	129.7	16966.4	834.9	320.4	1.21E+05	660.0	23.2	91.0	286.0
Cut	1.93E+06	3.07E+07	43.2	15.9	13240.4	245.4	39.0	4.41E+03	230.0	1.0	158.4	287.1
Cut	6.55E+05	9.61E+06	45.2	14.7	7436.4	185.8	37.8	2.52E+03	160.1	2.1	95.5	289.2
Cut	8.67E+05	1.33E+07	60.7	15.4	9371.8	343.2	52.2	5.87E+03	270.0	1.8	146.5	289.9
Cut	7.06E+05	1.36E+07	52.0	19.2	4729.9	334.3	54.2	8.15E+03	325.0	1.8	143.3	290.5
Cut	1.29E+06	5.15E+07	103.7	39.9	5757.7	458.3	97.6	1.67E+04	410.0	1.9	129.9	293.7
Cut	3.92E+05	7.08E+06	113.3	18.0	5304.9	339.3	77.3	6.90E+03	290.0	4.6	138.5	297.1
Cut	9.98E+05	1.63E+07	51.0	16.3	11728.1	278.5	47.8	3.57E+03	270.0	1.2	137.4	298.8
Cut	3.73E+05	3.26E+06	18.7	8.8	2829.9	226.6	22.3	2.30E+03	215.0	1.7	156.4	301.7
Cut	4.62E+06	1.39E+08	89.3	30.2	18835.4	434.3	73.8	1.29E+04	295.0	3.7	120.5	304.2
Cut	4.94E+05	6.56E+06	43.2	13.3	5763.8	255.9	36.3	4.04E+03	250.0	0.9	145.7	308.9
Cut	2.33E+06	5.95E+07	77.0	25.5	16048.5	405.9	67.6	1.14E+04	390.0	1.7	169.8	310.7
Cut	9.77E+05	1.78E+07	60.0	18.2	4464.4	351.1	51.6	9.37E+03	350.0	1.3	145.2	315.7
Cut	6.77E+05	1.51E+07	56.6	22.4	4698.8	265.5	47.7	6.89E+03	245.0	1.4	112.4	315.9
Cut	2.39E+05	2.33E+06	24.4	9.7	2286.1	195.4	24.8	2.45E+03	192.6	2.1	157.9	320.9
Cut	3.22E+06	3.56E+07	55.1	11.0	23626.3	313.5	63.2	6.98E+03	300.0	3.0	139.5	322.7
Cut	1.58E+06	1.03E+07	30.8	6.5	12139.4	289.4	30.5	1.45E+03	180.0	2.3	157.3	325.4
Cut	2.35E+06	2.97E+07	58.2	12.6	11568.1	344.3	49.2	3.45E+03	220.0	1.5	136.3	326.8
Cut	1.96E+06	7.99E+07	105.6	40.7	9299.8	498.4	84.4	1.70E+04	400.0	1.7	130.8	327.6
Cut	8.30E+05	1.15E+07	47.2	13.8	7316.4	290.5	40.6	4.57E+03	240.0	1.5	143.2	328.2
Cut	1.99E+06	3.31E+07	53.1	16.6	17043.3	441.3	46.2	4.09E+03	250.0	1.5	139.0	331.0
Cut	2.61E+05	8.64E+06	74.4	33.1	4368.5	324.4	65.6	6.53E+03	310.0	2.8	137.5	331.6
Cut	2.38E+06	7.72E+07	75.0	32.5	6459.7	480.8	75.3	1.42E+04	390.0	2.0	137.6	332.9
Cut	1.57E+06	2.90E+07	77.1	18.4	13091.2	434.2	66.9	5.90E+03	270.0	3.3	139.4	333.7
Cut	2.53E+06	2.89E+07	46.6	11.4	20490.6	312.1	41.2	6.50E+03	280.0	1.1	153.5	334.0
Cut	1.24E+06	2.45E+07	54.1	19.8	6215.2	383.8	49.7	6.44E+03	240.1	3.2	155.3	337.6
Cut	2.49E+06	7.45E+07	85.1	29.9	6763.3	700.6	82.3	1.68E+04	415.0	1.9	137.8	338.0

Cut	1.89E+06	6.73E+07	90.9	35.6	8762.8	465.2	83.4	1.44E+04	400.0	2.3	139.9	355.8
Cut	8.26E+05	1.78E+07	53.3	21.6	7293.0	301.1	48.4	6.23E+03	295.0	1.4	146.5	355.8
Cut	3.02E+05	3.03E+06	51.1	10.0	8971.1	253.0	38.1	2.90E+03	195.0	1.8	132.7	357.3
Cut	3.36E+05	2.74E+06	27.7	8.1	3416.7	241.3	28.1	3.03E+03	209.8	1.3	159.6	361.7
Cut	3.23E+05	4.65E+06	41.9	14.4	2896.0	262.6	36.2	3.80E+03	250.0	1.9	156.0	363.3
Cut	4.50E+06	1.05E+08	67.8	23.4	15630.8	962.6	54.6	9.18E+03	336.7	1.9	122.0	368.6
Cut	1.44E+06	4.77E+07	106.9	33.2	2865.6	743.7	95.8	1.65E+04	420.0	5.0	141.4	369.6
Cut	7.32E+05	1.06E+07	32.9	14.4	6307.8	237.0	28.9	2.34E+03	200.0	1.0	158.5	371.4
Cut	2.26E+06	4.39E+07	59.6	19.4	22382.9	283.1	43.4	5.30E+03	280.0	1.4	140.1	374.2
Cut	1.14E+06	1.63E+07	51.6	14.3	19883.0	347.2	61.6	5.14E+03	250.0	2.0	115.9	374.2
Cut	2.45E+06	6.31E+07	71.8	25.7	9481.0	429.7	85.2	1.89E+04	449.9	1.7	141.7	382.0
Cut	7.29E+05	1.47E+07	63.8	20.1	11045.4	446.5	47.0	6.48E+03	380.0	1.7	149.8	382.8
Cut	1.22E+06	3.26E+07	66.7	26.7	15276.5	391.0	49.4	9.52E+03	360.0	0.8	146.2	382.9
Cut	5.53E+05	1.28E+07	77.9	23.2	3803.8	408.2	70.9	9.32E+03	396.1	2.3	141.9	384.1
Cut	9.83E+05	1.75E+07	63.2	17.8	5786.3	356.0	56.9	7.40E+03	350.0	1.2	139.2	385.2
Cut	8.05E+06	1.74E+08	77.6	21.6	18230.8	336.6	56.8	7.42E+03	335.0	3.2	148.2	385.5
Cut	4.16E+05	6.17E+06	67.6	14.8	4452.0	344.8	59.6	4.17E+03	260.0	4.9	154.5	386.2
Cut	6.86E+05	1.96E+07	66.1	28.6	5147.3	387.1	51.9	8.05E+03	300.0	3.5	154.6	387.0
Cut	2.38E+06	3.53E+07	76.9	14.8	8391.5	499.4	73.7	6.20E+03	330.0	3.6	144.7	389.8
Cut	8.26E+05	1.02E+07	46.5	12.3	9566.3	280.5	38.7	4.67E+03	280.0	1.3	157.5	394.6
Cut	6.32E+05	5.16E+06	50.8	8.2	6051.7	262.1	38.1	3.96E+03	255.0	0.9	157.2	394.7
Cut	1.44E+06	2.41E+07	46.5	16.7	8894.3	479.2	38.3	3.84E+03	210.0	1.2	131.7	401.9
Cut	2.31E+06	4.67E+07	68.4	20.2	9602.3	351.8	67.2	1.09E+04	350.5	2.0	146.6	405.3
Cut	3.94E+05	2.96E+06	18.4	7.5	2667.7	304.2	15.9	1.59E+03	190.0	1.5	163.3	405.9
Cut	1.09E+06	2.10E+07	64.2	19.3	8318.9	412.3	58.1	1.00E+04	380.0	2.4	150.6	421.3
Cut	2.05E+06	6.10E+07	107.6	29.8	6292.6	570.9	102.3	2.24E+04	430.0	4.3	135.2	422.9
Cut	4.50E+06	1.79E+08	81.7	39.6	16191.8	462.4	77.0	1.62E+04	410.0	2.2	134.2	426.3
Cut	1.10E+06	4.54E+07	100.2	41.3	13389.9	343.4	75.5	6.98E+03	300.0	1.5	117.3	430.2
Cut	1.81E+06	2.26E+07	52.3	12.5	4816.0	870.0	54.4	6.19E+03	251.2	2.6	106.9	436.0
Cut	6.02E+06	1.51E+09	556.1	251.2	7096.2	743.9	373.3	1.75E+05	940.0	16.8	99.0	436.0
Cut	2.56E+06	4.75E+07	67.0	18.5	10541.2	470.6	64.2	8.49E+03	400.2	1.9	148.9	436.9
Cut	8.58E+05	1.38E+07	41.6	16.1	20021.3	440.6	29.7	3.01E+03	250.0	0.8	157.8	443.2
Cut	1.45E+06	2.32E+07	58.9	16.0	18029.5	312.4	52.2	4.73E+03	280.0	2.0	139.8	443.9
Cut	9.51E+05	2.04E+07	58.1	21.5	4945.0	508.0	57.1	1.22E+04	400.0	1.6	149.8	444.4
Cut	2.82E+06	6.90E+07	76.5	24.5	10699.3	375.3	71.1	8.15E+03	309.1	3.0	135.9	450.9
Cut	7.17E+05	1.02E+07	43.0	14.2	3859.9	293.7	44.1	7.18E+03	369.8	1.0	152.1	452.5
Cut	2.48E+06	1.14E+08	179.6	46.1	4354.9	840.5	175.4	5.46E+04	715.0	7.4	128.1	479.5
Cut	8.98E+05	2.26E+07	87.0	25.2	5922.0	339.5	86.6	1.59E+04	465.0	1.9	124.7	481.5
Cut	6.96E+05	6.20E+06	59.1	8.9	12089.1	381.0	48.7	6.20E+03	360.0	1.2	154.0	481.8

Cut	4.62E+05	8.59E+06	45.9	18.6	2106.2	355.0	43.3	8.83E+03	354.9	1.6	153.0	486.4
Cut	2.50E+06	9.63E+07	190.3	38.5	19976.8	754.4	173.3	4.57E+04	740.0	9.3	122.8	486.8
Cut	4.22E+06	1.13E+08	78.2	26.7	13684.6	742.3	62.6	5.05E+03	315.0	3.1	144.5	493.3
Cut	1.16E+07	2.75E+09	491.2	236.8	11637.6	1646.5	456.8	2.88E+05	1100.0	6.7	96.0	504.0
Cut	4.71E+05	7.26E+06	37.5	15.4	4125.4	352.2	32.2	3.16E+03	265.0	1.8	152.6	504.2
Cut	3.70E+05	8.65E+06	81.1	23.4	9251.0	470.1	83.4	1.49E+04	420.0	0.9	133.6	506.7
Cut	1.27E+06	4.30E+07	103.2	33.9	3534.9	546.5	100.8	2.17E+04	535.4	7.5	146.6	509.3
Cut	1.20E+06	1.48E+07	48.1	12.4	6022.1	408.7	40.3	6.28E+03	360.0	1.0	157.0	520.5
Cut	5.54E+05	8.00E+06	41.0	14.4	9464.3	275.1	33.8	2.92E+03	230.0	2.7	145.2	535.3
Cut	8.46E+05	1.16E+07	64.1	13.7	9446.7	492.4	53.5	9.11E+03	410.0	2.2	148.7	539.2
Cut	4.88E+05	5.11E+06	43.1	10.5	9671.8	345.5	39.6	3.63E+03	260.0	1.2	134.4	541.5
Cut	3.34E+06	1.37E+08	126.3	41.0	26236.4	501.6	103.3	2.35E+04	480.0	2.1	113.4	542.4
Cut	3.53E+06	9.01E+07	77.4	25.5	8103.6	661.9	71.0	1.77E+04	515.0	2.4	147.0	542.7
Cut	2.75E+06	3.92E+07	49.6	14.3	27249.4	334.4	38.1	1.85E+03	185.0	1.9	129.9	550.3
Cut	5.77E+05	1.05E+07	51.5	18.2	7159.8	196.2	38.3	2.29E+03	190.0	2.4	114.5	552.9
Cut	2.78E+06	5.58E+07	73.1	20.1	9044.8	551.4	72.9	1.10E+04	400.0	2.0	138.0	553.9
Cut	5.72E+05	5.57E+06	30.2	9.7	12634.1	185.3	23.5	1.31E+03	140.0	1.0	122.1	563.6
Cut	6.92E+05	1.28E+07	46.4	18.5	3279.3	338.4	40.7	4.68E+03	276.0	2.6	145.9	574.7
Cut	3.82E+05	6.91E+06	55.4	18.1	3683.4	337.2	40.4	4.87E+03	280.0	2.0	132.4	577.5
Cut	6.40E+05	9.70E+06	47.9	15.2	7773.4	219.9	25.0	2.24E+03	211.8	0.7	139.8	580.7
Cut	1.95E+06	3.00E+07	45.3	15.4	19088.9	362.7	38.8	7.64E+03	350.0	1.3	158.0	581.1
Cut	7.53E+05	7.36E+06	66.5	9.8	4523.0	616.5	65.0	7.76E+03	340.0	1.1	125.8	582.6
Cut	4.84E+05	5.39E+06	53.5	11.1	5773.6	398.2	43.0	7.15E+03	360.0	1.4	150.0	598.6
Cut	1.19E+06	2.04E+07	44.2	17.1	4637.1	500.8	44.8	1.02E+04	424.5	1.8	159.1	610.5
Cut	9.52E+05	1.48E+07	53.1	15.6	11363.1	444.0	47.3	7.59E+03	410.0	1.6	158.7	635.4
Cut	3.37E+06	1.22E+08	80.0	36.2	8838.6	753.4	82.7	2.13E+04	530.0	1.2	136.4	647.6
Cut	1.93E+07	2.68E+09	337.9	139.0	14893.4	2010.6	279.2	1.83E+05	1050.0	5.0	129.0	655.0
Cut	7.62E+05	9.73E+06	61.0	12.8	9003.2	452.8	45.6	8.73E+03	400.0	0.9	160.7	658.8
Cut	1.47E+05	1.22E+06	31.5	8.3	3807.1	271.3	20.3	1.31E+03	195.0	1.6	151.9	661.3
Cut	5.93E+05	6.34E+06	39.1	10.7	7366.5	321.1	31.1	4.53E+03	320.0	1.2	159.8	662.7
Cut	8.19E+06	9.64E+08	266.9	117.6	13005.9	1133.5	270.8	1.38E+05	1020.0	5.0	119.0	667.0
Cut	1.56E+06	3.55E+07	66.6	22.7	11851.2	325.5	57.5	4.24E+03	280.0	2.0	157.1	670.6
Cut	2.06E+06	5.10E+07	74.8	24.7	10431.0	620.8	64.5	2.19E+04	590.6	1.6	154.1	672.3
Cut	6.36E+05	8.35E+06	49.3	13.1	4978.6	291.5	38.5	2.63E+03	265.0	2.4	163.1	679.9
Cut	1.66E+07	7.99E+08	151.4	48.3	23326.7	1089.0	173.5	7.54E+04	900.0	3.8	136.7	684.9
Cut	8.76E+05	1.76E+07	52.7	20.1	5895.8	447.7	41.4	7.30E+03	400.0	0.8	158.9	689.1
Cut	4.80E+06	8.98E+08	424.0	187.1	6003.8	1016.1	494.0	3.35E+05	1320.0	10.7	116.0	700.0
Cut	1.47E+06	3.50E+07	117.7	23.7	18496.9	673.3	113.7	2.53E+04	620.0	1.9	152.8	722.0
Cut	1.08E+06	1.37E+07	58.5	12.7	6449.3	283.3	57.5	4.93E+03	270.0	1.7	104.2	724.0

Cut	1.47E+06	2.90E+07	70.9	19.7	18142.0	501.8	60.4	8.60E+03	460.0	1.7	157.8	729.4
Cut	3.73E+06	1.65E+08	107.2	44.4	18697.9	691.9	85.8	1.96E+04	630.0	0.9	148.1	729.9
Cut	1.50E+06	3.56E+07	91.1	23.7	13264.6	640.3	66.5	2.13E+04	590.0	0.8	152.6	734.7
Cut	5.24E+05	5.78E+06	43.6	11.0	8823.6	195.3	36.7	1.91E+03	160.0	2.0	129.4	765.1
Cut	8.27E+04	1.21E+06	44.0	14.6	1179.3	172.2	36.4	2.30E+03	160.0	1.9	104.1	766.9
Cut	1.15E+06	1.95E+07	39.1	17.0	9439.3	362.3	37.7	3.37E+03	280.0	1.6	158.4	769.2
Cut	1.31E+06	1.82E+07	55.7	13.8	16051.5	464.1	50.0	7.08E+03	420.0	1.0	160.5	770.0
Cut	4.72E+06	1.54E+08	100.7	32.6	18330.6	744.2	100.5	4.08E+04	720.0	1.5	150.4	771.0
Cut	8.90E+06	1.13E+09	296.2	126.4	11366.5	1519.1	284.7	1.60E+05	1190.0	9.4	124.0	779.0
Cut	1.92E+06	3.35E+07	45.1	17.4	15958.2	392.8	43.8	5.91E+03	330.0	1.0	152.8	792.9
Cut	5.09E+05	9.50E+06	58.7	18.7	3327.1	352.9	55.3	7.88E+03	340.0	2.6	146.4	801.8
Cut	5.19E+05	9.02E+06	55.6	17.4	7592.5	500.4	54.0	1.22E+04	495.0	1.5	157.2	809.0
Cut	4.16E+06	1.22E+08	96.7	29.5	7980.3	1181.3	92.6	2.39E+04	679.0	5.3	150.3	840.0
Cut	1.81E+06	4.92E+07	69.3	27.1	10356.9	432.9	62.3	1.13E+04	430.0	1.2	145.6	842.4
Cut	1.36E+06	1.46E+07	76.0	10.8	14449.7	419.3	70.2	8.54E+03	410.0	2.3	149.0	860.4
Cut	2.31E+06	2.27E+07	27.9	9.8	12766.6	489.3	29.1	2.59E+03	285.0	2.5	169.9	879.7
Cut	9.54E+05	1.29E+07	44.2	13.5	15412.7	369.6	34.9	4.18E+03	360.0	0.9	166.5	881.4
Cut	6.06E+05	8.56E+06	40.6	14.1	7392.3	375.9	27.7	3.45E+03	370.0	1.3	166.6	933.6
Cut	6.99E+05	1.11E+07	62.9	16.9	12562.9	488.4	61.9	1.31E+04	450.0	1.4	144.3	938.0
Cut	9.28E+05	1.02E+07	32.4	11.0	4953.2	340.8	32.9	3.92E+03	280.0	0.9	149.0	967.1
Cut	5.42E+05	9.41E+06	44.7	17.4	3455.3	356.3	37.8	3.12E+03	230.0	2.8	150.8	970.3
Cut	3.96E+06	1.36E+08	78.2	34.3	11464.0	711.8	75.6	2.24E+04	620.0	2.1	148.9	982.6
Cut	1.33E+06	3.31E+07	64.2	24.9	3194.3	616.2	57.2	1.75E+04	580.0	2.6	151.1	1010.8
Cut	9.78E+05	1.29E+07	44.6	13.2	7109.8	401.6	39.4	4.51E+03	380.0	0.9	162.7	1013.8
Cut	5.73E+05	1.96E+07	84.2	34.2	8191.3	596.0	80.9	2.40E+04	580.0	2.2	126.0	1036.3
Cut	1.31E+06	5.05E+07	108.8	38.6	4935.0	717.3	106.3	2.23E+04	714.8	9.6	158.6	1090.1
Cut	1.74E+07	2.06E+09	280.4	118.4	15707.5	1704.9	265.7	2.00E+05	1350.0	7.3	140.0	1120.0
Cut	1.10E+06	2.44E+07	67.7	22.2	5637.4	609.2	57.3	1.54E+04	590.0	1.6	163.1	1145.2
Cut	2.92E+07	4.52E+09	437.1	154.9	28204.5	1974.6	374.0	2.80E+05	1415.0	10.2	122.0	1171.0
Cut	1.57E+06	3.68E+07	52.5	23.4	12908.1	522.7	37.7	8.12E+03	510.0	2.3	165.9	1175.4
Cut	1.68E+06	2.80E+07	64.8	16.7	12134.2	665.4	63.4	1.94E+04	640.0	1.8	163.0	1209.2
Cut	1.12E+07	1.09E+09	293.3	97.3	11783.3	1278.9	237.6	1.28E+05	1290.0	4.5	133.0	1277.0
Cut	2.64E+07	4.36E+09	402.0	164.9	12837.0	2843.9	350.7	2.91E+05	1650.0	24.4	133.0	1304.0
Cut	1.53E+06	2.06E+07	41.8	13.5	4656.5	564.7	43.8	1.17E+04	420.0	2.5	135.4	1334.3
Cut	5.88E+05	7.05E+06	48.5	12.0	7389.8	475.1	43.5	9.63E+03	465.0	1.2	152.0	1363.1
Cut	9.96E+05	2.97E+07	84.4	29.9	4973.0	645.0	75.6	1.82E+04	610.0	1.6	155.5	1383.0
Cut	7.27E+06	2.41E+08	93.2	33.1	12496.0	1038.1	78.7	2.10E+04	781.1	4.2	161.9	1455.3
Cut	2.17E+06	2.17E+07	30.1	10.0	10294.4	567.0	24.3	2.19E+03	309.1	2.3	161.5	1490.8
Cut	2.45E+07	2.88E+09	345.1	117.8	21300.7	1677.9	305.0	3.00E+05	1560.0	5.3	135.0	1497.0

Cut	2.60E+07	5.57E+09	524.0	214.3	17619.9	2525.7	425.0	4.88E+05	1950.0	20.5	138.3	1657.0
Cut	2.15E+06	5.24E+07	61.0	24.3	11333.8	547.5	49.0	1.50E+04	720.0	3.3	163.0	1706.4
Cut	5.23E+06	2.32E+08	115.9	44.3	9592.0	885.4	107.9	5.46E+04	900.0	3.4	140.8	1719.4
Cut	1.40E+07	1.96E+09	339.9	139.7	12903.0	1475.2	412.5	2.99E+05	1480.0	7.5	110.0	1731.0
Cut	1.95E+07	2.48E+09	271.0	127.3	19643.6	1542.6	332.1	2.88E+05	1760.0	17.8	131.0	1734.0
Cut	9.36E+05	1.39E+07	36.9	14.8	6465.2	284.5	31.3	3.60E+03	179.4	2.5	151.4	1800.8
Cut	4.64E+07	1.20E+10	552.3	259.2	35132.5	2824.1	498.5	6.36E+05	2300.0	21.9	137.0	1816.0
Cut	1.10E+06	2.54E+07	56.3	23.2	10546.3	516.6	44.6	4.67E+03	480.0	1.1	158.5	1928.0
Cut	2.37E+06	9.06E+07	134.5	38.3	5268.4	1265.7	133.4	7.72E+04	1240.7	5.5	157.8	2107.9
Cut	1.38E+07	6.24E+08	159.6	45.2	24717.4	1120.3	164.5	7.67E+04	1140.0	6.1	152.8	2205.0
Cut	3.08E+07	1.64E+08	153.6	53.2	16330.9	593.8	155.3	3.34E+04	580.0	3.0	89.5	2339.5
Cut	4.56E+05	6.43E+06	38.6	14.1	2302.9	721.3	41.4	1.51E+04	739.7	1.4	171.0	2490.8
Cut	2.33E+07	4.96E+09	528.8	212.5	12818.2	2407.7	587.8	8.88E+05	3200.0	21.1	137.0	2704.0
Cut	5.43E+07	1.31E+10	573.1	242.1	23155.0	3514.8	519.8	5.54E+05	2500.0	21.0	135.0	2846.0
Cut	3.14E+06	9.14E+07	112.6	29.1	14403.6	1181.0	99.7	3.99E+04	730.0	6.2	164.8	2884.8
Cut	9.38E+06	6.56E+08	193.8	69.9	10463.2	1172.1	189.7	1.13E+05	1400.0	4.0	157.0	3419.0
Cut	2.71E+05	3.16E+06	41.3	11.6	4957.4	260.5	38.9	2.47E+03	190.0	1.2	110.7	3496.4
Cut	1.20E+07	2.13E+09	487.3	177.4	17393.7	2667.0	514.6	6.74E+05	2820.0	41.1	133.0	12741.0
Cut	5.45E+05	6.12E+06	51.1	13.5	7248.8	420.1	41.0	1.00E+04	420.0	0.7	175.9	19234.1
Cut	8.51E+05	1.36E+07	109.2	16.0	13649.6	1311.5	79.8	3.21E+04	1000.0	1.4	150.6	27140.7
Percussion	1.39E+05	7.83E+06	122.6	56.3	626.1	445.4	91.9	8.14E+03	180.0	5.5	96.8	90.2
Percussion	1.50E+05	3.82E+06	61.4	25.4	594.1	392.8	44.2	4.00E+03	184.9	3.8	137.4	140.8
Percussion	6.99E+05	7.00E+07	230.9	100.6	1442.2	822.6	237.4	8.87E+04	687.2	7.6	122.8	438.6
Percussion	2.88E+05	2.13E+07	144.6	74.0	870.9	520.6	128.1	4.08E+04	491.3	1.9	151.3	497.3
Percussion	3.15E+05	3.69E+07	390.8	117.3	1095.5	558.3	348.1	2.16E+05	950.0	11.8	120.1	521.8
Percussion	8.37E+05	6.17E+06	157.5	73.7	1556.6	1198.6	161.6	4.64E+04	598.9	4.8	139.1	572.0
Percussion	1.20E+06	2.03E+08	314.0	168.6	1540.1	1061.0	254.6	1.51E+05	980.0	6.4	123.9	587.1
Percussion	6.41E+05	7.78E+07	279.5	121.4	1056.5	961.0	230.9	1.05E+05	844.6	5.9	121.4	600.9
Percussion	1.23E+06	3.82E+08	674.2	310.0	1706.6	946.9	612.9	6.11E+05	1660.0	34.1	107.0	803.3
Percussion	1.05E+06	3.49E+08	743.4	331.9	1688.9	924.1	708.3	7.44E+05	1791.2	10.8	98.2	809.9
Percussion	3.83E+05	5.12E+07	413.3	133.6	1490.9	432.7	385.4	3.07E+05	1440.7	7.4	120.9	829.8
Percussion	4.08E+06	4.58E+08	279.5	112.2	3717.1	1698.0	245.0	1.48E+05	1170.2	5.9	135.8	850.4
Percussion	1.40E+05	1.93E+07	250.3	137.8	679.6	270.2	247.6	9.61E+04	654.1	14.8	111.4	949.7
Percussion	4.52E+05	9.00E+07	519.9	199.4	1718.1	395.8	486.4	5.42E+05	1730.0	10.5	124.4	996.5
Percussion	3.48E+05	5.42E+07	367.3	155.6	1437.1	462.9	349.2	1.82E+05	1400.0	8.1	133.9	1048.9
Percussion	9.00E+05	7.16E+07	154.6	79.6	1308.5	1160.8	113.6	4.98E+04	830.0	6.4	129.2	1114.8
Percussion	8.81E+05	1.05E+08	366.3	119.6	1602.2	865.7	299.1	2.75E+05	1560.0	2.5	139.9	1206.0
Percussion	3.01E+06	7.33E+08	588.1	243.1	2602.0	2034.5	469.8	5.48E+05	1900.0	16.8	126.7	1223.3
Percussion	4.49E+06	1.23E+09	1416.6	274.8	2928.9	2807.9	1240.4	1.77E+06	2805.0	65.1	91.6	1256.9

Percussion	1.15E+06	1.11E+08	226.1	96.9	1740.8	1490.1	188.3	5.78E+04	770.0	9.9	158.7	1345.0
Percussion	1.47E+06	2.55E+08	505.9	174.1	2177.5	992.7	501.6	5.67E+05	2185.9	14.4	130.3	1395.8
Percussion	3.43E+05	4.91E+07	276.4	143.3	1478.4	387.8	214.1	1.86E+05	1520.0	3.2	146.8	1424.1
Percussion	9.50E+05	9.14E+07	192.3	96.2	1267.8	1164.0	151.1	6.74E+04	940.0	5.6	123.8	1465.5
Percussion	4.98E+05	3.61E+07	118.3	72.5	1056.3	610.5	92.2	3.54E+04	651.4	1.6	112.0	1672.4
Percussion	1.90E+06	2.03E+08	355.3	107.0	2074.5	1480.0	338.3	1.88E+05	1498.7	13.0	149.2	1672.4
Percussion	9.67E+05	8.71E+07	191.1	90.1	1678.0	1157.4	138.4	7.40E+04	1210.0	5.1	158.7	1818.6
Percussion	1.72E+06	4.26E+08	614.6	248.1	2636.4	899.8	536.1	7.01E+05	2460.0	17.8	130.3	1917.8
Percussion	9.37E+05	1.28E+08	278.3	136.6	1911.4	673.7	226.4	2.54E+05	1675.0	5.1	154.8	1969.1
Percussion	4.53E+06	6.32E+08	282.2	139.4	3011.7	2581.5	247.6	2.74E+05	1925.0	22.7	133.8	2154.1
Percussion	3.99E+05	3.64E+07	220.1	91.3	1313.0	499.4	228.3	1.87E+05	1355.2	4.5	140.3	2182.5
Percussion	7.70E+05	3.43E+07	113.0	44.5	1335.1	886.4	98.3	2.62E+04	670.7	3.0	165.8	2211.8
Percussion	2.94E+06	3.06E+08	167.6	104.1	3012.0	1506.9	121.6	8.37E+04	1455.0	4.9	161.2	2322.5
Percussion	5.99E+06	1.09E+09	602.9	181.9	3128.4	2840.2	549.3	9.01E+05	3070.0	10.4	141.0	2477.0
Percussion	3.16E+06	7.50E+08	506.4	237.5	2662.6	2125.7	404.1	6.71E+05	2660.0	6.7	147.0	2479.4
Percussion	1.93E+06	2.25E+08	328.0	116.8	3241.9	1029.7	289.9	7.12E+04	941.2	7.0	70.0	2504.7
Percussion	3.05E+06	8.02E+08	795.8	262.8	3598.1	1712.2	691.9	1.42E+06	3600.0	12.4	131.8	2510.0
Percussion	6.39E+06	1.59E+09	542.6	248.9	3450.3	2870.2	530.8	7.99E+05	2980.0	31.0	142.9	2553.9
Percussion	6.26E+06	5.17E+08	188.1	82.6	3914.1	3491.1	159.0	9.10E+04	1340.0	12.8	164.7	2667.9
Percussion	3.49E+06	3.49E+08	287.1	99.8	2482.5	2208.7	243.7	3.10E+05	2075.0	8.2	156.5	2673.6
Percussion	8.43E+05	4.46E+07	214.3	52.9	1267.2	1112.9	235.0	7.28E+04	1115.0	12.4	152.8	2718.9
Percussion	3.93E+05	2.27E+07	123.3	57.9	937.0	605.8	118.3	4.55E+04	764.5	4.5	142.3	2975.5
Percussion	8.75E+05	1.45E+08	311.3	165.3	1624.8	749.0	253.5	2.49E+05	1449.0	4.4	134.6	3203.1
Percussion	1.46E+05	1.08E+07	220.0	74.4	1113.3	239.2	195.6	8.37E+04	1164.7	7.8	153.0	3218.5
Percussion	1.92E+06	3.31E+08	419.0	172.7	2849.8	1003.8	427.1	5.98E+05	2771.0	21.9	146.7	3293.9
Percussion	2.26E+05	1.63E+07	127.7	71.8	1245.7	295.2	104.5	8.97E+04	1269.6	3.0	162.2	3319.4
Percussion	6.82E+06	9.42E+08	431.3	138.1	3345.5	3041.5	427.8	6.07E+05	3100.0	17.6	152.9	3369.8
Percussion	2.05E+06	1.65E+08	174.9	80.4	2224.1	1506.0	173.8	1.14E+05	1382.8	10.9	127.8	3523.5
Percussion	1.04E+06	8.94E+07	257.9	85.9	2580.1	682.8	235.7	1.92E+05	2119.7	18.9	158.4	3874.6
Percussion	1.45E+06	4.08E+08	928.2	280.7	4482.5	588.7	842.8	1.43E+06	4685.0	23.9	139.3	3953.0
Percussion	6.48E+06	3.66E+08	150.8	56.6	3761.6	2084.8	157.2	1.32E+05	1840.9	9.4	164.8	4076.3
Percussion	2.25E+06	1.97E+08	182.9	87.5	1957.4	1940.6	148.3	1.30E+05	1600.0	3.6	165.1	4223.1
Percussion	4.10E+06	1.09E+09	572.2	264.5	3523.4	1691.5	370.0	6.27E+05	3380.0	7.6	155.0	4357.6
Percussion	5.95E+05	5.20E+07	225.6	87.3	2211.6	674.7	215.0	2.55E+05	2210.0	13.0	160.3	4454.3
Percussion	2.25E+06	2.81E+08	345.4	124.7	2732.2	1612.1	330.2	3.05E+05	2750.0	17.2	162.5	4610.2
Percussion	9.50E+06	2.34E+09	894.2	246.0	4942.8	3009.3	782.8	1.91E+06	4900.0	25.3	144.8	4755.5
Percussion	1.46E+07	2.26E+09	304.2	155.4	6994.8	3484.0	216.4	2.10E+05	2465.0	15.3	163.6	5126.0
Percussion	5.99E+06	1.66E+09	906.2	276.7	5797.1	1583.6	824.3	2.71E+06	5790.0	8.7	147.6	5535.1
Percussion	5.83E+06	1.09E+09	771.0	187.7	5144.3	1503.1	708.9	1.18E+06	4450.0	16.7	154.7	5711.7

Percussion	9.79E+06	1.44E+09	467.6	147.6	5079.1	2771.9	492.1	6.27E+05	3255.0	19.6	143.5	5819.0
Percussion	1.53E+06	3.54E+08	447.0	231.9	3510.5	691.0	358.5	7.66E+05	3530.0	11.5	162.2	6146.8
Percussion	1.04E+07	8.04E+08	237.0	77.0	7734.0	2334.0	226.4	2.74E+05	2323.9	22.0	150.8	6380.9
Percussion	2.23E+06	2.13E+08	239.8	95.5	3392.3	1014.9	197.6	1.61E+05	1830.0	5.3	150.0	6508.3
Percussion	5.49E+06	9.75E+08	971.7	177.5	6222.5	2193.2	910.4	2.30E+06	6225.0	25.3	147.5	7476.1
Percussion	1.66E+07	2.29E+09	296.6	138.1	6979.1	2976.0	273.8	4.57E+05	3405.0	10.5	155.5	7604.1
Percussion	4.73E+06	1.05E+09	666.9	221.2	5037.1	1744.1	636.4	1.61E+06	5040.0	11.0	147.3	8215.4
Percussion	1.74E+06	2.09E+08	468.6	120.2	3291.3	924.8	409.0	5.14E+05	3310.0	14.4	159.6	8501.2
Percussion	1.06E+07	3.48E+09	645.0	326.9	5580.6	3431.0	535.0	7.89E+05	3810.0	21.3	166.6	9329.6
Percussion	8.30E+06	1.58E+09	476.3	190.2	4556.8	2986.4	398.1	3.41E+05	2860.0	24.6	144.8	10439.1
Percussion	8.93E+05	7.78E+07	210.3	87.2	3274.4	469.8	172.6	2.47E+05	3270.0	8.8	170.4	10440.0
Percussion	3.61E+06	4.69E+08	366.8	129.8	4047.5	1256.7	318.5	7.68E+05	4065.0	8.2	164.9	10723.3
Percussion	2.09E+07	1.25E+10	1416.8	597.9	9509.4	3227.1	1297.6	7.51E+06	9525.0	13.8	154.3	10977.6
Percussion	9.61E+06	1.12E+09	430.4	116.5	5977.9	3431.5	391.4	5.12E+05	3370.0	15.9	144.8	11607.9
Percussion	2.51E+06	2.62E+08	293.5	104.2	4591.0	1134.6	295.7	6.40E+05	4639.6	20.5	165.5	12988.6
Percussion	2.27E+06	3.29E+08	387.1	144.7	3324.0	1365.4	355.4	4.18E+05	3345.0	20.9	154.9	13509.7
Percussion	1.45E+06	9.79E+07	150.6	67.7	2389.4	836.4	143.8	1.63E+05	2360.0	7.7	147.9	15106.1
Percussion	4.71E+05	1.89E+07	128.4	40.0	1400.4	538.2	99.1	5.74E+04	1410.0	6.1	169.3	16315.2
Percussion	1.06E+07	1.55E+09	377.6	145.6	4139.8	3246.2	352.5	6.51E+05	4310.0	10.1	170.5	17047.4
Percussion	1.49E+07	3.56E+09	754.7	238.0	7918.7	3507.2	748.0	2.75E+06	8270.0	17.7	165.7	17954.8
Percussion	1.83E+07	8.24E+09	1587.5	451.4	14196.7	2954.4	1389.7	1.12E+07	13460.0	24.0	159.3	21415.5
Percussion	6.76E+06	9.83E+08	387.8	145.4	6958.3	1674.2	321.3	9.98E+05	6830.0	9.5	170.7	24482.7
Percussion	6.20E+06	5.97E+08	288.9	96.4	4885.1	1879.2	248.5	4.54E+05	4135.0	13.3	171.4	25213.3
Percussion	1.11E+07	2.23E+09	507.8	200.6	8088.0	2215.0	408.4	1.25E+06	7500.0	10.0	172.9	31285.6
Percussion	1.19E+07	4.14E+09	833.9	347.1	9540.8	2016.9	525.6	2.00E+06	9500.0	23.5	171.0	32684.8
Percussion	6.20E+06	4.77E+08	202.1	76.9	5984.3	1922.2	181.2	4.82E+05	5730.0	4.7	173.1	38478.0
Percussion	3.54E+07	1.32E+10	1487.7	372.1	15801.4	4468.9	1445.6	9.83E+06	16285.0	25.0	163.7	42554.6
Percussion	3.85E+06	3.04E+08	191.6	79.0	4929.6	1136.1	197.4	5.37E+05	4995.6	5.1	175.6	52373.0
Percussion	2.48E+06	3.47E+08	233.8	139.8	4044.2	1412.3	148.2	3.48E+05	4050.0	8.7	176.5	59171.9
Percussion	1.20E+07	1.06E+09	217.4	88.7	7320.9	2102.6	217.2	5.97E+05	6380.0	7.0	172.6	79005.8
Trample	2.23E+05	3.68E+06	63.0	16.5	2844.1	150.6	62.3	2.84E+03	115.0	3.8	69.1	50.6
Trample	1.69E+05	3.37E+06	64.2	19.9	1705.7	210.9	48.9	1.88E+03	115.0	3.6	103.1	57.5
Trample	1.48E+06	3.60E+07	78.6	24.3	12966.7	165.2	28.0	1.50E+03	110.0	1.5	125.1	68.0
Trample	1.27E+06	3.03E+07	129.2	23.8	6824.3	313.2	141.5	9.23E+03	185.0	14.5	70.3	72.1
Trample	2.11E+05	1.83E+06	26.2	8.7	2643.2	187.5	14.2	5.62E+02	80.0	1.4	144.2	76.2
Trample	4.03E+05	5.63E+06	53.3	14.0	7443.3	109.9	23.1	9.83E+02	95.0	1.7	131.0	78.6
Trample	1.95E+05	2.38E+06	43.5	12.2	2366.3	129.4	12.3	3.22E+02	80.0	1.2	142.8	80.3
Trample	4.46E+05	5.07E+06	39.6	11.4	6016.6	165.5	26.2	1.70E+03	135.0	1.5	126.4	82.5
Trample	3.13E+05	3.28E+06	38.2	10.5	6835.8	112.5	30.0	1.17E+03	110.0	3.8	132.4	89.4

Trample	4.47E+05	2.81E+06	33.4	6.3	4355.2	362.7	29.6	1.63E+03	130.0	2.5	132.3	91.9
Trample	2.58E+05	4.42E+06	63.1	17.1	7123.5	185.7	58.3	6.08E+03	180.0	4.2	112.8	93.6
Trample	7.51E+05	3.82E+06	30.8	5.1	7039.1	380.2	27.4	1.56E+03	120.0	2.5	127.8	93.7
Trample	3.20E+05	6.97E+06	64.7	21.8	2459.9	254.5	46.2	4.19E+03	165.0	2.0	122.9	96.3
Trample	3.64E+05	2.86E+07	216.1	78.5	1715.5	201.4	206.8	2.14E+04	210.7	7.6	44.2	97.9
Trample	2.44E+05	2.30E+06	32.3	9.4	2762.7	143.0	23.4	1.38E+03	125.0	2.1	137.8	99.0
Trample	5.13E+05	4.22E+06	28.8	8.2	8108.8	220.2	24.4	1.32E+03	125.0	1.8	131.3	115.8
Trample	9.31E+05	8.16E+06	46.5	8.8	10372.5	225.0	44.3	3.56E+03	175.0	3.8	132.9	125.0
Trample	8.79E+05	9.86E+06	50.5	11.2	17542.8	179.8	33.2	2.00E+03	140.0	4.1	142.0	129.5
Trample	1.86E+05	2.35E+06	36.1	12.6	3370.9	134.3	13.0	7.08E+02	110.0	0.9	153.2	130.7
Trample	5.80E+05	1.01E+07	55.2	17.4	7474.1	155.8	26.0	2.41E+03	145.0	1.6	146.0	133.8
Trample	1.90E+05	2.37E+06	35.8	12.4	4326.9	122.8	15.0	6.32E+02	105.0	1.3	135.6	138.9
Trample	1.39E+06	5.31E+07	104.6	38.2	8637.3	338.9	87.9	7.82E+03	235.0	6.5	116.1	143.9
Trample	3.55E+05	2.60E+06	32.2	7.3	6505.2	135.3	28.4	1.14E+03	133.2	3.9	144.6	147.4
Trample	4.23E+05	3.74E+06	28.0	8.9	3718.9	229.2	22.8	1.31E+03	145.0	1.8	144.1	148.8
Trample	3.24E+05	3.26E+06	36.5	10.0	5867.1	134.5	27.6	9.47E+02	133.7	3.4	145.9	154.1
Trample	6.15E+05	6.27E+06	48.9	10.2	6600.2	212.6	37.5	3.13E+03	180.0	3.1	143.3	163.9
Trample	6.54E+05	1.38E+07	67.2	21.1	3165.7	354.5	45.6	5.16E+03	225.0	1.9	129.8	165.4
Trample	2.85E+05	2.97E+06	44.1	10.4	3656.4	180.1	21.1	1.91E+03	160.0	0.6	149.8	167.0
Trample	1.65E+06	3.31E+07	69.8	20.1	10575.6	455.8	46.8	2.45E+03	210.0	5.1	130.1	174.6
Trample	6.24E+05	7.40E+06	44.5	11.8	11381.0	138.0	14.0	8.98E+02	125.0	1.2	153.4	178.3
Trample	2.70E+05	3.59E+06	37.9	13.3	2862.1	173.9	21.3	9.81E+02	130.0	2.3	152.9	178.7
Trample	8.60E+05	3.42E+07	106.7	39.8	3017.9	781.0	107.8	1.61E+04	310.0	5.6	96.1	190.0
Trample	5.76E+05	5.00E+06	52.3	8.7	5538.2	209.4	35.9	1.21E+03	155.0	4.0	138.1	196.2
Trample	4.42E+06	5.29E+07	60.1	11.9	13360.9	602.9	59.5	7.85E+03	283.2	1.9	133.6	200.5
Trample	8.62E+05	1.01E+07	41.8	11.7	8822.1	278.7	57.1	8.29E+03	260.0	1.8	140.1	200.8
Trample	4.62E+06	1.35E+08	131.4	29.1	18530.8	1020.0	134.5	2.13E+04	390.0	3.9	113.6	206.4
Trample	9.91E+05	4.46E+07	127.0	45.0	4106.5	384.5	106.6	1.73E+04	360.0	2.8	120.5	207.6
Trample	1.61E+06	2.12E+07	56.8	13.2	9488.6	527.0	63.2	5.33E+03	255.0	3.3	133.4	213.3
Trample	1.28E+06	1.63E+07	51.9	12.7	17416.6	310.2	30.1	3.68E+03	210.0	2.2	150.3	221.9
Trample	1.35E+06	3.33E+07	80.6	24.7	11556.5	376.3	86.2	1.03E+04	310.0	3.0	120.7	225.4
Trample	2.28E+05	1.38E+06	23.4	6.0	2846.8	142.9	22.0	1.06E+03	140.0	3.0	159.6	251.8
Trample	4.92E+05	6.45E+06	56.4	13.1	7070.2	287.5	39.9	2.11E+03	180.0	4.1	143.5	252.3
Trample	1.04E+06	2.14E+07	56.5	20.5	5668.1	420.7	50.8	5.69E+03	290.0	2.1	145.2	256.7
Trample	3.15E+06	4.65E+07	77.1	14.8	9105.2	723.1	83.1	1.16E+04	345.0	4.7	137.3	268.8
Trample	5.34E+05	8.46E+06	73.5	15.8	4999.0	270.9	32.8	3.63E+03	240.0	2.4	154.3	272.1
Trample	8.32E+05	1.13E+07	63.3	13.6	5286.4	245.7	18.9	1.39E+03	180.0	1.4	155.8	277.0
Trample	5.21E+05	7.13E+06	44.5	13.7	3125.1	234.9	38.1	3.76E+03	230.0	3.1	153.4	285.1
Trample	6.98E+05	9.85E+06	54.9	14.1	5610.8	304.7	40.3	5.99E+03	285.0	3.0	130.2	294.4

Trample	4.90E+05	8.81E+06	42.6	18.0	3577.3	194.7	17.8	1.34E+03	175.0	2.5	161.8	297.4
Trample	2.76E+05	3.17E+06	43.4	11.5	3488.2	207.2	39.9	1.76E+03	170.0	3.9	135.1	319.1
Trample	3.12E+05	3.41E+06	37.3	10.9	3925.6	289.3	40.8	4.71E+03	251.2	1.9	147.8	322.4
Trample	1.27E+06	1.89E+07	43.4	14.9	8284.1	251.1	27.6	2.48E+03	225.0	2.4	158.0	331.7
Trample	1.20E+06	3.45E+07	81.8	28.8	4936.2	545.7	90.4	1.61E+04	425.0	2.5	131.2	339.9
Trample	1.02E+06	1.99E+07	53.6	19.5	5769.5	261.3	30.1	1.79E+03	180.0	3.7	156.9	354.3
Trample	1.85E+06	3.42E+07	62.2	18.5	6210.8	489.9	66.4	1.61E+04	388.5	1.9	138.9	355.4
Trample	1.33E+06	2.72E+07	78.6	20.6	10784.5	284.4	45.2	4.15E+03	280.0	1.6	153.4	358.6
Trample	7.81E+05	9.78E+06	63.5	12.5	7382.2	181.6	21.7	1.56E+03	180.0	1.4	157.0	378.0
Trample	4.94E+05	4.98E+07	225.2	100.8	1199.0	650.7	209.8	6.59E+04	650.0	24.5	108.7	378.3
Trample	1.10E+06	2.31E+07	49.1	21.1	4438.4	397.8	46.3	9.20E+03	355.0	1.3	150.9	378.6
Trample	6.69E+05	6.45E+06	36.0	9.6	8815.1	509.1	22.0	2.32E+03	215.0	1.1	159.6	380.8
Trample	6.14E+05	6.71E+06	57.7	10.9	7845.0	246.1	49.1	5.03E+03	215.0	0.8	106.3	381.8
Trample	7.75E+06	3.99E+08	174.9	51.4	12488.0	1219.1	121.7	2.86E+04	540.0	6.5	129.2	395.4
Trample	1.32E+07	4.21E+08	146.0	31.9	16838.5	2395.8	110.0	1.82E+04	430.0	5.6	120.2	412.9
Trample	1.64E+06	3.96E+07	134.8	24.1	8311.6	510.5	153.9	2.13E+04	450.0	9.2	138.0	420.5
Trample	1.82E+06	4.54E+07	95.4	24.9	8636.5	532.4	95.8	3.12E+04	530.0	3.7	143.6	448.7
Trample	4.21E+05	6.68E+06	48.0	15.9	2200.2	295.7	31.2	3.61E+03	240.0	1.6	134.4	453.7
Trample	2.74E+06	4.08E+08	60.3	14.9	7478.8	626.6	60.2	7.28E+03	355.0	4.4	138.9	476.3
Trample	1.10E+06	4.32E+07	105.4	39.2	3352.9	692.0	101.7	1.99E+04	390.0	4.0	145.1	478.5
Trample	3.40E+06	5.95E+07	78.1	17.5	16482.2	485.6	58.9	7.40E+03	365.0	4.6	158.1	489.7
Trample	3.36E+06	1.48E+08	164.8	44.1	6270.5	880.0	149.7	3.25E+04	620.0	11.7	141.0	505.6
Trample	1.22E+06	1.19E+07	39.2	9.8	7364.6	327.5	31.2	2.37E+03	260.0	2.8	161.6	543.1
Trample	6.71E+05	1.87E+07	78.5	27.9	3464.8	474.0	23.4	3.99E+03	330.0	0.8	163.9	550.9
Trample	4.95E+06	3.14E+08	204.5	63.5	8332.4	939.5	208.7	8.24E+04	785.0	6.5	118.8	557.3
Trample	4.02E+05	6.31E+06	41.5	15.7	3553.0	314.9	26.7	2.10E+03	220.0	2.2	156.6	560.9
Trample	3.34E+06	8.16E+07	100.5	24.4	8728.3	762.0	98.6	1.71E+04	525.0	7.3	146.3	572.3
Trample	4.03E+06	1.52E+08	139.2	37.7	11415.9	929.9	106.0	4.38E+04	515.0	4.1	104.5	593.6
Trample	1.42E+06	1.27E+08	181.6	89.5	2451.5	876.9	175.1	6.96E+04	725.0	7.1	107.8	695.9
Trample	8.92E+05	9.87E+06	52.7	11.1	6009.6	427.6	45.3	9.11E+03	425.0	1.9	161.4	706.3
Trample	4.81E+06	7.92E+07	95.3	16.5	11308.2	1039.9	87.0	1.20E+04	470.0	4.3	156.6	726.9
Trample	2.88E+06	6.74E+07	147.7	23.4	13359.0	562.2	76.4	7.56E+03	520.0	8.2	153.5	738.1
Trample	1.42E+06	3.01E+07	69.7	21.2	9981.4	358.7	19.6	2.27E+03	270.0	1.2	165.5	757.8
Trample	1.19E+06	6.41E+07	141.0	53.8	2822.5	617.0	167.9	5.24E+04	635.0	10.8	103.5	768.8
Trample	1.69E+06	4.89E+07	82.5	28.9	6659.1	734.3	74.8	1.73E+04	490.0	3.4	158.9	774.4
Trample	3.89E+06	3.78E+07	42.1	9.7	8126.9	1074.6	35.8	3.89E+03	350.0	2.9	163.9	781.0
Trample	1.14E+07	5.72E+08	145.3	50.1	15784.1	1639.8	140.7	5.40E+04	860.0	4.6	148.5	830.5
Trample	4.56E+06	1.31E+08	87.8	28.7	9005.6	892.1	88.6	2.97E+04	625.0	3.4	135.3	843.0
Trample	3.09E+06	1.02E+08	105.4	33.0	9881.7	795.8	100.6	3.44E+04	730.0	4.5	144.1	867.4

Trample	1.94E+06	2.28E+07	57.5	11.8	9534.7	603.8	56.4	1.30E+04	465.0	3.3	161.0	878.0
Trample	1.13E+06	2.41E+07	66.2	21.4	7006.5	586.2	56.7	1.25E+04	533.7	6.4	158.9	965.9
Trample	1.62E+06	3.07E+07	79.1	19.0	4593.5	690.7	92.1	6.26E+03	545.0	12.6	141.1	999.1
Trample	6.76E+05	1.02E+07	47.6	15.2	6688.8	200.0	11.1	9.93E+02	195.0	1.2	170.3	1001.9
Trample	3.77E+06	1.81E+08	164.6	48.0	10480.2	679.3	159.6	5.64E+04	660.0	7.6	151.9	1008.0
Trample	6.81E+06	4.14E+08	157.0	60.8	11843.3	1070.5	127.9	4.45E+04	730.0	13.2	155.8	1029.1
Trample	1.87E+05	5.74E+06	64.7	30.7	2757.1	198.2	14.5	1.15E+03	195.0	1.1	157.3	1111.4
Trample	2.90E+07	1.41E+09	175.3	48.5	22031.7	2970.3	202.2	6.62E+04	995.0	13.7	136.3	1142.6
Trample	1.08E+06	1.14E+07	38.3	10.6	10923.9	306.5	13.5	1.61E+03	270.0	1.3	172.5	1149.3
Trample	6.21E+06	4.64E+08	157.8	74.7	6695.6	1585.7	112.5	5.82E+04	945.0	5.7	153.1	1149.8
Trample	2.95E+06	4.83E+07	53.2	16.3	7290.9	498.1	58.6	1.12E+04	415.0	5.0	170.4	1151.9
Trample	3.50E+06	1.59E+08	135.6	45.5	6776.7	1164.9	141.9	3.65E+04	723.7	10.5	150.0	1169.0
Trample	3.93E+06	7.93E+07	88.7	20.2	10083.0	684.0	89.8	1.60E+04	460.0	2.7	122.8	1328.5
Trample	4.18E+06	1.70E+08	134.5	40.7	6313.2	1234.8	164.0	8.78E+04	1120.0	5.5	156.4	1499.2
Trample	9.76E+06	8.96E+08	222.9	91.8	8985.1	1552.7	214.5	1.31E+05	1135.0	6.2	146.1	1532.6
Trample	4.90E+05	7.36E+06	38.6	15.0	3260.9	364.5	18.0	2.59E+03	305.0	1.0	170.9	1542.8
Trample	1.88E+06	2.42E+07	43.8	12.9	8296.6	416.5	24.2	3.06E+03	330.0	1.5	164.1	1640.6
Trample	6.20E+06	1.06E+08	78.1	17.2	8268.0	958.6	72.4	2.99E+04	770.0	3.9	165.1	1701.1
Trample	7.48E+06	4.96E+08	149.1	66.4	10342.8	2021.1	154.8	1.04E+05	1045.0	6.8	161.1	1718.6
Trample	2.02E+06	2.62E+08	290.6	129.5	2296.9	1945.7	304.2	3.27E+05	1730.0	6.0	149.4	1787.4
Trample	3.15E+07	1.87E+09	224.7	59.3	27795.1	2146.1	228.0	1.34E+05	1255.0	5.0	134.0	1851.6
Trample	5.08E+06	1.01E+08	112.5	20.0	8086.0	1063.3	102.2	3.92E+04	995.0	4.5	159.3	1926.9
Trample	1.74E+07	8.29E+08	202.9	47.6	18017.2	1587.3	223.3	1.04E+05	915.0	9.9	152.8	1958.7
Trample	1.32E+07	3.84E+08	90.0	29.0	16634.1	2105.9	77.7	2.37E+04	825.0	7.2	166.9	2087.1
Trample	4.32E+06	3.12E+07	52.8	7.2	10827.0	887.0	56.6	5.72E+03	510.0	6.2	169.8	2101.8
Trample	1.02E+06	2.65E+07	70.2	25.9	7436.1	465.3	20.7	4.07E+03	415.0	1.2	173.7	2251.0
Trample	4.21E+06	1.68E+08	123.4	40.0	7862.4	1750.0	123.3	4.75E+04	1095.0	5.4	158.2	2394.5
Trample	4.71E+06	4.75E+07	39.1	10.1	10874.8	610.7	34.5	7.02E+03	545.0	2.9	170.9	3062.6
Trample	2.23E+06	2.62E+07	83.1	11.7	4038.2	942.8	97.9	2.91E+04	930.0	6.2	168.0	3095.0
Trample	6.18E+06	1.84E+08	104.5	29.8	7063.1	1641.8	97.8	5.34E+04	1230.0	3.6	168.5	3119.5
Trample	5.78E+06	1.25E+08	86.8	21.6	12618.1	949.2	50.6	5.75E+03	645.0	5.6	170.1	3364.8
Trample	1.35E+07	9.35E+08	199.3	69.3	22312.3	1505.2	160.0	8.62E+04	1350.0	7.4	169.8	3439.3
Trample	7.26E+06	4.46E+08	152.7	61.5	4922.2	2120.3	155.4	9.67E+04	1555.0	3.8	157.1	4124.4
Trample	1.08E+07	4.23E+08	137.1	39.4	11545.2	2375.9	147.7	4.79E+04	955.0	5.5	151.4	5589.1
Trample	6.03E+05	5.75E+06	51.1	9.5	4685.2	414.2	59.3	7.75E+03	405.0	2.9	95.1	6010.9
Trample	1.49E+07	5.65E+08	132.5	38.1	9414.5	2127.4	123.6	8.06E+04	1750.0	5.5	171.7	6184.8
Trample	4.46E+06	1.65E+08	129.9	37.1	3362.3	2457.6	125.9	9.37E+04	1720.0	9.1	171.4	6508.9
Trample	7.27E+06	5.93E+07	48.2	8.2	17059.6	892.5	44.0	8.03E+03	730.0	2.2	171.6	6654.9
Trample	1.66E+07	1.18E+09	209.8	71.4	10754.4	2352.8	191.6	1.63E+05	2190.0	19.3	173.5	11594.1

Trample	2.14E+07	3.06E+08	49.7	14.3	16348.1	1636.0	37.2	2.23E+04	1370.0	2.4	176.8	15354.2
Trample	7.65E+05	1.16E+07	46.5	15.2	3277.7	641.2	43.8	5.99E+03	525.0	2.2	140.2	19229.2
Trample	1.99E+07	6.37E+08	146.2	32.1	21243.5	3114.0	135.7	5.50E+04	1845.0	10.1	176.5	42516.4
Trample	6.12E+06	7.78E+07	80.4	12.7	7849.3	2221.9	82.5	3.15E+04	1610.0	3.8	168.8	47056.5

APPENDIX J – RAW DATA FROM THE EXPERIMENTALLY PRODUCED HUMAN AND CARNIVORE TOOTH MARKS

		Three Dimensional Measurements						**Two Dimensional Measurements**					
Species	**Mark ID**	**Surface Area**	**Volume**	**Maximum Depth**	**Mean Depth**	**Maximum Length**	**Maximum Width**	**Maximum Depth**	**Area**	**Width**	**Roughness**	**Angle**	**Radius**
Human	1.01a	5.33E+05	4.29E+07	173.4	80.3	1885.0	527.0	142.0	2.28E+04	314.7	2.9	91.8	157.2
Human	1.01b	9.05E+05	5.38E+07	130.9	59.5	1794.6	917.8	100.9	3.18E+04	686.9	6.1	148.0	696.3
Human	1.02b	1.94E+05	1.33E+07	139.8	68.5	578.8	394.3	72.9	9.86E+03	289.7	1.0	115.2	327.4
Human	1.02c	2.05E+05	1.09E+07	100.3	52.9	925.4	310.9	104.8	1.64E+04	215.8	2.7	103.2	108.9
Human	1.02d	1.65E+05	8.55E+06	113.0	51.7	796.4	341.5	123.9	1.78E+04	213.0	2.0	83.8	94.9
Human	1.02e	1.60E+05	6.01E+06	99.9	37.7	891.5	303.3	87.5	1.19E+04	330.1	1.0	88.4	483.8
Human	1.03a	1.85E+05	1.60E+07	172.0	86.7	550.8	444.4	102.8	1.69E+04	476.8	2.4	124.9	288.8
Human	1.04a	1.29E+05	1.44E+07	180.3	111.5	686.6	300.9	168.5	3.99E+04	310.3	1.5	98.4	157.8
Human	1.04b	1.45E+05	1.02E+07	119.2	70.5	605.4	384.7	126.4	2.94E+04	383.8	1.7	112.1	263.0
Human	1.04c	3.85E+04	1.99E+06	79.5	51.5	269.5	187.5	75.1	8.57E+03	176.0	1.7	97.3	93.7
Human	2.01a	1.24E+06	1.01E+08	158.0	81.2	1803.2	916.6	170.4	1.13E+05	972.2	5.1	150.9	1051.7
Human	2.01b	1.88E+05	1.01E+07	102.8	53.6	630.4	425.8	97.6	1.84E+04	402.9	3.6	110.6	305.3
Human	2.01c	1.84E+05	1.05E+07	118.3	56.9	637.0	385.6	111.9	2.54E+04	373.1	1.8	119.9	335.0
Human	2.01d	2.86E+05	1.20E+07	112.0	42.1	918.8	399.9	122.2	2.88E+04	421.1	3.3	134.5	1057.5
Human	2.01e	5.07E+05	3.40E+07	127.6	67.0	1802.5	395.6	125.5	2.82E+04	419.7	3.6	136.4	338.7
Human	2.01f	7.44E+05	5.47E+07	138.3	73.5	2380.9	518.1	146.8	3.15E+04	428.4	3.2	90.6	191.1
Human	3.01a	2.47E+05	7.42E+06	61.0	30.0	889.4	412.1	58.7	1.18E+04	419.0	2.2	136.3	462.4
Human	3.01b	1.12E+05	4.24E+06	84.3	37.9	443.1	395.6	65.9	9.73E+03	360.0	1.7	133.1	391.1
Human	3.01c	6.92E+04	1.75E+06	61.2	25.3	567.6	204.7	48.8	5.51E+03	213.1	1.7	100.8	140.3
Human	3.01d	2.16E+05	9.67E+06	79.6	44.7	841.1	375.0	70.1	1.60E+04	355.8	2.3	133.8	245.2
Human	3.02a	1.56E+06	8.36E+07	128.1	53.6	1829.7	1758.4	141.5	1.30E+05	1841.2	10.2	171.5	11438.0
Human	5.01a	1.40E+06	1.35E+08	198.0	96.6	1822.6	1320.9	153.0	6.06E+04	650.0	16.6	142.3	531.1
Human	5.01b	1.42E+05	1.04E+07	141.5	73.3	764.2	297.2	96.0	1.22E+04	249.8	4.6	111.8	133.4
Human	5.01d	5.08E+05	2.98E+07	116.8	58.6	1822.4	519.3	116.5	2.97E+04	469.9	2.2	131.0	318.3
Human	5.01e	1.94E+05	1.27E+07	125.1	65.6	797.5	353.2	88.8	1.47E+04	308.1	3.3	110.5	234.8
Human	5.01f	3.91E+05	3.00E+07	151.4	76.7	1278.1	446.0	134.2	2.08E+04	359.8	6.5	109.1	175.5
Human	5.02a	9.63E+05	8.51E+07	165.6	88.4	1795.1	949.6	159.1	7.02E+04	869.1	11.5	156.6	1017.2
Human	5.02b	2.11E+05	1.27E+07	103.5	60.2	1045.6	392.9	78.5	1.11E+04	366.1	1.3	104.7	328.1
Human	5.02c	1.30E+05	7.32E+06	100.2	56.2	711.3	235.8	71.5	1.00E+04	210.8	4.3	104.1	114.9
Human	5.02d	1.21E+06	4.34E+07	112.6	35.8	2538.4	745.0	123.8	3.81E+04	660.3	13.0	147.7	696.0
Human	5.02e	1.67E+05	6.87E+06	101.6	41.2	1141.6	260.0	96.4	1.26E+04	262.3	2.2	89.6	346.3
Human	5.03a	3.43E+05	1.30E+07	77.5	38.0	1161.1	534.4	71.2	1.77E+04	490.6	1.5	158.5	815.7
Human	5.03b	3.82E+04	1.16E+06	60.2	30.4	472.5	117.4	36.0	2.08E+03	114.0	0.5	86.5	51.2
Human	5.03c	3.39E+05	1.11E+07	54.1	32.7	1052.4	525.5	59.2	1.53E+04	434.7	1.7	156.3	638.7

Human	5.03d	8.81E+04	2.37E+06	62.5	26.8	586.5	190.6	48.0	3.98E+03	263.7	3.0	134.4	210.9
Human	7.01a	5.56E+05	9.58E+07	293.9	172.5	1369.9	506.7	370.1	1.47E+05	585.0	10.4	79.2	246.9
Human	7.02a	9.17E+05	6.25E+07	174.3	68.2	1313.2	829.7	161.7	6.70E+04	817.0	7.6	104.8	4219.9
Human	7.02b	2.07E+05	2.10E+07	181.2	101.8	663.6	448.5	159.0	4.97E+04	485.8	2.0	122.4	281.0
Human	7.02c	3.42E+05	4.02E+07	212.0	117.5	1027.4	525.6	187.5	6.32E+04	585.1	9.4	121.1	340.7
Human	7.02d	2.39E+06	3.53E+08	266.4	148.1	2277.6	1714.2	302.0	3.68E+05	1756.1	18.2	133.8	2705.7
Human	9.01a	1.10E+06	1.09E+08	207.1	98.6	1783.9	855.8	151.4	5.36E+04	680.3	6.2	128.2	510.1
Human	9.02a	1.49E+06	1.03E+08	152.7	69.2	3061.3	760.1	138.1	5.47E+04	808.2	8.5	145.2	751.3
Human	9.02b	1.54E+06	9.21E+07	140.2	59.7	3908.6	599.3	150.5	4.06E+04	496.9	3.4	126.6	444.7
Human	9.02c	5.99E+05	3.45E+07	116.9	57.6	2020.3	432.7	113.0	2.30E+04	460.8	2.8	123.8	364.8
Human	9.03a	1.21E+06	1.09E+08	207.8	89.9	1723.5	1167.9	204.7	1.01E+05	824.7	11.2	125.2	610.8
Human	10.01a	3.18E+05	1.64E+07	101.6	51.7	1081.0	366.9	80.7	1.67E+04	389.8	1.1	124.8	246.4
Human	10.02a	8.53E+05	1.16E+08	247.5	135.8	1277.2	979.2	229.6	1.52E+05	1042.7	6.8	142.1	876.8
Human	10.02b	1.35E+06	2.21E+08	262.2	163.6	1513.8	1383.7	183.5	1.64E+05	1396.2	6.5	153.3	2135.3
Human	10.03a	4.51E+05	2.28E+07	99.1	50.6	1269.0	530.5	68.9	1.17E+04	439.7	2.9	136.8	4728.1
Human	10.03b	6.29E+05	2.63E+07	96.9	41.8	1212.7	836.2	85.6	2.82E+04	834.9	7.7	166.5	1929.6
Human	10.04a	6.12E+05	2.27E+07	75.9	37.1	1241.7	687.3	65.2	2.53E+04	689.6	3.3	163.2	1348.2
Human	10.05a	3.07E+05	1.95E+07	130.6	63.7	905.4	520.3	91.7	1.67E+04	319.6	3.6	112.4	163.2
Human	11.01a	1.71E+06	1.13E+08	157.5	66.1	1711.0	1412.9	103.5	3.23E+04	1250.3	6.7	165.6	2712.4
Human	11.01b	1.11E+06	6.05E+07	136.0	54.4	1471.5	1371.2	121.9	6.02E+04	839.5	10.5	130.0	2629.5
Human	11.02a	1.48E+06	7.37E+07	120.5	49.7	1643.8	1565.8	120.3	6.95E+04	1295.6	4.6	149.8	13596.3
Human	11.03a	5.49E+05	3.04E+07	102.9	55.4	1619.6	590.6	105.9	4.18E+04	694.8	7.7	164.0	1275.8
Human	11.03b	2.86E+06	1.39E+08	106.7	48.7	3390.6	1096.2	128.0	5.81E+04	860.1	5.4	158.1	1287.0
Human	12.01a	1.52E+06	1.16E+08	161.6	75.9	2463.6	1452.9	131.9	6.41E+04	1249.6	9.4	167.0	2487.9
Human	12.01b	5.47E+05	4.61E+07	148.2	84.1	1181.5	900.9	142.6	3.13E+04	739.9	6.2	104.9	44581.7
Human	12.02a	2.27E+05	6.17E+06	65.7	27.2	655.5	498.0	62.7	1.55E+04	460.3	0.9	151.6	493.2
Human	12.03a	1.82E+05	5.91E+06	84.2	32.5	745.3	465.9	73.0	1.26E+04	343.8	2.9	130.7	242.6
Human	13.01a	2.77E+06	1.19E+08	117.3	43.0	3167.7	1417.7	94.2	2.25E+04	664.7	7.6	144.6	2318.1
Human	13.01b	1.60E+06	6.98E+07	106.7	43.5	1942.7	1264.5	81.9	2.19E+04	960.5	2.9	147.1	5534.8
Human	13.02a	1.94E+06	1.11E+08	127.2	57.4	2442.9	1135.4	129.1	3.08E+04	403.3	3.4	112.3	287.6
Human	13.02c	1.01E+06	4.87E+07	110.2	48.0	2613.0	815.4	90.2	1.88E+04	476.8	1.0	123.8	698.9
Human	13.02d	7.86E+05	4.16E+07	92.1	53.0	2448.0	556.8	75.6	1.23E+04	308.3	1.2	114.2	208.7
Human	13.03a	3.74E+06	2.51E+08	174.5	67.0	4696.9	1181.0	173.4	6.34E+04	619.6	9.9	136.0	1079.1
Human	14.01c	2.98E+05	2.12E+07	125.6	71.2	1831.8	249.7	116.7	2.38E+04	299.8	2.2	103.9	182.8
Human	14.02a	1.54E+06	1.11E+08	174.9	71.9	2252.4	1028.9	147.1	5.05E+04	984.5	12.4	153.0	1335.2
Human	14.02b	8.45E+05	8.98E+07	246.2	106.4	1528.8	922.6	185.0	6.23E+04	753.7	12.3	118.3	401.9
Human	14.02c	9.09E+05	1.08E+08	225.8	118.4	1976.6	727.2	221.1	8.90E+04	653.8	7.5	121.1	485.3
Human	14.02d	6.98E+05	6.79E+07	186.5	97.3	1654.5	732.6	185.9	8.09E+04	634.8	15.4	126.4	450.6
Human	14.02e	5.46E+05	6.95E+07	236.1	127.2	1171.3	888.0	175.0	7.99E+04	800.9	10.8	127.6	812.9

Human	14.04a	1.51E+06	9.98E+07	124.7	66.0	3383.5	661.3	132.5	5.30E+04	658.8	13.0	125.7	1697.0
Human	14.04c	4.14E+05	2.30E+07	117.8	55.4	1971.9	310.0	114.7	2.05E+04	346.1	4.6	112.4	196.2
Human	14.05a	6.95E+05	1.07E+08	298.4	153.5	1974.9	730.9	228.8	7.95E+04	656.0	6.3	105.7	333.2
Human	14.05b	8.77E+05	7.38E+07	200.9	84.2	1767.9	885.7	188.6	8.66E+04	864.2	11.9	137.7	670.0
Human	14.05c	6.49E+05	7.54E+07	230.5	116.2	1731.8	603.7	174.6	4.67E+04	437.7	3.1	106.8	234.2
Human	15.04a	2.28E+06	1.47E+08	149.4	64.5	2159.2	1888.7	124.1	8.02E+04	1268.8	5.3	157.8	2090.3
Human	15.04b	7.92E+05	8.77E+07	311.5	110.7	1248.8	1172.8	217.7	6.30E+04	996.2	10.7	122.0	2069.8
Human	15.05a	1.05E+06	7.18E+07	150.5	68.5	2082.3	1044.7	167.3	9.03E+04	1074.9	7.4	147.7	1141.5
Human	15.05b	4.68E+05	5.12E+07	161.6	109.5	1464.0	725.0	115.4	2.93E+04	330.7	0.5	84.6	229.5
Human	15.06a	2.14E+06	1.35E+08	156.2	63.1	3207.0	1093.0	128.0	3.29E+04	673.1	15.7	156.5	942.2
Human	15.06b	4.51E+05	2.83E+07	149.6	62.8	1539.9	486.8	120.6	1.93E+04	315.5	3.2	110.8	157.9
Human	15.06c	1.72E+06	9.76E+07	174.3	56.9	3510.9	803.1	156.8	3.65E+04	667.8	1.6	87.8	1239.8
Human	16.01a	5.02E+05	2.33E+07	107.2	46.4	1080.0	832.4	98.3	2.43E+04	594.4	6.9	138.1	2134.9
Human	16.01b	4.70E+05	3.48E+07	149.1	74.0	1118.3	637.5	72.2	1.64E+04	671.4	10.3	160.3	989.0
Human	16.01c	6.92E+05	3.66E+07	98.2	53.0	1453.0	701.8	105.7	4.10E+04	710.2	3.3	138.5	2174.7
Human	17.01a	5.71E+05	3.35E+07	111.2	58.7	1352.1	559.7	123.1	4.61E+04	525.9	8.3	166.3	1010.4
Human	17.02a	7.12E+05	2.18E+07	74.5	30.6	1618.3	800.5	76.9	2.98E+04	809.1	7.4	173.7	3649.1
Human	17.02b	8.76E+05	8.25E+07	160.5	94.2	1413.1	772.3	88.8	4.12E+04	718.5	3.2	162.5	1797.9
Human	17.03a	8.12E+05	6.17E+07	148.3	76.1	1772.0	680.2	141.8	5.18E+04	637.3	6.4	134.8	492.8
Human	18.01a	7.06E+05	6.29E+07	159.9	89.2	1436.6	646.5	107.9	3.19E+04	698.0	6.5	112.8	2350.2
Human	18.02a	5.13E+06	3.17E+08	165.9	61.9	5165.0	1737.5	174.5	1.44E+05	1683.6	21.6	171.6	6238.5
Human	18.03a	2.24E+05	1.38E+07	111.0	61.6	972.1	364.3	76.9	7.46E+03	189.8	1.9	86.4	79.8
Human	18.03b	4.52E+05	2.28E+07	107.1	50.4	976.3	705.5	85.8	3.04E+04	770.2	3.6	146.5	1989.1
Human	18.03c	1.37E+05	9.71E+06	123.4	70.8	578.4	397.2	106.3	2.00E+04	331.9	2.4	109.1	165.3
Human	18.03e	1.21E+06	8.79E+07	165.0	72.7	2839.4	826.5	156.8	7.60E+04	785.4	6.1	142.8	698.8
Human	18.04a	1.29E+06	6.25E+07	100.9	48.5	1591.6	1248.2	97.6	5.66E+04	1019.9	3.1	162.6	1709.3
Human	18.04b	5.73E+05	3.61E+07	147.9	63.0	1084.7	693.1	129.0	4.41E+04	609.7	5.5	138.7	539.6
Human	18.04c	4.48E+05	1.57E+07	70.5	35.1	1215.8	538.2	53.8	1.34E+04	499.8	0.8	147.6	583.1
Human	18.05a	5.28E+05	2.38E+07	112.1	45.0	1118.5	589.2	102.2	2.40E+04	402.0	1.5	119.1	274.4
Human	19.02a	5.51E+05	3.72E+07	151.5	67.5	1373.4	673.0	119.2	2.96E+04	630.1	5.2	123.5	639.5
Human	19.03a	4.79E+05	4.71E+07	166.6	98.3	855.5	819.2	114.7	3.11E+04	521.4	6.8	131.8	359.2
Human	19.03b	4.39E+05	2.10E+07	103.9	47.7	857.6	710.1	79.5	1.87E+04	573.7	10.9	150.6	952.0
Human	19.04b	5.88E+05	3.39E+07	121.2	57.6	1745.3	562.0	100.2	2.53E+04	528.6	5.7	144.7	591.2
Human	19.04c	1.42E+05	5.17E+06	62.2	36.5	814.4	249.4	50.8	6.22E+03	243.1	2.7	130.3	242.0
Human	19.04d	4.03E+05	1.31E+07	98.7	32.4	1169.4	480.1	82.2	1.33E+04	444.9	3.0	118.8	397.6
Human	19.04e	1.24E+06	8.58E+07	121.1	69.2	1513.4	1242.9	101.7	5.46E+04	917.9	8.0	161.8	1390.6
Human	19.04f	3.56E+05	1.28E+07	107.8	35.8	1074.3	553.1	100.0	1.93E+04	453.8	2.9	131.6	308.3
Human	19.05a	1.11E+06	8.58E+07	131.3	77.3	1601.9	1130.4	87.8	5.54E+04	1110.3	3.7	141.6	81125.0
Human	20.01a	1.59E+06	1.62E+08	242.0	101.8	1987.2	1253.3	232.5	1.72E+05	1362.2	8.7	155.5	1806.3

Human	20.01c	4.72E+05	3.76E+07	170.9	79.7	1275.9	598.7	123.3	3.01E+04	540.0	8.9	134.2	439.8
Human	20.02a	8.28E+05	1.52E+08	336.5	183.4	1891.6	772.6	321.4	1.38E+05	765.3	14.1	108.8	469.4
Human	20.02b	1.33E+06	1.24E+08	211.4	93.2	2957.2	666.4	182.2	6.59E+04	639.7	10.8	124.4	457.2
Human	20.03a	1.26E+06	1.55E+08	255.7	123.2	2024.3	906.8	188.3	8.40E+04	903.9	8.9	138.2	814.9
Human	20.03c	3.80E+05	3.29E+07	164.4	86.6	1526.6	330.7	120.8	2.25E+04	296.1	2.7	101.8	141.5
Human	20.04a	1.07E+06	8.47E+07	166.2	79.1	1577.9	1047.7	159.7	8.43E+04	1027.9	7.5	137.5	1573.3
Human	20.05a	5.68E+05	3.70E+07	128.3	65.2	1449.2	667.0	103.6	2.28E+04	405.9	5.8	118.3	283.5
Human	20.05b	3.18E+05	2.71E+07	141.4	85.2	1227.8	394.0	146.8	3.72E+04	427.0	4.6	108.4	323.6
Human	20.05c	2.19E+06	2.34E+08	201.6	106.6	3243.3	1018.0	172.7	9.24E+04	984.7	13.8	137.8	1798.7
Human	20.06a	7.00E+05	6.58E+07	189.3	94.0	2115.8	488.3	156.9	4.52E+04	441.9	2.2	104.9	215.8
Human	20.06b	4.61E+05	2.70E+07	117.3	58.7	1258.4	435.8	93.8	1.94E+04	417.3	2.3	132.7	318.1
Human	20.06c	5.74E+05	3.51E+07	117.0	61.2	1673.5	618.8	87.3	2.21E+04	758.1	6.6	145.8	1034.7
Human	20.06d	9.11E+05	8.09E+07	204.5	88.9	1466.6	1012.3	161.5	6.04E+04	860.6	7.5	138.2	664.4
Human	20.06e	3.54E+05	1.83E+07	102.6	51.7	1164.3	376.6	95.4	2.01E+04	431.1	1.3	119.2	323.7
African Wild Dog	DZD1-1	1.83E+06	1.60E+08	152.8	87.3	2548.6	1120.7	111.3	6.35E+04	1170.0	3.3	152.8	1506.8
African Wild Dog	DZD1-2	1.41E+06	1.03E+08	170.1	73.6	2231.6	796.3	164.4	6.16E+04	685.0	10.6	132.5	440.4
African Wild Dog	DZD1-4A	2.83E+06	2.96E+08	216.6	104.7	2488.7	1618.0	192.0	1.49E+05	1480.0	6.6	155.2	2209.6
African Wild Dog	DZD1-4B	2.97E+06	3.27E+08	222.4	110.3	2529.0	1522.9	264.6	2.38E+05	1635.0	20.8	150.7	1681.4
African Wild Dog	DZD1-5	5.13E+06	4.00E+08	160.0	78.0	5959.3	1130.4	142.2	8.20E+04	1370.0	2.6	167.4	4567.8
African Wild Dog	DZD2-1	1.79E+06	8.56E+07	114.5	47.7	2324.5	1094.4	103.2	4.65E+04	1030.0	4.4	166.1	8862.5
African Wild Dog	DZD4-2	4.48E+05	2.35E+07	116.1	52.5	949.4	556.0	74.7	1.47E+04	490.0	2.4	149.7	675.3
African Wild Dog	DZD4-3A	7.64E+05	5.27E+07	153.0	69.0	1727.0	626.3	151.7	5.18E+04	895.0	7.4	144.8	912.6
African Wild Dog	DZD4-3B	5.92E+05	4.12E+07	127.3	60.7	1249.7	584.5	93.5	2.91E+04	640.0	3.8	142.6	706.4
African Wild Dog	DZD4-4	2.89E+05	2.54E+07	158.6	87.8	883.9	383.2	103.5	2.10E+04	460.0	2.3	116.4	261.5
African Wild Dog	DZD4-5	6.77E+05	2.00E+07	77.3	29.6	1201.2	704.1	70.8	2.40E+04	915.0	3.5	163.9	2475.3
African Wild Dog	DZD4-6	1.01E+06	3.11E+07	74.2	30.9	1371.1	1096.1	66.9	3.45E+04	950.0	2.6	170.4	2560.8
African Wild Dog	DZD4-7	3.14E+05	6.98E+06	61.0	22.3	829.1	486.1	59.4	1.18E+04	430.0	2.0	162.9	700.1
African Wild Dog	DZD4-8	1.17E+06	5.14E+07	118.1	44.0	1895.5	896.0	107.8	4.92E+04	850.0	3.8	154.0	1187.6
African Wild Dog	DZD4-9	2.25E+06	1.54E+08	137.0	68.2	2407.4	1052.4	131.2	9.52E+04	1290.0	3.4	157.7	1757.2
African Wild Dog	DZD4-10	1.24E+06	7.07E+07	105.4	44.8	1710.7	811.5	99.4	5.21E+04	850.0	3.1	158.2	1214.9
African Wild Dog	DZD4-11	9.87E+05	4.28E+07	112.4	43.3	2740.4	653.1	117.3	3.70E+04	665.0	5.7	151.7	796.7
African Wild Dog	DZD4-12	2.14E+06	1.83E+08	222.3	85.7	2389.2	1244.7	206.0	1.32E+05	1345.0	3.0	144.4	1334.2
African Wild Dog	DZD4-14	3.74E+05	5.48E+06	54.5	14.6	1481.2	325.5	52.5	6.79E+03	340.0	2.6	156.9	536.0
African Wild Dog	DZD4-15A	3.58E+05	5.11E+06	47.9	14.2	1467.3	307.3	49.8	8.47E+03	360.0	2.0	162.6	608.6
African Wild Dog	DZD4-15B	3.89E+05	5.86E+06	61.2	15.0	1495.1	343.7	55.2	5.11E+03	320.0	3.2	151.2	463.5
African Wild Dog	DZD6-1	1.24E+06	6.03E+07	117.8	48.4	2870.5	590.2	127.5	4.77E+04	735.0	4.4	139.3	569.7
African Wild Dog	DZD7-1	7.01E+05	2.62E+07	92.1	37.4	1164.1	809.7	92.3	3.92E+04	830.0	2.1	153.9	1307.3
African Wild Dog	DZD7-2	2.06E+05	5.40E+06	76.3	26.1	612.3	363.2	61.5	8.56E+03	315.0	2.9	144.9	271.2
African Wild Dog	DZD7-3	5.16E+05	1.42E+07	73.5	26.8	1157.8	573.2	68.6	2.01E+04	550.0	2.6	155.0	925.2

African Wild Dog	DZD7-4	6.42E+05	1.09E+07	52.3	16.9	1697.1	546.7	52.0	1.26E+04	525.0	2.7	166.2	1197.3
African Wild Dog	DZD8-1A	5.50E+05	2.47E+07	83.3	44.9	1106.4	643.4	98.4	4.90E+04	870.0	3.2	157.4	1114.7
African Wild Dog	DZD8-1B	2.47E+05	9.97E+06	77.7	40.3	615.0	496.3	53.1	1.27E+04	460.0	2.7	157.6	635.7
African Wild Dog	DZD8-1C	2.84E+05	1.30E+07	98.4	46.0	723.1	454.1	77.1	1.44E+04	380.0	1.9	153.3	470.1
African Wild Dog	DZB8-2A	2.79E+05	4.93E+06	48.0	17.7	810.6	567.2	43.2	9.54E+03	580.0	3.0	152.0	3683.8
African Wild Dog	DZB8-2B	3.38E+04	7.66E+05	43.8	22.6	223.6	191.4	35.1	3.95E+03	180.0	2.0	145.2	167.0
Gray Wolf	WSN1-1	2.29E+06	1.08E+08	137.8	47.4	2387.3	1423.3	147.3	1.14E+05	1780.0	7.2	164.7	3786.3
Gray Wolf	WSN2-1	8.93E+05	7.42E+07	224.9	83.0	1141.9	1049.6	216.6	1.35E+05	1240.0	8.9	141.2	1018.9
Gray Wolf	WSN2-2	4.85E+05	2.48E+07	128.0	51.2	1099.1	550.0	139.3	7.15E+04	975.0	3.6	146.4	894.7
Gray Wolf	WSN2-3	2.06E+06	9.36E+07	123.1	45.4	2018.9	1454.9	115.9	9.51E+04	1515.0	3.9	159.4	3366.6
Gray Wolf	WSH1-2	2.92E+06	2.07E+08	147.2	70.8	1839.3	2112.4	162.6	2.21E+05	2055.0	6.7	164.7	4340.5
Gray Wolf	WSH1-3	4.30E+06	5.78E+08	381.8	134.6	3136.3	1725.4	401.5	3.92E+05	2070.0	12.8	134.1	1417.5
Gray Wolf	WSH1-4	4.15E+06	4.78E+08	324.2	115.2	3393.5	1844.7	331.9	2.77E+05	1675.0	9.7	132.6	1150.8
Gray Wolf	WSH1-5	2.79E+06	1.73E+08	150.5	62.0	2625.1	1163.3	158.4	1.06E+05	1610.0	7.1	156.6	4149.4
Gray Wolf	WSH1-7	8.72E+05	5.96E+07	156.1	68.4	1620.7	974.3	163.3	9.08E+04	1190.0	5.5	150.5	1202.6
Gray Wolf	WSH1-8	1.54E+06	7.77E+07	140.6	50.6	3277.9	789.5	144.0	5.02E+04	955.0	4.3	147.0	972.1
Gray Wolf	WSH1-9	1.98E+06	1.16E+08	141.4	58.5	2514.7	988.3	133.3	6.99E+04	1195.0	2.6	158.5	1764.4
Gray Wolf	WSH1-10	3.86E+06	2.61E+08	188.0	67.7	3216.5	1558.9	211.5	1.88E+05	1720.0	8.2	153.1	1951.5
Gray Wolf	WSH1-13	9.58E+05	5.20E+07	155.5	54.2	1108.3	1104.3	121.2	5.45E+04	900.0	6.6	146.9	859.9
Gray Wolf	WSH3-1	1.11E+06	3.89E+07	109.3	35.2	4626.6	479.3	120.0	2.51E+04	545.0	7.5	141.6	475.1
Gray Wolf	WST1-1	1.39E+06	4.11E+07	69.6	29.5	1913.9	761.1	70.1	2.69E+04	900.0	1.8	148.2	3112.3
Gray Wolf	WST1-2A	3.50E+05	1.26E+07	85.4	36.2	800.6	583.4	87.7	2.96E+04	620.0	2.6	149.9	645.4
Gray Wolf	WST1-2B	2.90E+05	9.77E+06	89.0	33.7	742.1	468.9	92.7	2.46E+04	670.0	2.3	153.6	713.5
Gray Wolf	WST1-7	1.10E+06	1.59E+07	49.7	14.5	3213.1	477.4	62.4	2.06E+04	710.0	2.1	163.8	1529.9
Gray Wolf	WST1-8	2.95E+05	4.33E+06	46.9	14.7	640.7	707.3	41.7	9.56E+03	585.0	2.7	166.1	1479.0
Gray Wolf	WST1-9	3.38E+05	8.26E+06	69.3	24.4	724.8	687.3	82.9	2.27E+04	530.0	3.1	146.5	483.0
Gray Wolf	WST1-11	2.55E+06	9.31E+07	110.1	36.5	3872.7	968.0	98.6	4.80E+04	1390.0	2.9	158.1	9218.5
Gray Wolf	WST1-12	1.02E+06	7.67E+07	169.8	75.2	1065.7	1110.6	119.5	6.22E+04	1045.0	4.8	154.1	1262.5
Gray Wolf	WST1-15	1.73E+06	1.67E+08	168.8	96.3	1418.3	2082.2	189.9	1.61E+05	1415.0	6.3	166.8	3423.5
Gray Wolf	WST1-17	6.67E+05	2.13E+07	92.7	31.9	1075.2	766.7	93.0	3.35E+04	715.0	4.1	151.1	748.5
Gray Wolf	WST1-18A	6.01E+05	2.40E+07	84.1	39.9	1060.3	875.3	81.3	4.06E+04	995.0	2.4	160.9	1501.2
Gray Wolf	WST1-18B	5.14E+05	1.76E+07	73.1	34.2	984.6	763.8	73.1	3.25E+04	785.0	3.0	160.5	1182.4
Gray Wolf	WST1-21	3.05E+06	3.18E+08	247.5	104.5	2755.8	1639.7	258.6	2.25E+05	1650.0	9.7	143.6	1403.3
Gray Wolf	WST1-23	1.91E+06	1.42E+08	180.6	74.3	1730.4	1325.0	182.7	1.50E+05	2115.0	7.3	160.2	3201.1
Gray Wolf	WST1-3	3.86E+05	2.08E+07	104.3	53.9	992.0	632.4	110.4	3.42E+04	520.0	5.3	140.3	444.3
Spotted Hyena*	NGO25-3-1	6.19E+05	3.10E+08	169.0	50.1	4267.0	2332.5	174.8	2.09E+05	2395.0	8.7	163.6	4767.0
Spotted Hyena*	NGO25-3-3	2.66E+06	1.72E+08	160.0	64.8	4316.6	816.0	146.9	6.18E+04	850.0	5.0	146.7	832.3
Spotted Hyena*	NGO25-3-7	1.96E+06	7.59E+07	96.1	38.6	1949.3	1582.9	114.4	6.33E+04	1005.0	3.0	159.4	1478.6
Spotted Hyena*	NGO25-6-2	5.22E+06	5.64E+08	267.9	107.9	2589.4	2826.9	241.9	4.10E+05	2815.0	5.2	161.8	4582.6

Spotted Hyena*	NGO25-7-1	5.08E+06	3.52E+08	225.3	69.3	5013.3	1366.5	214.7	1.41E+05	1455.0	3.4	151.0	1651.1
Spotted Hyena*	NGO25-18-1	3.31E+06	2.11E+08	215.6	63.9	3163.4	2199.2	208.6	2.08E+05	2150.0	9.3	155.9	3544.5
Spotted Hyena*	NGO25-18-2	1.04E+07	7.06E+08	184.1	67.7	5969.0	2342.9	196.5	2.82E+05	2520.0	6.2	162.2	4463.5
Spotted Hyena*	NGO25-21-1	2.73E+06	1.36E+08	114.4	49.7	2448.6	1440.7	109.2	7.70E+04	1275.0	2.0	163.4	2458.7
Spotted Hyena*	NGO25-22-1	4.47E+05	3.24E+07	163.8	72.5	842.6	764.0	139.7	5.94E+04	775.0	6.2	138.2	557.4
Spotted Hyena*	NGO25-14-1	2.72E+06	3.86E+08	317.9	142.0	3555.3	1255.4	302.5	2.38E+05	1465.0	4.4	136.6	1055.4
Spotted Hyena*	NGO25-14-2	7.57E+05	5.32E+07	172.3	70.3	1215.5	945.4	177.7	8.78E+04	1015.0	3.7	135.4	746.0
Spotted Hyena*	NGO25-14-3	5.25E+06	1.14E+09	592.8	217.6	3349.7	1887.6	576.0	5.14E+05	2065.0	20.7	117.5	1142.1
Spotted Hyena*	NGO25-14-5	3.16E+06	4.89E+08	367.7	154.6	2476.1	1328.3	369.2	2.87E+05	1500.0	6.1	126.3	914.2
Spotted Hyena*	NGO25-10-2	4.29E+06	3.55E+08	222.7	82.7	5359.9	1217.3	252.9	1.84E+05	1455.0	5.1	141.4	1218.8
Spotted Hyena*	NGO25-10-3	6.52E+06	8.17E+08	296.0	125.4	5209.1	2758.2	299.3	4.23E+05	2750.0	2.9	151.4	4425.5
Spotted Hyena*	NGO25-1-1	4.02E+06	2.43E+08	181.0	60.3	3971.7	1583.7	164.7	9.60E+04	1205.0	7.9	143.2	951.3
Spotted Hyena*	NGO25-1-2	2.00E+06	6.58E+07	105.0	32.9	4026.0	823.8	103.9	2.06E+04	690.0	9.2	149.0	957.8
Spotted Hyena*	NGO25-1-4	5.96E+06	2.74E+08	101.1	46.0	4777.3	2808.6	92.5	9.55E+04	2845.0	4.4	170.6	18192.0
Spotted Hyena*	NGO25-1-5	1.26E+06	4.34E+07	82.1	34.5	1680.3	1370.8	86.2	3.44E+04	755.0	2.8	159.4	929.8
Spotted Hyena*	NGO25-2-1	3.02E+06	1.90E+08	209.5	63.0	4320.0	1377.2	170.2	4.66E+04	455.0	4.5	82.1	244.9
Spotted Hyena*	NGO25-2-2A	3.49E+06	5.00E+08	364.2	143.4	3644.3	1463.6	346.7	1.77E+05	980.0	9.6	106.1	490.4
Spotted Hyena*	NGO25-2-2B	9.98E+05	5.47E+07	189.9	54.7	1777.6	941.9	195.7	9.08E+04	910.0	8.8	135.6	589.1
Spotted Hyena*	NGO25-2-3A	3.31E+06	1.01E+08	106.2	30.6	3852.2	2042.7	90.7	2.83E+04	850.0	4.8	157.1	1315.6
Spotted Hyena*	NGO25-2-3B	1.09E+06	4.76E+07	128.6	43.8	2307.1	760.0	130.1	4.17E+04	660.0	6.7	132.5	465.8
Spotted Hyena*	NGO25-2-3C	7.44E+05	3.02E+07	98.4	40.5	1565.1	694.2	90.4	2.50E+04	565.0	3.7	145.2	508.0
Spotted Hyena*	NGO25-2-4A	3.94E+05	1.67E+07	126.3	42.5	706.5	857.4	119.7	4.70E+04	840.0	4.4	147.0	827.3
Spotted Hyena*	NGO25-2-4B	1.24E+05	3.59E+06	63.4	28.9	592.4	282.2	63.2	9.75E+03	295.0	2.2	139.5	226.1
Spotted Hyena*	NGO25-2-5	1.77E+06	9.86E+07	148.6	55.6	3522.2	1263.6	135.3	7.78E+04	1300.0	5.6	160.7	2288.1
Spotted Hyena*	NGO25-1-6	2.66E+06	2.98E+08	261.6	111.7	1980.2	1881.9	246.4	2.40E+05	1995.0	13.9	144.3	2741.7
Spotted Hyena	DZHP1-1	8.22E+06	1.29E+09	272.7	157.1	4214.5	2139.3	150.3	1.67E+05	2340.0	6.0	168.8	6167.4
Spotted Hyena	DZHP1-2	8.71E+05	4.43E+07	124.8	50.9	1125.8	968.0	129.1	7.22E+04	1000.0	6.1	150.9	1138.3
Spotted Hyena	DZHP1-3	1.03E+06	8.86E+07	200.1	85.7	1319.7	931.2	184.9	7.64E+04	1030.0	6.4	140.3	878.2
Spotted Hyena	DZHP2-1	7.40E+06	1.35E+09	482.4	182.8	3288.0	3037.9	472.8	9.53E+05	3220.0	11.4	122.3	7569.1
Spotted Hyena	DZHP2-2	5.00E+06	5.07E+08	286.3	101.3	3148.5	2208.3	292.8	2.98E+05	2270.0	12.2	154.9	2764.7
Spotted Hyena	DZHP3-1A	3.39E+06	2.10E+08	226.4	62.1	1644.7	1730.0	202.6	1.15E+05	1365.0	5.0	144.5	1630.7
Spotted Hyena	DZHP3-1B	2.70E+06	1.68E+08	191.5	62.2	2833.5	981.6	179.4	1.17E+05	1545.0	4.8	149.7	1655.6
Spotted Hyena	DZHP3-2	4.93E+06	4.64E+08	249.2	94.2	4255.9	1624.6	269.7	3.25E+05	2055.0	6.6	122.3	2418.8
Spotted Hyena	DZHP4-1	4.96E+06	4.85E+08	267.7	97.8	3702.2	1916.5	281.2	3.11E+05	2160.0	9.4	138.6	2591.7
Spotted Hyena	DZHP4-3	3.66E+06	2.92E+08	182.7	79.8	2845.8	1760.9	206.5	1.91E+05	1660.0	8.7	153.2	1867.7
Spotted Hyena	DZHP5-1	1.21E+07	8.31E+08	197.7	68.6	11203.9	1431.2	181.5	1.33E+05	1515.0	4.1	150.3	1795.5
Spotted Hyena	DZHP5-2	7.64E+06	4.96E+08	150.0	59.5	7680.7	1164.4	144.4	1.05E+05	1470.0	3.3	158.2	2790.6
Spotted Hyena	DZHP5-3	3.17E+06	1.60E+08	102.3	50.3	4157.6	897.6	107.4	7.74E+04	1425.0	2.4	166.1	3785.7
Spotted Hyena	DZHP5-5	3.25E+06	2.12E+08	164.8	65.2	3119.1	1294.8	175.9	1.20E+05	1460.0	2.9	153.2	1638.7

Spotted Hyena	DZHP5-7	9.07E+06	8.47E+08	219.5	93.4	5529.5	2386.3	191.8	2.29E+05	2620.0	5.7	162.0	4923.0
Spotted Hyena	DZHP5-11	1.33E+07	1.12E+08	202.7	83.5	1627.9	721.7	205.3	1.12E+05	1040.0	7.7	148.2	1013.9
Spotted Hyena	DZHP5-12A	8.30E+05	1.88E+07	59.6	22.7	2355.9	613.8	61.4	1.59E+04	580.0	3.3	163.1	959.0
Spotted Hyena	DZHP5-13	2.53E+06	1.09E+08	121.4	43.0	3674.1	775.0	132.5	6.49E+04	1180.0	3.4	153.7	1962.4
Spotted Hyena	DZHP5-15	6.89E+05	3.82E+07	117.8	55.4	801.3	1054.6	115.7	6.18E+04	1060.0	4.5	153.2	1201.2
Spotted Hyena	DZHP5-16	3.16E+06	3.29E+08	268.3	104.2	2161.2	1901.4	239.0	2.04E+05	1985.0	15.1	150.9	2140.5
Spotted Hyena	DZHP5-17	1.04E+07	2.10E+09	493.0	203.3	4735.3	2980.9	479.0	7.85E+05	3255.0	6.9	146.7	3125.8
Spotted Hyena	DZHP5-18	1.47E+06	8.39E+11	149.7	60.4	1128.1	1096.1	136.1	7.94E+04	1155.0	136.7	136.7	1908.0
Spotted Hyena	DZHP6-1A	6.14E+05	1.98E+07	80.3	32.2	959.9	916.3	72.6	3.42E+04	860.0	3.1	162.6	1519.7
Spotted Hyena	DZHP6-1B	2.44E+06	7.98E+07	86.8	32.8	3568.1	1081.8	85.4	6.65E+04	1785.0	8.5	173.1	9290.1
Spotted Hyena	DZHP6-4	2.14E+07	4.77E+09	595.2	223.2	8309.4	3810.5	506.9	9.55E+05	3685.0	14.2	148.8	3617.7
Spotted Hyena	DZHP6-5	8.70E+06	1.41E+09	448.4	162.3	3814.5	2343.3	452.7	6.86E+05	3090.0	10.4	149.5	3545.2
Spotted Hyena	DZHP6-6	9.73E+06	2.42E+09	655.9	248.3	4455.0	2440.2	580.7	6.19E+05	3250.0	20.2	142.7	7327.6
Spotted Hyena	DZHP6-7	1.22E+07	2.04E+09	413.0	167.0	4199.3	3375.6	358.6	4.75E+05	2680.0	14.0	149.9	3346.9
Spotted Hyena	DZHP6-8	1.91E+06	2.42E+08	242.8	126.9	1837.8	1234.5	239.2	3.09E+05	1940.0	8.0	154.4	2419.9
Spotted Hyena	DZHP9-1	1.84E+06	2.17E+08	220.3	117.7	1999.3	1281.7	207.4	1.63E+05	1390.0	3.0	130.2	1362.2
Striped Hyena	DZHT1-2	1.30E+07	1.17E+09	252.7	89.7	9324.8	2020.7	245.9	2.17E+05	1895.0	6.5	155.7	2359.0
Striped Hyena	DZHT1-3	1.23E+07	8.35E+08	173.5	68.0	9557.7	1734.4	173.7	1.42E+05	1705.0	5.8	155.1	2944.5
Striped Hyena	DZHT1-4	7.69E+06	1.57E+08	85.9	20.4	8070.3	1145.7	91.7	3.94E+04	1270.0	3.1	165.6	3497.3
Striped Hyena	DZHT1-5	5.60E+07	2.77E+08	141.5	49.4	7957.4	1297.5	132.5	5.94E+04	1100.0	5.5	161.4	1859.3
Striped Hyena	DZHT1-6	4.79E+06	1.35E+08	123.6	28.3	11501.3	1095.8	125.8	6.14E+04	1065.0	5.2	163.0	1928.8
Striped Hyena	DZHT1-7	5.48E+06	2.46E+08	178.8	45.0	5824.4	1453.6	172.2	8.86E+04	1340.0	4.8	151.7	1512.9
Striped Hyena	DZHT1-8	7.18E+06	4.13E+08	172.0	51.5	8154.1	1024.4	191.3	7.37E+04	1130.0	7.9	148.7	1794.2
Striped Hyena	DZHT1-9	3.04E+06	2.41E+08	218.0	79.3	1985.4	1864.0	212.8	1.65E+05	1815.0	10.9	159.9	2560.6
Striped Hyena	DZHT1-10	4.14E+07	7.56E+09	507.3	182.5	16038.3	4263.8	601.5	1.35E+06	4600.0	16.5	151.5	5264.9
Striped Hyena	DZHT1-11	5.36E+06	3.58E+08	193.4	66.8	3178.4	2165.3	214.7	2.05E+05	2505.0	8.5	168.5	6815.6
Striped Hyena	DZHT2-1	2.93E+07	3.56E+09	293.8	121.5	14237.7	2172.5	268.6	2.64E+05	2130.0	16.3	165.9	4979.9
Striped Hyena	DZHT2-2A	1.43E+06	5.49E+07	105.0	38.5	2283.6	1033.7	99.6	5.13E+04	1020.0	3.5	163.7	2136.9
Striped Hyena	DZHT2-2B	9.37E+05	3.69E+07	94.3	39.4	1457.2	582.3	80.7	2.43E+04	565.0	2.3	146.8	563.1
Striped Hyena	DZHT2-3	7.49E+05	4.69E+07	158.8	62.6	1191.5	911.8	158.9	6.69E+04	990.0	6.5	154.4	963.5
Striped Hyena	DZHT2-4	2.11E+06	8.94E+07	94.4	42.5	2948.5	1046.0	117.4	6.55E+04	1150.0	4.4	160.6	2060.2
Striped Hyena	DZHT2-5	3.52E+06	6.30E+07	81.5	17.9	5313.8	972.6	86.4	3.00E+04	910.0	6.0	167.1	2448.2
Striped Hyena	DZHT2-6	3.98E+06	1.06E+08	90.3	26.6	4500.2	1054.7	99.3	7.08E+04	1675.0	6.0	168.5	4649.5
Striped Hyena	DZHT2-7	1.76E+06	1.25E+08	175.7	71.2	1863.2	1101.9	186.3	1.18E+05	1135.0	3.7	155.6	1371.6
Striped Hyena	DZHT2-8	3.12E+06	1.71E+08	151.5	54.8	3334.3	1256.2	125.4	5.64E+04	1020.0	3.8	156.7	1386.7
Striped Hyena	DZHT2-9	5.24E+06	4.68E+08	241.4	89.3	3726.7	1837.3	211.7	1.40E+05	1470.0	10.4	159.2	3319.7
Striped Hyena	DZHT2-10	2.37E+07	2.70E+09	247.6	114.0	12870.5	2549.8	248.3	2.10E+05	1905.0	15.5	156.4	2735.9
Striped Hyena	DZHT3-1A	1.59E+06	7.57E+07	121.6	47.5	2447.8	753.7	130.5	5.64E+04	925.0	6.6	152.9	977.4
Striped Hyena	DZHT3-1B	9.88E+05	3.59E+07	93.1	36.3	1765.3	722.6	99.6	4.32E+04	925.0	3.1	163.9	3286.8

Striped Hyena	DZHT3-2	1.06E+07	1.32E+09	382.4	124.5	5786.8	2716.3	321.2	2.87E+05	2370.0	8.1	127.4	5953.0
Striped Hyena	DZHT3-3	7.16E+06	6.06E+08	224.8	84.7	3901.9	3028.5	192.5	2.68E+05	3130.0	8.8	165.5	8736.6
Striped Hyena	DZHT3-4A	2.55E+06	1.70E+08	210.0	66.5	2229.3	1412.5	203.2	1.47E+05	1830.0	15.8	157.0	2811.3
Striped Hyena	DZHT3-4B	2.89E+06	1.90E+08	141.2	65.7	3135.5	1249.0	151.5	1.15E+05	1605.0	5.4	160.4	2347.3
Striped Hyena	DZHT3-5	6.10E+06	1.07E+09	359.3	175.8	3189.4	2273.8	367.1	4.71E+05	2820.0	8.4	147.9	2906.2
Striped Hyena	DZHT3-7A	2.97E+06	4.26E+08	316.7	143.5	2242.3	1411.9	339.8	2.86E+05	1810.0	10.5	144.2	1637.6
Striped Hyena	DZHT3-7B	1.38E+06	5.61E+07	93.0	40.5	1507.2	1520.1	86.5	4.17E+04	1015.0	4.6	164.6	2089.8
African Lion*	A1	2.15E+06	5.89E+07	74.0	27.4	2451.9	766.8	65.9	2.00E+04	835.0	3.0	165.0	1767.4
African Lion*	A2	5.53E+06	3.45E+08	128.8	62.4	5537.6	1395.6	75.0	5.16E+04	1480.0	3.5	171.7	5806.1
African Lion*	A3	4.57E+06	2.29E+08	132.6	50.0	5479.6	1095.6	82.6	3.18E+04	800.0	3.8	165.7	2102.6
African Lion*	B1	2.11E+06	4.50E+07	66.1	21.3	9083.3	407.9	56.5	1.31E+04	490.0	2.4	156.8	2015.2
African Lion*	B2	2.49E+06	5.26E+07	57.6	21.1	6235.3	578.1	51.7	1.36E+04	500.0	2.4	161.3	830.4
African Lion*	C1	1.55E+06	3.99E+07	85.7	25.8	3030.0	625.6	96.9	3.67E+04	725.0	3.7	150.7	866.8
African Lion*	C2	3.32E+05	1.65E+07	100.3	49.6	801.1	475.1	104.4	2.98E+04	520.0	5.0	138.3	388.2
African Lion*	E1	1.47E+06	2.68E+07	56.8	18.3	3500.7	567.7	52.9	1.65E+04	580.0	3.0	160.3	893.4
African Lion*	E2	1.90E+06	4.08E+07	78.6	21.5	4685.8	515.8	70.2	1.63E+04	455.0	1.9	147.2	426.6
African Lion*	E3	3.11E+06	6.51E+07	64.8	20.9	7513.4	953.6	73.6	3.79E+04	855.0	3.0	165.3	1775.8
African Lion*	I1	1.65E+06	3.38E+07	66.7	20.5	3066.8	853.4	77.3	2.30E+04	580.0	3.5	143.3	840.3
African Lion*	J1	8.10E+06	3.77E+08	175.6	46.5	9062.3	1123.9	200.6	1.03E+05	1160.0	5.9	142.5	1030.5
African Lion*	J2	6.73E+06	5.36E+08	201.4	79.7	7024.4	1387.3	205.3	1.56E+05	1250.0	4.4	147.5	1170.4
African Lion*	K1	1.21E+06	8.62E+07	160.1	71.4	1851.2	1017.5	163.5	1.06E+05	1050.0	6.1	150.2	1142.2
African Lion*	K2	1.34E+06	2.57E+07	68.0	19.3	3278.6	662.7	70.6	2.27E+04	545.0	4.1	160.7	835.0
African Lion*	L1	6.44E+06	4.52E+08	219.7	70.2	7396.0	1288.3	226.7	1.26E+05	1295.0	5.3	138.2	993.7
African Lion*	N1	2.69E+06	8.56E+07	89.1	31.8	6043.1	815.1	85.3	3.49E+04	695.0	1.5	154.2	807.9
African Lion*	N2	3.94E+06	9.79E+07	91.5	24.8	7946.2	762.1	84.9	3.43E+04	745.0	2.8	150.2	770.9
African Lion*	N3	4.98E+06	1.85E+08	105.4	37.1	6877.8	916.8	115.5	5.12E+04	1200.0	2.3	154.5	2032.2
African Lion*	O1	2.11E+06	7.60E+07	84.3	36.0	4338.9	561.9	50.6	1.56E+04	550.0	2.1	162.9	1046.1
African Lion*	O2	4.26E+06	1.20E+08	74.4	28.3	6161.1	864.4	56.9	2.67E+04	905.0	3.4	168.6	4416.7
African Lion*	O3	3.02E+06	1.38E+08	147.5	45.7	5533.3	964.8	162.4	7.24E+04	1135.0	5.3	158.3	1667.4
African Lion*	O4	9.06E+06	7.24E+08	207.0	79.1	7922.3	1944.7	231.1	1.34E+05	1270.0	6.4	143.9	1071.7
African Lion*	O5	1.03E+06	9.03E+07	234.7	87.7	1218.4	1147.9	256.8	1.73E+05	1325.0	5.3	141.6	1159.0
African Lion*	P1	3.00E+06	2.88E+08	225.7	96.0	4862.0	1185.5	237.6	1.67E+05	1345.0	3.7	146.3	1121.4
African Lion*	P2	3.92E+06	4.37E+08	246.6	11.5	5278.2	1009.9	206.7	1.10E+05	975.0	6.1	149.2	938.1
African Lion*	Q1	1.09E+07	2.41E+09	460.4	220.2	6948.7	2481.4	410.4	4.52E+05	2185.0	19.4	139.7	1851.4
African Lion*	S1	2.67E+06	1.87E+08	167.5	69.9	3090.4	1194.0	168.6	1.13E+05	1205.0	3.3	149.8	1255.7
African Lion*	S2	1.15E+06	8.14E+07	165.6	10.7	1105.9	1310.3	165.3	1.27E+05	1335.0	5.2	149.6	1776.0
African Lion	DZL1-1	1.04E+06	1.04E+08	237.3	100.3	1331.0	1077.2	219.8	8.99E+04	810.0	12.4	110.0	436.0
African Lion	DZL1-4	2.11E+06	6.00E+07	77.7	28.5	3602.8	873.2	77.9	2.07E+04	625.0	3.4	164.0	1087.4
African Lion	DZL1-6	4.28E+06	2.64E+08	170.9	61.7	6679.9	1275.1	143.2	6.20E+04	1070.0	4.7	148.0	1411.7

African Lion	DZL1-7A	2.84E+05	6.23E+06	54.3	22.0	630.4	536.8	53.2	1.36E+04	480.0	1.9	153.7	775.2
African Lion	DZL1-7B	3.30E+05	8.56E+06	73.4	25.9	847.6	480.5	78.1	2.20E+04	480.0	1.4	147.8	501.4
African Lion	DZL1-7C	2.99E+06	9.74E+07	101.2	32.6	5391.3	640.5	99.3	3.47E+04	775.0	4.2	156.9	1017.6
African Lion	DZL1-7D	8.06E+05	2.40E+07	76.7	29.7	1857.4	698.6	73.2	2.57E+04	775.0	2.2	160.1	1282.3
African Lion	DZL1-7E	6.63E+05	1.81E+07	67.4	27.3	1211.4	591.8	70.4	2.73E+04	715.0	1.9	158.2	1240.8
African Lion	DZL1-10	2.04E+06	3.24E+07	58.2	15.9	3840.8	600.2	65.1	1.88E+04	780.0	3.8	161.7	1591.9
African Lion	DZL3-2	1.89E+05	4.65E+06	76.1	24.6	503.2	403.9	78.4	1.47E+04	430.0	1.5	142.0	368.1
African Lion	DZL3-3	1.86E+05	5.05E+06	67.6	27.1	544.1	500.0	65.3	1.53E+04	395.0	1.3	141.3	330.1
African Lion	DZL3-4	9.18E+05	1.51E+07	54.6	16.4	1972.4	585.0	25.7	1.37E+03	440.0	1.4	164.0	17847.5
African Lion	DZL3-5B	6.22E+05	1.17E+07	48.8	18.8	2596.2	360.0	44.0	6.50E+03	330.0	1.2	145.6	310.2
African Lion	DZL3-5C	5.98E+05	1.69E+07	70.8	28.7	2785.1	300.3	63.1	1.00E+04	285.0	1.6	119.5	169.1
African Lion	DZL3-5D	4.95E+05	8.04E+06	43.6	16.3	1931.0	313.7	36.4	5.29E+03	265.0	1.1	144.8	280.9
African Lion	DZL3-5E	5.85E+05	7.39E+06	41.6	12.6	4514.7	214.9	40.4	1.68E+03	175.0	0.4	156.1	230.7
African Lion	DZL3-5F	5.02E+05	6.98E+06	64.0	13.9	2963.6	234.5	58.1	5.54E+03	285.0	2.8	136.4	291.0
African Lion	DZL3-6	1.20E+06	1.10E+08	209.7	91.8	2215.5	777.0	202.5	1.02E+05	900.0	4.5	126.8	547.9
African Lion	DZL3-7	5.72E+05	2.60E+07	95.9	45.5	1969.2	363.2	86.8	2.38E+04	575.0	3.1	127.1	516.8
African Lion	DZL3-8	4.96E+05	1.36E+07	65.3	27.3	1886.8	294.3	64.3	8.38E+03	400.0	1.8	143.9	365.5
African Lion	DZL3-9	6.97E+05	4.39E+07	164.0	63.0	1109.6	781.5	156.3	6.30E+04	945.0	6.4	143.6	785.1
African Lion	DZL3-12A	2.45E+05	6.73E+06	61.4	27.4	1008.2	254.1	67.8	1.05E+04	320.0	2.0	132.0	216.3
African Lion	DZL3-12B	2.54E+05	5.38E+06	54.8	21.2	994.9	389.6	54.1	7.72E+03	315.0	2.0	147.7	313.9
African Lion	DZL3-12C	2.47E+05	8.40E+06	76.2	34.0	587.4	466.9	79.8	2.52E+04	575.0	3.9	146.3	526.3
African Lion	DZL3-12D	1.45E+05	4.17E+06	60.9	28.8	571.0	277.0	45.4	7.39E+03	345.0	2.4	154.4	462.8
African Lion	DZL3-13A	6.57E+05	2.03E+07	75.5	31.0	1829.8	545.9	41.7	9.94E+03	565.0	1.4	165.6	1229.8
African Lion	DZL3-13B	1.24E+06	5.54E+07	98.9	44.8	3724.3	585.0	75.4	2.72E+04	625.0	2.9	149.5	769.7
African Lion	DZL3-13C	2.88E+05	1.46E+07	134.9	50.6	597.8	610.0	122.4	4.17E+04	700.0	3.6	143.5	613.6
Nile Crocodile	SCP4.1 1A	9.36E+06	9.61E+08	327.3	102.7	10117.2	1620.1	314.1	2.28E+05	1700.0	21.5	139.5	1347.3
Nile Crocodile	SCP4.1 1B	7.29E+06	8.36E+08	325.0	114.7	7273.4	1703.9	313.4	2.84E+05	1620.0	12.6	132.6	1135.8
Nile Crocodile	FEM 1A	1.59E+07	1.17E+09	222.7	73.5	11347.6	1645.8	228.7	2.50E+05	2180.0	11.8	158.5	3174.8
Nile Crocodile	FEM 1B	9.21E+06	1.01E+09	202.0	109.1	5819.0	2142.6	211.3	1.92E+05	1600.0	4.8	153.9	2026.9
Nile Crocodile	FEM 1C	6.53E+06	5.45E+08	160.3	83.5	5181.3	1398.9	156.4	1.46E+05	1750.0	10.2	158.7	2469.9
Nile Crocodile	HUM4.2 3	5.85E+05	1.71E+07	76.6	29.2	3243.2	321.1	77.2	9.52E+03	255.0	2.2	121.5	142.8
Nile Crocodile	HUM4.2 4	6.28E+06	7.92E+08	293.9	126.1	5138.8	1694.6	297.6	2.91E+05	1905.0	10.3	147.4	1869.3
Nile Crocodile	HUM4.2 6A	1.50E+06	5.37E+07	77.1	35.8	1665.0	1198.0	85.1	5.87E+04	1315.0	3.7	167.2	3059.8
Nile Crocodile	HUM4.2 6B	1.35E+06	6.26E+07	153.0	46.2	2180.2	1280.0	146.3	5.45E+04	775.0	6.7	150.7	749.1
Nile Crocodile	HUM4.2 7	8.15E+06	8.74E+08	310.6	107.3	3947.2	3104.2	310.1	4.85E+05	4495.0	9.6	156.9	19148.2
Nile Crocodile	HUM4.2 8	1.97E+07	7.54E+09	1097.6	383.1	11409.2	3410.2	111.1	2.16E+06	3750.0	16.7	115.4	1918.9
Nile Crocodile	HUM4.2 9	4.10E+06	1.10E+08	91.6	26.9	9151.5	670.9	95.0	3.43E+04	825.0	2.6	150.9	899.1
Nile Crocodile	HUM4.2 10	2.15E+06	1.23E+08	154.7	57.1	3027.1	984.0	156.5	7.34E+04	1080.0	3.1	143.2	1499.1
Nile Crocodile	KRM4 1	1.20E+07	2.22E+09	402.6	185.2	10819.7	1761.0	373.0	3.13E+05	1670.0	18.6	132.8	1170.1

Nile Crocodile	RAD4.3 1	9.99E+06	9.58E+08	315.2	95.8	12251.6	1909.0	300.7	2.79E+05	2075.0	11.4	135.3	2340.7
Nile Crocodile	RAD4.3 3A	7.77E+06	1.87E+09	562.7	240.8	3978.4	2952.2	552.1	8.80E+05	2740.0	12.1	146.3	3696.2
Nile Crocodile	RAD4.3 3B	2.26E+06	2.35E+08	331.7	104.3	1740.5	1922.3	331.4	2.44E+05	1800.0	17.3	137.7	1538.9
Nile Crocodile	RAD4.3 4	6.28E+06	1.65E+09	642.7	262.5	3421.5	2696.1	626.8	9.19E+05	2850.0	13.0	131.3	1984.4
Nile Crocodile	RAD4.3 5	7.22E+06	1.07E+09	486.6	148.4	3012.2	3399.9	492.9	7.56E+05	3800.0	15.9	153.9	5565.3
Nile Crocodile	RAD4.3 6	4.97E+06	2.42E+08	128.7	48.7	2662.8	3720.7	133.5	1.68E+05	2300.0	5.3	168.3	6463.3
Nile Crocodile	RAD4.3 7	1.44E+07	3.59E+09	562.2	249.0	7054.9	3047.1	553.3	9.35E+05	2950.0	12.5	136.2	2117.6
Nile Crocodile	RAD4.3 9	7.28E+06	1.48E+08	73.8	20.3	10630.1	1169.6	72.7	3.89E+04	1350.0	2.6	170.9	5871.1
Nile Crocodile	RAD4.3 10	6.51E+06	1.65E+09	674.6	252.5	4093.5	2940.7	668.9	1.10E+06	2900.0	23.7	131.7	1970.0
Nile Crocodile	RAD4.3 11	4.03E+06	1.31E+08	111.8	32.5	2945.1	2421.6	118.1	1.47E+05	2300.0	5.0	170.4	7827.9
Nile Crocodile	RAD4.3 12	2.34E+06	2.00E+08	217.3	85.2	3802.2	1130.3	224.1	1.21E+05	1190.0	6.0	135.7	1059.4
Nile Crocodile	RAD4.3 13	5.58E+05	2.06E+07	85.5	36.9	1284.6	688.4	84.4	2.78E+04	765.0	4.7	147.2	987.2
Nile Crocodile	RAD4.3 14	1.15E+07	8.97E+08	214.3	78.1	6211.5	4067.5	215.9	1.75E+05	2600.0	15.0	161.9	5397.4
Nile Crocodile	RAD4.3 15	1.33E+07	3.05E+09	588.2	229.5	5660.5	3398.2	609.9	9.51E+05	3795.0	13.0	142.2	3350.9
Nile Crocodile	RAD4.3 16A	3.96E+06	5.00E+08	343.7	126.0	2995.2	2201.0	359.9	3.25E+05	1730.0	23.7	133.5	1336.7
Nile Crocodile	RAD4.3 16B	2.69E+06	3.03E+08	338.6	112.5	2543.6	1834.2	340.2	3.04E+05	1920.0	18.2	139.3	1658.5
Nile Crocodile	RAD4.3 17	8.24E+06	6.12E+08	219.3	74.3	11079.8	1381.6	212.5	1.94E+05	1550.0	4.2	147.0	1511.4
Nile Crocodile	RAD4.3 18	9.14E+05	7.77E+07	241.7	84.9	1221.4	980.0	217.7	9.67E+04	1185.0	10.0	123.2	1138.4
Nile Crocodile	RAD4.3 21	1.45E+06	3.49E+07	83.6	24.0	2784.0	1058.4	96.4	4.41E+04	1230.0	4.1	162.8	2603.4
Nile Crocodile	RAD4.3 23A	1.64E+06	8.05E+07	180.3	49.2	2432.1	988.7	176.7	8.22E+04	1015.0	4.7	146.9	1057.6
Nile Crocodile	RAD4.3 23B	4.51E+05	9.89E+06	60.5	22.0	2428.8	433.4	55.7	1.25E+04	425.0	1.7	149.2	421.7
Nile Crocodile	RAD4.3 24	1.06E+06	2.79E+07	69.0	26.2	3609.6	940.9	60.1	3.10E+04	960.0	1.4	163.9	2833.5
Nile Crocodile	RAD4.3 27	1.46E+07	4.67E+09	913.2	319.0	8782.7	3230.5	875.2	1.47E+06	3475.0	26.4	116.5	1890.1
Nile Crocodile	RAD4.3 28	5.95E+06	1.56E+09	651.4	261.5	2849.3	3651.1	623.3	9.33E+05	3540.0	20.3	147.6	3611.7
Nile Crocodile	RAD4.3 29A	9.75E+05	5.39E+07	162.6	55.3	2759.0	572.2	172.5	4.06E+04	600.0	11.5	123.1	355.1
Nile Crocodile	RAD4.3 31A	1.25E+06	6.49E+07	122.6	51.8	2848.4	828.2	122.5	3.90E+04	625.0	3.7	122.0	684.2
Nile Crocodile	RAD4.3 31B	1.17E+06	3.09E+07	85.1	26.3	1965.2	907.3	89.0	2.25E+04	940.0	5.6	160.1	2518.3
Nile Crocodile	RAD4.3 32	1.39E+06	1.52E+08	253.1	109.7	2818.6	744.9	252.4	1.08E+05	1005.0	6.3	123.2	579.8
Nile Crocodile	RAD4.3 35	3.06E+06	1.85E+08	146.5	60.3	5012.3	863.2	143.1	5.82E+04	745.0	3.0	133.9	514.1
Brown Bear	DZB1-2	3.52E+07	3.49E+09	342.2	99.3	12001.0	3166.2	368.2	5.69E+05	3440.0	21.9	167.3	8120.9
Brown Bear	DZB1-3	1.31E+07	1.46E+09	257.2	111.4	6996.7	2216.4	276.9	3.40E+05	2090.0	10.7	160.2	3417.4
Brown Bear	DZB2-1A	6.23E+06	2.51E+08	144.6	40.3	8365.3	1465.4	149.3	7.67E+04	1295.0	4.7	164.4	2442.7
Brown Bear	DZB2-1B	5.02E+06	1.46E+08	110.6	29.1	7324.1	1127.5	115.0	4.78E+04	1050.0	4.2	147.2	2506.1
Brown Bear	DZB2-2	3.59E+07	3.43E+09	276.0	95.6	12469.6	3574.3	247.3	2.95E+05	3065.0	8.6	171.1	8379.3
Brown Bear	DZB2-4	9.86E+06	5.00E+08	164.4	50.7	5744.1	2368.1	146.2	1.31E+05	2490.0	7.4	168.2	6917.1
Brown Bear	DZB2-6	1.93E+07	1.69E+09	230.0	77.3	8824.1	2737.1	225.2	2.70E+05	2455.0	9.9	131.4	10785.4
Brown Bear	DZB2-7	2.25E+07	2.88E+09	316.0	117.1	9053.9	3575.0	322.8	6.68E+05	4320.0	12.7	160.2	8213.6
Brown Bear	DZB2-8	1.60E+07	1.79E+09	270.0	111.9	4632.3	4895.2	299.2	7.72E+05	5325.0	9.1	172.7	19759.9
Brown Bear	DZB2-9	4.84E+06	4.92E+08	252.9	101.5	3449.0	1943.2	248.0	4.05E+05	3535.0	7.0	171.4	15156.6

Brown Bear	DZB2-10	3.48E+06	1.78E+08	199.0	51.1	3923.0	1169.2	198.1	1.06E+05	1345.0	8.5	159.8	2564.8
Brown Bear	DZB3-1	3.40E+06	3.43E+08	229.1	100.7	1460.9	3391.1	228.8	3.57E+05	3530.0	14.4	172.5	1883.6
Brown Bear	DZB3-2B	1.93E+06	1.38E+08	176.8	71.5	2903.8	985.1	182.0	8.38E+04	750.0	3.6	132.6	507.0
Brown Bear	DZB3-2A	3.37E+06	3.78E+08	247.0	112.2	1654.4	3182.1	250.2	4.89E+05	3515.0	6.1	164.6	7060.4
Brown Bear	DZB3-3	1.15E+07	1.00E+09	243.5	86.9	9415.5	1745.2	253.0	1.92E+05	2025.0	20.6	152.7	2834.5
Brown Bear	DZB3-4	3.67E+07	6.86E+09	472.6	187.1	10251.7	4158.6	368.0	7.29E+05	4615.0	14.2	168.2	15659.3
Brown Bear	DZB3-5	2.41E+07	2.47E+09	299.7	105.3	9498.8	2691.3	322.6	4.55E+05	2765.0	16.3	163.7	8179.2
Brown Bear	DZB4-1	4.09E+07	7.72E+09	343.4	188.6	14367.9	3642.0	233.4	4.42E+05	3605.0	6.7	169.5	10768.4
Brown Bear	DZB4-2	2.96E+07	4.22E+09	297.2	140.1	10278.4	3856.2	267.1	4.12E+05	3055.0	8.2	178.4	8597.5
Brown Bear	DZB4-3	2.44E+07	2.01E+09	254.7	82.4	8486.0	3965.8	242.8	3.75E+05	2865.0	7.1	166.1	6464.6
Brown Bear	DZB4-5	4.50E+07	5.80E+09	372.5	128.9	12151.9	4726.3	337.1	4.09E+05	4235.0	21.5	172.7	16796.5
Brown Bear	DZB5-3	3.34E+07	2.52E+09	220.8	75.6	12380.4	4193.7	197.3	2.93E+05	3510.0	6.8	169.6	11576.6
Brown Bear	DZB5-4	9.15E+06	4.55E+08	123.8	49.8	6957.2	1933.5	130.9	1.28E+05	1950.0	7.7	165.9	4429.1
Brown Bear	DZB6-1	5.27E+07	5.12E+09	284.7	97.1	17318.9	4355.5	294.5	6.58E+05	4690.0	8.0	172.7	27220.6
Brown Bear	DZB6-3	1.88E+07	5.17E+09	693.0	274.7	6350.4	3827.2	732.6	7.92E+05	2625.0	32.2	121.2	1559.8
Brown Bear	DZB6-4	1.04E+07	1.95E+09	370.4	186.7	4283.1	3389.1	423.7	6.66E+05	3060.0	15.9	154.4	3810.0

Note: An asterisk in the "Species" column indicates the tooth mark and associated data is from a wild animal.

APPENDIX K – RAW DATA FROM HUMAN RESERARCH PARTICIPANTS: TOOTH GROUP FREQUENCIES

Table K.1) The number of bites recorded for each tooth group per research participant during experimental stage one for the pork rib bones. Participants had no bite limit.

Rib Bone – Experimental Stage One: Removing Meat

Participant ID	Front Teeth	Middle Teeth	Back Teeth	Total
1	9	0	0	9
2	6	0	0	6
3	9	0	0	9
4	10	1	0	11
5	9	0	0	9
6	10	0	0	10
7	17	0	0	17
8	9	0	0	9
9	14	0	0	14
10	16	0	0	16
Total	109	1	0	**110**

Table K.2) The number of bites recorded for each tooth group per research participant during experimental stage two for the pork rib bones. Participants had a 10-bite limit.

Rib Bone – Experimental Stage Two: Bone Biting

Participant ID	Front Teeth	Middle Teeth	Back Teeth	Total
1	4	5	1	10
2	1	9	0	10
3	4	3	3	10
4	4	6	0	10
5	2	8	0	10
6	4	6	0	10
7	4	5	1	10
8	2	6	2	10
9	0	8	2	10
10	2	5	3	10
Total	27	61	12	**100**

Table K.3) The number of bites recorded for each tooth group per research participant during experimental stage one for the pork leg bones. Participants had no bite limit.

Leg Bone – Experimental Stage One: Removing Meat				
Participant ID	**Front Teeth**	**Middle Teeth**	**Back Teeth**	**Total**
1	11	4	0	15
2	10	0	0	10
3	17	1	0	18
4	9	2	0	11
5	13	0	0	13
6	13	0	0	13
7	20	2	0	22
8	5	10	0	15
9	6	8	0	14
10	10	3	0	13
Total	114	30	0	**144**

Table K.4) The number of bites recorded for each tooth group per research participant during experimental stage two for the pork leg bones. Participants had a 10-bite limit.

Leg Bone – Experimental Stage Two: Bone Biting				
Participant ID	**Front Teeth**	**Middle Teeth**	**Back Teeth**	**Total**
1	5	4	1	10
2	3	7	0	10
3	8	2	0	10
4	8	2	0	10
5	8	2	0	10
6	7	3	0	10
7	6	4	0	10
8	7	3	0	10
9	8	2	0	10
10	8	2	0	10
Total	68	31	1	**100**

Table K.5) The total number of bites recorded for each tooth group per research participant for the pork rib bones.

Rib Bone – Experimental Stage One & Two: Totals				
Participant ID	**Front Teeth**	**Middle Teeth**	**Back Teeth**	**Total**
1	13	5	1	19
2	7	9	0	16
3	13	3	3	19
4	14	7	0	21
5	11	8	0	19
6	14	6	0	20
7	21	5	1	27
8	11	6	2	19
9	14	8	2	24
10	18	5	3	26
Total	136	62	12	**210**

Table K.6) The total number of bites recorded for each tooth group per research participant for the pork leg bones.

Leg Bone – Experimental Stage One & Two: Totals				
Participant ID	**Front Teeth**	**Middle Teeth**	**Back Teeth**	**Total**
1	16	8	1	25
2	13	7	0	20
3	25	3	0	28
4	17	4	0	21
5	21	2	0	23
6	20	3	0	23
7	26	6	0	32
8	12	13	0	25
9	14	10	0	24
10	18	5	0	23
Total	182	61	1	**244**