Middle Stone Age Hominin Foraging Ecology in Tanzania: An Archaeozoological Study of the Loiyangalani Open-Air Site and Magubike Rockshelter

by

Frank Mwandu Masele

A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Anthropology
University of Alberta

Abstract

The nature of Middle Stone Age (MSA) hominin foraging ecology in Africa is still hotly debated. In particular, MSA people have been portrayed as ineffective hunters of large-sized, prime-adults, and dangerous animals. They are rather seen as passive scavengers of carnivore-defleshed carcasses only to enjoy surviving scraps of meat and bone marrow. This study examined MSA hominin foraging economy at the Loiyangalani open-air site and Magubike rockshelter in Tanzania within the broad concept of the emergence of modern human behaviour. The taphonomy of the faunal assemblages was initially evaluated, followed by a zooarchaeological interpretation of the results guided by the diet breadth and published experimental and ethnoarchaeological datasets. Multivariate taphonomic analyses implicate MSA hominins as a key agent in the modification and accumulation of the faunal assemblages and carnivore played a marginal role.

MSA hominins exploited a broad spectrum of species, but bovids were the most abundant. They also included suids, that are dangerous prey, and equids, but both are present in relatively small proportions. MSA hominins mainly foraged on large-sized animals (size 3-4 bovids) and prime-aged adults and these were the key sources of meat and marrow. Overall, there appears to be a greater focus on medium-sized ungulates (size 3 bovids). Frequently hunted prey also included size 4 bovids. The proportions of prime-adults are above 70% at both sites. Small-sized (size 1-2 bovids) animals were also exploited to maximize the foraging net return rates, but only in relatively small quantities. These were added to the broadening diet breadth especially when encounters with the large-sized (size 3-4 bovids) animals over the landscape declined. Fish, tortoises, and birds also supplemented the optimal diet. There is also clear evidence that fish and tortoises were exploited at Loiyangalani. A general characteristic noted at both sites is the rarity of the cranial and lower limb bones.

Regarding the intensity of carcasses processing, there is also evidence at both sites that MSA hominins transported and processed complete or relatively complete carcasses. The overall incidence of cut marks is 10% and 8% in the Loiyangalani and Magubike faunal assemblages respectively. The majority of the cut-marked elements are the high meat and marrow-bearing long bones. The facts that sharp-edged flakes constitute considerable portions of the MSA lithic assemblage at both sites certainly were used in the manipulation of the meat-bearing bones. The percentages of cut marks and percussion marks on long bone midshafts also fall within the range of variation documented in experimental studies replicating hominin primary (early) access to fully-fleshed carcasses. The axial elements and the midshaft sections of the upper limb bones (ULB) and the intermediate limb bones (ILB) that commonly preserve no scraps of meat after consumption by carnivores, bear more cut marks than tooth marks. Carnivore tooth marks are incredibly rare and only at approximately 6% and 1.5% in the Loiyangalani and Magubike faunal assemblage respectively. The percentages of tooth marks on long bone midshafts indicate that carnivores had the secondary (late) intervention to the bone fragments discarded at the sites. The new findings from Loiyangalani site and Magubike support the view that scavenging was not the main mode of prey procurement.

Acknowledgements

This study would not have been possible without financial support from a number of sources. The financial support from the University of Dar es Salaam and the SSHRC Standard Research Grants awarded to Professor Pamela Rae Willoughby made possible the study of the Loiyangalani and Magubike faunal assemblages. Supports from the two institutions are highly acknowledged and have brought me to this point.

I am also grateful to the Department of Anthropology at the University of Alberta for continued support through various departmental scholarships, which enabled me to conduct preliminary arrangements and to gain access to the comparative collections of eastern African wildlife and domesticate animals in Tanzania.

I would like to thank my supervisor, Professor Pamela Rae Willoughby, for the permit to study the faunal remains from Magubike rockshelter. She also gave me academic guidance, reading several drafts of my dissertation, proof reading the manuscript and moral support over the entire period of my study at the University of Alberta. She also constantly commented on the theoretical organization and structure of this dissertation that helped me finalize the work and make it a reality.

Many thanks are due to Dr. Robert Losey of the Department of Anthropology who served as my second supervisory committee member. As my mentor in the zooarchaeology field most kindly provided encouragements and opportunities to gain his personal experiences in the study of fossil faunal collections. I deeply thank him for fruitful discussions that greatly improved this dissertation. I must also express my thanks to Dr. Alison Murray of the Department of Biological Sciences who also served as a member of my supervisory committee and provided me with books on African wildlife and direction as my research developed.

Special thanks should go to Professor John F.R. Bower and his collaborator Professor Audax Z.P. Mabulla of the Serengeti Genesis Project for inviting me to participate in Loiyangalani excavations between 2003 and 2005. They also permitted me to study the Loiyangalani faunal assemblage and provided some photos used in this work. Many thanks are due to Professor Carl Vondler for the study of the Loiyangalani site geology.

Many thanks should also go to the students from the Department of Archaeology and Heritage Studies at University of Dar es Salaam who helped in the excavations. Finally, I would like to convey heartfelt acknowledgments and appreciations to all my colleagues at the University of Alberta who, in one way or another, contributed in the form of time, efforts, and emotional support, Jennifer M. Miller and Joseph J. Werner; words cannot express my gratitude.

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

ACM	Associate Colleges of Midwest
AD	Anno Domino
AXL	Axial
BMD	Bone Mineral Density
BP	Before Present
C-H	Carnivore-to-Hominin
CM	Cut Marks
CO	Carnivore-Only
CRA	Cranial
DK	Douglas Korongo
DNA	Deoxyribonucleic Acid
ESA	Early Stone Age
ESR	Electron Spin Resonance
F-H	Felid-to-Hominin
FFI	Fracture Freshness Index
FLK	Frida Leakey Korongo
FTI	Fluvial Transport Index
GIS	Geographic Information System
GUI	General Utility Index
H-C	Hominin-to-Carnivore
HO	Hominin-Only
IA	Iron Age

ILB	Intermediate Limb Bones
IRAP	Iringa Region Archaeological Project
ITCZ	Intertropical Convergence Zone
KYA	Thousand Years Ago
LGM	Last Glacial Maximum
LH	Laetoli Hominid
LLB	Lower Limb Bones
LSA	Later Stone Age
MAU	Minimal Animal Unit
MGUI	Modified General Utility Index
MIS	Marine Isotope Stage
MNE	Minimal Number of Elements
MNI	Minimal Number of Individuals
MP	Middle Paleolithic
MSA	Middle Stone Age
MtDNA	Mitochondrial Deoxyribonucleic Acid
MYA	Million Years Ago
NEMC	National Environment Management Council
NISP	Number of Identified Specimens
NTAXA	Number of Taxa
OH	Olduvai Hominid
OSL	Optically Stimulated Luminescence
PM	Percussion Marks

PN	Pastoral Neolithic
SASES	Standardized African Site Enumeration System
SFUI	Standardized Food Utility Index
SSHRC	Social Sciences and Humanities Research Council of Canada
SWI	Saturated Weight Index
SWRI	Serengeti Wildlife Research Institute
TANAPA	Tanzania National Parks
TL	Thermoluminescence
TM	Tooth Marks
UDSM	University of Dar es Salaam
ULB	Upper Limb Bones
UMI	Unsaturated Marrow Index
UP	Upper Paleolithic
URT	United Republic of Tanzania
WB-C	Whole Bone-to-Carnivore

CHAPTER 1

INTRODUCTION AND BACKGROUND TO THE RESEARCH PROBLEM

1.1. Introduction

The origin, spread, and adaptations of the anatomically modern humans (i.e. *Homo sapiens*) during the Pleistocene have always been at the center of productive debates in paleoanthropology. The Pleistocene epoch as a whole was extremely dynamic being characterized by the shifts between chronic cold and dry conditions to wetter and warmer ones in rapid succession. The Middle and Upper Pleistocene period (composed of Marine Isotope Stages 6-2 between 191 to 29 kya) also saw significant changes that played a critical role in the evolution of our own species (Cann et al. 1987; Bandelt et al. 2006; Klein 2009; Grine 2016; Jones and Stewart 2016a, b). It is also during this period, which anatomically modern humans evolved and all the important cultural advancements that gave them competitive advantages over the Neanderthals and other archaic hominin populations in Eurasia emerged (Clark 1989; Mellars and Stringer 1989; Mellars et al. 2007; Bräuer 1989, 2008; Bräuer and Smith 1992; McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Klein 2009). In Africa, the large part of the Middle and Upper Pleistocene is associated with the archaeological period known as the Middle Stone Age (MSA) that date in most sites between 300 and 30 kya (Deino and McBrearty 2002; Sahle et al. 2014; Hublin et al. 2017; Richter et al. 2017). Accordingly, the MSA is a critical period to examine the questions related both to the emergence and manifestations of the human behavioural traits that are considered modern.

Given the widely accepted view that anatomically modern humans first arose in sub-Saharan Africa during the MSA and that their behaviour significantly changed in response to the changing environmental conditions, it is critical to understand their foraging ecology and behavioural adaptations (Bräuer 1989, 2008; Mellars and Stringer 1989; Mellars et al. 2007; Bräuer and Smith 1992; Klein 2009; Jones and Stewart 2016a, b; Grine 2016). Analyses of the MSA faunal assemblages are one of the critical parts of the research agenda (Binford 1984, 1987, 1991; Nitecki and Nitecki 1987; Mellars and Stringer 1989; Hovers and Kuhn 2006; Hublin and McPherron 2009; Hublin and Richards 2009; Klein 2009; Clark and Speth 2013).

One of the major issues in the studies of the MSA hominin foraging ecology in Africa has been the understanding of their hunting proficiency (i.e. the MSA and LSA hominins subsistence contrast hypothesis). For over four decades, some archaeologists have cogently argued the MSA hominins were less effective hunters in comparison to their Later Stone Age (LSA) successors (Klein and Cruz-Uribe 1984, 1996, 2000; Klein 2009; Steele and Klein 2009). Some believe that they mostly acquired the large-sized prey mainly by passive scavenging from the carnivore-killed carcasses only to enjoy for scraps of meat and bone marrow (Binford 1984, 1985, 1987, 1988, 1991; Binford et al. 1988). Nevertheless, our knowledge of the changes in the subsistence strategy from the MSA to the LSA in Africa is also still relatively limited in some areas (Marean and Assefa 1999, 2005; Assefa 2002, 2006; Klein 2009; Steele and Klein 2009; Clark and Speth 2013).

With the above debate in mind detailed taphonomic and zooarchaeological analyses of the MSA faunal assemblages recently excavated from the Loiyangalani open-air site in the Serengeti National Park and Magubike rockshelter from the southern highlands of Tanzania were conducted (Figure 1.2). The justification for the selection of the two archaeological sites for this study is presented in subsection 1.7 below, and their detailed descriptions are provided in Chapter 3. Specifically, this study examined faunal resources exploitation patterns (*sensu lato,* prey procurement, carcass parts transport and processing intensity) in order to infer MSA hominins subsistence strategies. This has significant implications for the understanding on how the anatomically modern humans (*Homo sapiens*) survived and how their descendants subsequently managed to disperse out of Africa to eventually outcompete the Neanderthals and other indigenous hominin populations in Eurasia (Figure 1.1).

1.2. Models on Origins of Modern Human

The quest for the origin of the anatomically and behaviourally modern humans has consistently been a contentious topic in paleoanthropology. Around twenty years ago, there were two major competing evolutionary models, the Recent African Origin (RAO) model (or Out-of-Africa 2) and the Multiregional or Regional Continuity model. Both models made use of the genetic, hominin fossils record and the archaeological evidence to substantiate their arguments. For a comprehensive summary of the genetic evidence see Relethford (2008), for the archaeological evidence see (Mellars and Stringer 1989; Mellars et al. 2007; McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Klein 2009) and for a recent comprehensive reviews of the hominin fossils record from MIS 6-2 see (Bräuer 1989, 2008; Clark 1989; Grine 2016).

The Out-of-Africa 2 model emerged in the mid-1980s and holds that anatomically modern humans *(Homo sapiens)* evolved exclusively in Africa about 200 kya and later dispersed throughout the rest of the world, mostly replacing the resident hominin populations such as the Neanderthals in Eurasia with little interbreeding (Stringer and Andrews 1988; Stringer 1990, 2001, 2002). This model is widely supported by the hominin fossils record, chronometric dates from the critical sites, archaeological evidence from Africa, Eurasia and the Near East, and by the genetic evidence of the extant humans from different parts of the world (Cann et al. 1987; Clark 1989; Mellars and Stringer 1989; Mellars et al. 2007; Stoneking and Cann 1989; Wilson and Cann 1992; Aitken et al. 1992; Ingman et al. 2000; Templeton 2002; McBrearty and Brooks 2000; Bandelt et al. 2006; Hovers and Kuhn 2006; Bräuer 1989, 2008; Clark 1989; Grine 2016). Proponents of the Out-of-Africa 2 model, often view the Neanderthals as a separate species, both biologically and culturally different from the anatomically modern humans (Taçon 2010). However, over the past five years this model has been to some extent re-modified. This is due to the new evidence resulting from the ancient DNA studies which have discovered not only that the Neanderthals and early modern humans were capable of interbreeding, they actually did so with the Middle East being the likely place where the interactions would have first occurred (Green et al. 2010; Krause et al. 2010).

The (African) Replacement with hybridization model (now also called "Leaky replacement") is a variant of the Out-of-Africa 2 model that both acknowledges a recent African origin and some levels of admixture through interbreeding between the expanding anatomically modern humans and the indigenous Eurasian hominin populations (Bräuer 1989, 2008; Clark 1989; Stringer 1990, 2001, 2002; Eswaran 2002;

Gibbons 2011a, b). Its main divergence from the Out of Africa 2 model it is mainly on the amount of interbreeding between the anatomically modern humans and the indigenous hominin populations that existed in Eurasia. The Out of Africa 2 model mostly envisages little or no interbreeding at all, whereas the Leaky Replacement argues for a small but significant amount of interbreeding between the hominin populations (Stringer and Andrews 1988; Stringer 1990, 2001, 2002). This has been lately supported by the recent complete genomic sequencing of three female Neanderthals specimens dating 38 kya from Vindija Cave in Croatia and a previously unknown archaic hominin from Denisova Cave in southern Siberia (Reich et al. 2011; Gibbons 2011b). Svante Pääbo has also recently reported that many of the Europeans and Asians share about 1 - 4% of their nuclear DNA with the Neanderthals but not with the modern sub-Saharan Africans, which is an indication that some gene flow happened after the Out of Africa 2 migration (Pääbo 2003).

The Multiregional model that actually preceded the original Out of Africa idea, accentuates the role of genetic continuity over time through gene flow between contemporaneous African and Eurasian hominin populations throughout the Middle and Upper Pleistocene (Figure 1.1). Multiregional proponents (now few) argue that anatomically modern humans arose not only in Africa but also in Europe and Asia from their local Middle Pleistocene forebears *Homo erectus* or *Homo heidelbergensis* at around 800 kya and so retained certain regional skeletal characteristics (Thorne and Wolpoff 1981, 1992; Wolpoff 1989, 1992; Wolpoff and Caspari 1997). Some proponents of multiregionalism have argued that there is some continuity between the Neanderthals and anatomically modern humans mostly attained through gene flow, and that the

Neanderthals contributed to the gene pool of the subsequent hominin populations (Smith 1992; Smith et al. 2005; Frayer 1997). Unfortunately, this model is not supported by the genetic evidence and has mostly been deserted in the recent years except by a few adherents.

Fred H. Smith, a former student of M.H. Wolpoff (Smith et al. 1989), proposed the assimilation model (a variant of the Multiregional model). It accepts an African origin for anatomically modern humans, but it grossly rejects replacement or migration as the major factors for the emergence. Instead, it emphasizes the importance of gene flow from Africa and genetic admixture between the hominin populations. In the light of the recent genetic and hominin fossil record, as well as the archaeological evidence, the likely and most plausible explanation for the origin of anatomically modern humans and their successful dispersal out of Africa is some amalgamation of the Out of Africa 2 model with the Leaky Replacement model (see Figure 1.1 below).

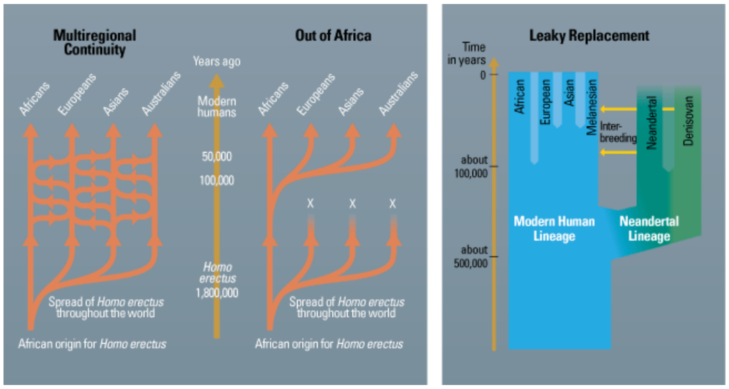


Figure 1.1. Models of Modern Human Origins (Adapted from Gibbons 2011a).

1.3. The Hominin Fossils and Genetic Evidence

The hominin fossils record and genetic evidence from the living people have unequivocally demonstrated that anatomically modern humans (i.e. *Homo sapiens*) first arose as a separate species in sub-Saharan Africa around 200 kya and later dispersed out of their natal continent to eventually become the ancestors of all the living humans worldwide (Cann et al. 1987; Bandelt et al. 2006). Of note, *Homo sapiens* remains recently re-dated from Jebel Irhoud in Morocco have pushed back the origin of our own species by more than 100 kya (Hublin et al. 2017; Richter et al. 2017). Nevertheless, the prevalent consensus amongst paleoanthropologists and archaeologists is that some *Homo sapiens* began dispersing from Africa by at least 100 kya in several waves, reached Australia by at least 45 kya and possibly East Asia by 55 kya with an event followed by the extinction of all the indigenous hominin populations in Eurasia (O'Connell and Allen 2004; Krause et al. 2010; Benazzi et al. 2011). Later on their descendants reached the Americas (see Figure 1.1). Nonetheless, the precise timing and dispersal routes involved for a long time have not been entirely resolved.

The Out of Africa 2 model proposes that Africa is the only continent with the continuity for the past 200 kya in the skeletal morphology and diversity from the archaic *Homo sapiens* to anatomically modern humans and that by 100 kya all humans in sub-Saharan Africa were fully anatomically modern (Bräuer 1989, 2008; Clark 1989; Bandelt et al. 2006; Grine 2016). Surprisingly, anatomically modern humans appear to have remained in Africa until roughly 50 kya. This period coincides with the onset of the LSA in Africa and the Upper Paleolithic (UP) in the Eurasia (Klein 1992, 1995, 2000, 2008, 2009).

For Africanist researchers, the main conundrum remains why there is no evidence of an earlier dispersal of anatomically modern humans out of Africa? Anatomically modern humans appear to have been beleaguered by a bottleneck associated with the onset of cold and dry glacial conditions, as well as by other catastrophic events such as the Toba volcanic eruption at 73 kya (Harpending et al. 1993, 1998; Rodgers and Jorde 1995). Worldwide plant resources enormously declined to a few punctuated refuge patches, and temperatures were totally unstable (Jones and Stewart 2016a, b). This in turn profoundly affected the anatomically modern human populations, which consequently declined to just around 10,000 individuals between 60 and 40 kya (Klein 1998, 2008, 2009). The northern and southern tropical Africa regions, for example, were completely deserted by humans (Jacobs and Roberts 2009; Hublin and McPherron 2009; Hublin and Richards 2009). The bottleneck is also reflected in a limited amount of the genetic diversity among members of our own species today, and by a sharp drop in the number of the archaeological sites, as well as the African hominin fossils dating to this period (Bräuer 1989, 2008; Clark 1989; Ingman et al. 2000; Klein 2009; Steele and Klein 2009; Grine 2016). Besides, the bottleneck is also reflected in Africa by the dearth of the LSA occupations in the most deeply stratified MSA cave sites from the southern Africa coast such as at Klasies River, Montagu Cave, Blombos Cave, and Die Kelders Cave 1. These were only re-occupied from around 20 kya or much later (Klein 2009). In southern Africa, the majority of the LSA sites such as those from Border Cave and Rose Cottage Cave are dated by less than 18 kya (Wadley 1997). Accordingly, many paleoanthropologists and archaeologists consider the climatic instabilities mainly hindered the movements of the anatomically modern humans and dispersal out of Africa and even between the regions within the continent itself until roughly 50 kya.

Today the East Africa region, which includes Tanzania, Kenya, Uganda, Ethiopia, Eritrea, Djibouti, Sudan, South Sudan, Rwanda, and Burundi, is widely covered by the mixed tropical rain forests (Basell 2008). In the past it was quite different (Blome et al. 2012; Maslin et al. 2014). Some parts in the region, however, were relatively moist through the bottleneck, and may have served as refugia for the environmental fluctuations troubled *Homo sapiens* populations (Ambrose 1998; Basell 2008). Some researchers working in East Africa region have also recently correlated the large-scale Pleistocene environmental fluctuations to the emergence and dispersal of anatomically modern humans (see Clark 1989; Scholz et al. 2007; Basell 2008; Blome at al. 2012; Maslin et al. 2014; Willoughby 2012b).

The Eastern Arc Mountains, which cover much of the areas close to the Indian Ocean coast in Tanzania and Kenya are today mostly characterized by moist montane forests (URT 2010). Palaeoecological evidence also indicates they have experienced long-term environmental and ecosystem stability (Finch et al. 2016). Sediments core drilling in the Dama Swamp near the Udzungwa National Park in Iringa Region about 70 km away from Magubike rockshelter have shown that the southern highlands of Tanzania also had more favourable climate conditions (stable temperatures and rich plant resources) between 50 and 18 kya making it an attractive place for the animals and hominin populations as they escaped the more drier low altitude areas (Mumbi et al. 2008; Finch et al. 2009). Accordingly, the Eastern Arc Mountains and the southern highlands of Tanzania may have served as the highland refugia during a large part of the

Upper Pleistocene. The Great and Little Ruaha Rivers and their tributaries dissecting the southern highlands of Tanzania might have afforded the wildlife and hominins access to reliable fresh water sources, edible resources and their valleys may have constituted important escape routes in search for the ecologically rich and hospitable pockets during environmental crises of the Pleistocene. Recent archaeological evidence from the rockshelters and open-air sites in Iringa Region has also recently suggested that hominins might have uninterruptedly settled the southern highlands of Tanzania from the Early Stone Age to historical times, thereby surviving several glacial cycles (Kimaro 2008; Collins 2009; Bushozi 2011; Willoughby 2012b; Miller and Willoughby 2014; Sawchuk and Willoughby 2015; Biitner et al. 2007, 2017; Werner and Willoughby 2017).

Starting in the mid-1970s, MSA assemblages from sub-Saharan Africa came under close scrutiny mainly on the account of their association with the remains of the anatomically modern humans. The new chronometric dates showed that the MSA assemblages could be of much greater antiquity than previously thought (Wendorf et al. 1975; Clark 1988; Aitken et al. 1992). However, some impeding factors are noted (see Conard 2008; Sahle et al. 2014; Grine 2016; Hutson 2016 and references therein). A lot research has concentrated on the studies and evidence from the coastal cave sites from southern and northern Africa that often have deep stratified deposits documenting several cultural periods (Conard 2008; Hublin and McPherron 2009; Hublin and Richards 2009; Lombard 2012; Faith 2011a, b; Clark and Speth 2013; Sahle et al. 2014). In large part of Africa, few MSA sites with deep deposits rich in lithic and well-preserved organic remains spanning during and across the Pleistocene have been discovered (Marean and Assefa 1999, 2005; Assefa 2002, 2006; Steele and Klein 2009; Grine 2016). The number of the hominin fossil remains is also generally few and usually include isolated teeth, fragmentary cranial and postcranial elements to barely complete skeletons (Bräuer 1989, 2008; Clark 1989; Klein 2009:475; Grine 2016:323; Hublin et al. 2017:289). Of note, there is also an evident lack of the faunal assemblages that span the transition from the Middle to Later Stone Age (dating between 60 and 20 kya) from the most of the sub-Saharan Africa (Steele and Klein 2009:113). Securely and well-dated MSA sites and deposits are also rare which poses massive challenges to address the questions pertaining to the manifestations of modern human behaviour. For example, in the whole of the East Africa region there are fewer than 60 well-dated MSA sites (Mehlman 1989; Deino and McBrearty 2002; Tryon and McBrearty 2006; Tryon and Faith 2013; Basell 2008; Gliganic 2011; Gliganic et al. 2012; Morgan and Renne 2008; Sahle et al. 2014; Grine 2016). The absence of secure chronological dates for the majority of the MSA sites often make archaeological studies more challenging. Besides, animal remains recovered from numerous MSA sites in sub-Saharan Africa region are also heavily fragmented and frequently pose massive analytical difficulties and interpretative challenges (Turner 1989; Marean and Kim 1998; Marean et al. 2000; Bartram and Marean 1999; Reynard 2011; Badenhorst and Plug 2011). It is also evidently clear that our knowledge of the later human evolution in sub-Saharan Africa is essentially still patchy. In order to steadily alleviate the problems new archaeological investigations should now be undoubtedly directed towards comprehensive studies of the stratified MSA deposits that are chronometrically well-dated. To further our understanding on the complex interplay and to test the biological models against the cultural models the new studies should be complemented by high-resolution paleoecological datasets (Cohen et al. 2007; Scholz et al 2007; Basell 2008; Blome et al. 2012; Maslin et al. 2014; Jones and Stewart 2016a, 2016).

Since the early-20th century, geologists, palaeontologists, and archaeologists have widely surveyed and studied the geological exposures, rockshelters and open-air sites in sub-Saharan Africa (Shaw 1989; Robertshaw 1990a, b; Phillipson 2005). The East Africa region has produced the largest corpus of datasets documenting each period and stage in the hominin biological and cultural evolution. The region also preserves rich records of the archaic and early anatomically modern humans in several sites, many of which date between 200 and 100 kya (Bräuer 1989, 2008; Clark 1989; Klein 2009; Grine 2016). Of note, the oldest hominin fossil remains assigned to *Homo sapiens* in Africa may now be from Jebel Irhoud in Morocco, re-dated to 315 kya from burnt flints associated with abundant fossilized animal bones and MSA stone tools (Hublin 1992; Hublin et al. 2017; Smith et al. 2007; Richter et al. 2017). The second oldest are the fragmentary cranium and postcranial bones from Omo Kibish 1 in southern Ethiopia dated to 196 kya (McDougall et al. 2005). The third oldest are from Herto in the Middle Awash region of Ethiopia and are dated between 160 and 154 kya (White et al. 2003). The Singa cranium from Sudan is dated to around 133 kya (McDermott et al. 1996).

From Tanzania, a nearly complete adult skull attributed to archaic *Homo sapiens* (LH 18) was recovered eroding out of the Ngaloba Beds at Laetoli (Day et al 1980; Cohen 1996). Magori and Day (1983) initially gave the age 120 kya for the cranium. Later Hay (1987) came with an age estimate of 129 ± 4 kya by U-Th date for it. Manega (1993) pushed back the date to approximately 200 kya on the basis of amino-acid racemization of ostrich eggshell. Three isolated hominin molars recovered from Bed VI-

B at Mumba rockshelter nearby are also attributed to *Homo sapiens* and are dated by Uranium-thorium and uranium-protactinium between 132 and 109 kya respectively (Bräuer and Mehlman 1988; Gliganic 2011; Gliganic et a. 2012). A new frontal bone of *Homo sapiens* recovered from the Eyasi Basin lakebed site is dated by ESR and U-series (^{230}Th/^{234}U), to between 104 and 92 kya respectively (Domínguez-Rodrigo et al. 2008). Magubike rockshelter from the southern highlands of Tanzania has also recently yielded isolated *Homo sapiens* teeth from its MSA deposits dating to at least 50 kya (Feathers 2016; Miller and Willoughby 2014). These may be significantly older since ESR date on associated land snail shells suggests an age in excess of 200 kya (Spiller et al. 2014; Grine 2016:350).

From southern Africa region, anatomically modern human remains are mostly fragmentary specimens from Klasies River, Pinnacle Point 13B A, Die Kelders Cave 1, Border Cave, Blombos Cave, Sea Harvest, and Hoedjiespunt (Bräuer 1989, 2008; Clark 1989; Klein 2009; Grine 2016).

Early known anatomically modern humans remains reported from outside of Africa include the finds from Skhul and Qafzeh caves close to the Mediterranean coast in Israel. These are dated by Thermoluminescence (TL) and Electron Spin Resonance (ESR) techniques to between 100 and 92 kya respectively and are generally thought to represent a northward expansion of anatomically modern humans out of Africa during the MIS 5e (Valladas et al. 1998). This area was also home to the Neanderthals who went extinct between 50 and 30 kya (Figure 1.1). In Europe the oldest anatomically modern human remains are possibly the isolated teeth, initially classified as Neanderthals, but recently re-dated between 45 and 43 kya from Grotta del Cavallo in southern Italy (Benazzi et al.

2011). In Australia, the oldest anatomically modern human fossil dates between 50 and 42 kya (Bowler et al. 2003; O'Connell and Allen 2004).

A spate of genetic studies over the past four decades has also considerably contributed the debate on the emergence of anatomically modern humans and their ancient demographic dynamics (Bandelt et al. 2006). Mitochondrial DNA (mtDNA), that is inherited maternally and not subject to recombination, is commonly used to measure genetic evolutionary events. Cann and colleagues studies of the living human populations (147 individuals) from different parts of the globe demonstrated that the living Africans represent an ancestral population characterized by the greatest diversity of within-group variability compared to the rest, and that all other living people today have descended from a single common African population ancestor who lived between 200 and 100 kya in sub-Saharan Africa (Cann et al. 1987; Stoneking and Cann 1989; Wilson and Cann 1992). This model is often dubbed as the "Mitochondrial Eve" in reference to the Biblical first woman (Templeton 1993, 2002; Ayala 1995).

Cann and colleagues (1987) genetic studies, however, were later ferociously attacked by other scholars especially on the grounds of the mutation rates estimation, method used to derive the genealogical trees, and the use of the African-Americans to represent the African population (see Excoffier and Langaney 1989; Maddison 1991; Templeton 1992, 1993, 1997; Pearson 2004, 2008 for the details of the critiques). While some scholars critiqued their results, Cann and colleagues pioneering work later led to numerous subsequent complete genomic sequence studies to be conducted. Later mtDNA studies, such as those carried out by Vigilant and colleagues (1991), Penny and colleagues (1995) and Horai and colleagues (1995) consistently confirmed the earlier mtDNA results.

More recent analyses of Y-chromosomes, which are paternally inherited, have also strongly supported a single African origin and the idea that anatomically modern humans experienced a rapid ancient demographic expansion at around 100 kya after some population bottleneck events (see Rogers and Jorde 1995; Hammer 1995; Harpending and Rodgers 2000; Underhill and Kivisild 2007; Underhill et al. 2001).

1.4. Middle Stone Age and the Behavioural Modernity Debate

The major input of archaeology to the debate on the origin of anatomically modern humans is to address the manifestations of modern behaviour across time and space (Nitecki and Nitecki 1987; Stringer and Andrews 1988; Mellars and Stringer 1989; Mellars et al. 2007; McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Hublin and Richards 2009; Hublin and McPherron 2009; Klein 2009; Clark and Speth 2013). However, the timing and nature of the emergence of modern human behaviour during the Upper Pleistocene have been hotly debated and have divided archaeologists for over a half-century now. Models are split into two major perspectives: the Late Upper Pleistocene Model and the Early Upper Pleistocene Model. The debate mostly gravitates on two major aspects: what made these people “anatomically modern” as opposed to “behaviourally modern” (McBrearty and Brooks 2000; Henshilwood and Marean 2003; Klein 2009).

The Late Upper Pleistocene Model

Some researchers (a minority) believe that anatomically modern humans and fully modern behaviour emerged and spread abruptly and relatively late in Africa, sometime between 50 and 40 kya (Klein 1992, 1995, 2000, 2008, 2009). This would place it at the transition from the MSA to the LSA, making it coeval with the "Upper Paleolithic Revolution" of Eurasia (Mellars 1989, 2005, 2006; Reynolds 1991; Bar-Yosef 1998, 2002, 2007). A broad spectrum of the radical biological, demographic, and cultural advancements accompanied the onset of modern human behaviour. According to Richard G. Klein, a highly advantageous neural mutation (the Neural Advancement Model, considered by some archaeologists as a variant of the Late Upper Pleistocene Model) propelled an abrupt shift into "fully modern behaviour" (Klein 1992, 1995, 2000, 2008, 2009). The brain rewiring bolstered the anatomically modern humans cognitive power, facilitated technological innovations, complex language, and symbolic mediated behaviour. A list of traits thought to appear as a result include blade, bone and ivory tool production, hafting to produce composite tools, effective hunting of the large-sized and dangerous animals, specialization in hunting of one or two animal species, production of art, personal ornamentation, pigment use, more elaborate ritualistic burials, cave paintings, long-distance trade and exchange, expansion into harsh environments as well as exploitation of the avian, and aquatic resources (see Henshilwood and Marean 2003:628 for a comprehensive summary of the traits list). Together, these permitted the successful dispersal of the anatomically modern humans out of Africa and permitted them to outcompete the resident archaic hominin populations such as the Neanderthals in Eurasia (Figure 1.1). These traits are mostly typical of the African LSA and the UP in

Europe and are also comparable to the well-documented modern hunter-gatherers toolkit (Lee and Dally 1999b; Kelly 2007). Proponents of the Late Upper Pleistocene model also broadly consider the antecedent MSA period to be overall static and characterised with few major changes for a long time (see Klein 2009 for the details; but also see McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Shea 2011a, b for contra views). Of note, the main strength of the neural advancement mutation model proposed by Klein is that it prudently explains the causal mechanism for the instantaneous and amplified cultural innovations at around 50 kya and how they spread across the globe (Klein 2009).

Many other scholars, however, have critiqued the trait list summarised above on the epistemological and taphonomic grounds, as it is largely based on a richer European archaeological record in which the transition from the Middle Paleolithic (MP) to the Upper Paleolithic (UP) corresponds well to the appearance of *Homo sapiens* there at around 50 kya (Conard and Bolus 2003; Benazzi et al. 2011). In Europe, it is notably marked by outstanding inventions such as durable art, ornamentation, ritual, and bone tool technology (Henshilwood and Marean 2003). However, throughout the African continent and in the Levant, anatomically modern humans appeared well before the transition from the MSA/MP to LSA/UP and many of the traits listed above are not diagnostic of the archaeological assemblages originating from the tropical and subtropical Africa (Henshilwood and Marean 2003). Decoding diagnostic characteristics of modern behaviour that discriminate the MSA/MP from those of the LSA/UP is also problematic as there is still no absolute agreement as to the uniform definition of “modern behaviour” amongst archaeologists (Wadley 2001; Bower 2005). In addition, the spatial-temporal distribution of these cultural innovations (Mellars and Stringer 1989; Mellars et al. 2007; McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Willoughby 2007; Clark and Speth 2013), the contributions of the environmental disasters in their appearance (Cohen et al. 2007; Scholz et al 2007; Basell 2008; Blome et al. 2012; Maslin et al. 2014; Jones and Stewart 2016a, b), and their direct correlation to the emergence of modern human behaviour largely still remain debated. Some scholars have even pointed out that some of the so-called "modern traits" do not match up well with the alleged higher cognitive power thought to mark the onset of the behavioural modernity and some even advocate the term "modernity" should be discarded altogether (see Shea 2011a, b). Again, the alleged neurological mutation purported to have triggered the amplified cultural innovations at around 50 kya also cannot be tested against the hominin fossils record, as humans were already anatomically modern well before this date. This also makes the neural mutation model to be a poor guide to explain the advent of modern human behavioural capacities as opposed to the gradual and increasing complexities as mirrored in the archaeological record (McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Willoughby 2007).

The Early Upper Pleistocene Model

Others (now the majority) had cogently argued that advanced modern human behaviour accumulated gradually and deeper in the Pleistocene as well as long before 50 kya in Africa where also all other early major steps in hominin evolution took place. Proponents of this model points to the growing accretion and early glimmering of the typical markers of modern human behaviour in the MSA in Africa and the European MP archaeological assemblages that both predate 50 kya, and appear in time and space to be mostly gradual and heterogeneous (McBrearty and Brooks 2000; Henshilwood and Marean 2003; McDougall et al. 2005; Hovers and Kuhn 2006; Clark and Speth 2013). Of note, the African MSA also covers a relatively long time span compared to the LSA and predates the "Upper Palaeolithic Revolution" as well as the purported neural mutation at 50 kya proposed by Klein (Deino and McBrearty 2002; Morgan and Renne 2008; Sahle et al. 2014; Hublin et al. 2017; Richter et al. 2017). As Paul Mellars (2005:16) recently stated, "it is now possible to show beyond any reasonable doubt that many of the classic, distinctive archaeological markers of the Upper Paleolithic in Europe can be documented at least 40 to 30 kya earlier in some areas in Africa than anywhere in Europe itself". Comprehensive reviews of the MSA findings in Africa in support of the Early Upper Pleistocene model are extensively appraised in several publications (Mellars and Stringer 1989; Mellars et al. 2007; McBrearty and Brooks 2000, Henshilwood and Marean 2003; Hovers and Kuhn 2006; Willoughby 2007) and their details lie beyond the scope of this chapter.

As of recent, many scholars have turned to other plausible alternative interpretative frameworks to explain the emergence of modern human behaviour and successful dispersal out of Africa which mostly include the social, technological development, climatic changes, demographic expansion and pressure as well as behavioural ecological factors (see Clark 1989; Shennan 2001; Winterhalder and Smith 2000; Bird and O'Connell 2006; Scholz et al. 2007; Cohen et al. 2007; Basell 2008; Powel et al. 2009; Blome et al. 2012; Maslin et al. 2014). The new major research questions that mostly remain to be pondered currently include: when (during the MSA), where (in Africa), in which region within the African continent (East Africa), why (is one of the regions that have produced some of the oldest dates for the *Homo sapiens* remains and MSA archaeological assemblages), what were the ecological conditions for the an evolutionary event (some parts of the region served as refugia for the environmental fluctuations troubled *Homo sapiens* populations) and the nature and range of variability in MSA hominin foraging behaviour when they became behaviourally modern in all aspects. The MSA faunal assemblages are one of the critical parts of the research agenda and can be fruitfully used to address diverse paleoanthropological research questions (Nitecki and Nitecki 1987; Marean and Assefa 1999, 2005; Assefa 2002, 2006; Henshilwood and Marean 2003; Hublin and McPherron 2009; Hublin and Richards 2009; Klein 2009; Clark and Speth 2013).

1.5. Middle Stone Age Faunal Remains and the Behavioural Modernity Debate

Unceasing effort is usually needed by any individual organism to maintain its relative fitness and its ability to live and to produce offspring. Hominins do not deviate from this fundamental need and always have in their evolution engaged themselves in food foraging (Lee and DeVore 1968; Lee and Daly 1999b; Nitecki and Nitecki 1987; Bettinger 1991; Stanford and Bunn 2001; Ungar 2007; Ungar and Teaford 2002; Kelly 2007). Foraging refers to the activity of food acquisition without producing them. Food provides energy and the essential nutrients to meet the bodily metabolic needs.

Hominin foraging is mostly based on hunting wild animals, gathering plants, and fishing (Lee and Daly 1999a:3). Animal prey provides hominins with both the dietary resources (meat, marrow, and grease) and raw materials (bone, antler, skin and sinew) for tool production. More specifically, meat provides the necessary nutrition source of calories to hominins and often supplements the plants as well as other gatherable recourses portions of their diet spectrum to meet the metabolic demands associated with their relatively larger brain size (Speth 1989; Aiello and Wheeler 1995; Bunn 2007). This in prehistory might have afforded them special key traits such as expansion of the neo-cortex of the brain, change in life histories, may have promoted food sharing and other cooperative behaviours (Kaplan et al. 2000; Isaac 1971, 1978; Driver 1990, 1995; Winterhalder 1997; Stiner et al. 2009).

Many paleoanthropologists and archaeologists agree that animal hunting is unquestionably an important component of the modern human behaviour repertoire the view that can be traced back during the Man the Hunter Symposium (Lee and DeVore 1968). During the symposium, animal hunting and meat eating were listed as pivotal hominin adaptations and were added to the inventory of the behavioural traits that distinguished them from the other great apes. But, meat is among the most difficult resources to garner from the environment (Stiner et al. 2009:13207).

The advent of effective animal hunting in hominin evolution is also universally considered one of the defining characteristics of modern human behaviour (Washburn and Lancaster 1968; Nitecki and Nitecki 1987; Stanford and Bunn 2001; Ungar and Teaford 2002; Ungar 2007; Hublin and Richards 2009; Clark and Speth 2013). Besides, effective large-sized animal hunting often requires cooperative group efforts of people, complex coordinated communication, and sophisticated technologies (Behrensmeyer 1987; Hayness 1988; Driver 1990, 1995; Knecht 1997; Winterhalder 1997; Kaplan et al. 2000; Kaplan and Robinson 2002; Alvard 2001; Shea 2006, 2009; Hublin and McPherron

2009; Hublin and Richards 2009; Clark and Speth 2013). Accordingly, many palaeontologists and archaeologists consider animal prey procurement strategies are also one of the paleoanthropological evaluative research avenues.

For over five decades, scholars have hotly debated on the relative importance of hunting versus scavenging by the Plio-Pleistocene hominins (see Domínguez-Rodrigo 2002; Domínguez-Rodrigo and Pickering 2003; Dominguez-Rodriguez et al. 2007b for recent comprehensive reviews). Others have focused on the MSA/MP and LSA/UP in an effort to address the manifestations of modern human behaviour during the Upper Pleistocene. Over the past five decades, a variety of models have been invoked to explain diverse MSA/MP hunting strategies some have seen them mostly as ineffective hunters (Klein 1975, 1976, 1977, 1978, 1979, 1981, 1987, 1989, 2009; Klein and Cruz-Uribe 1984, 1996, 2000; Steele and Klein 2009). Others see them as passive scavengers of the carnivore killed and defleshed carcasses (Binford 1984, 1985, 1987, 1988, 1991; Binford et al. 1988), or full adept hunters (Chase 1983, 1988, 1989; Milo 1994, 1998; Marean and Kim 1998; Marean et al. 2000; Assefa 2002, 2006; Faith 2008; Thompson 2008; Dusseldorp 2010, 2012) and/or flexible hunters (Stiner 1991a, b, 1994, 2005). Recurrent issues emphasized in the models mainly include effective hunting of the large-sized, dangerous animals, prime-adults as well as the exploitation of the aquatic and avian resources (Marean and Assefa 1999, 2005; Assefa 2002). For the reasons of preservation, hominin subsistence strategies during the Upper Plio-Pleistocene have always been inferred from the fossil faunal remains, associated stone tools and more recently by using stable isotope chemistry (Nitecki and Nitecki 1987; Stanford and Bunn 2001; Hublin and McPherron 2009; Hublin and Richards 2009; Ungar 2007; Ungar and Teaford 2002;

Clark and Speth 2013; Bocherens et al. 2014;). Nonetheless, direct evidence of plant food exploitation is critically absent (Sept 2001; Kuhn and Stiner 2006; Hublin and Richards 2009; Clark and Speth 2013).

The majority of the faunal assemblages that have been commonly used in the reconstructions of the MSA hominin foraging ecology and predatory behaviour in Africa have come from the southern Africa region where there is also a long history of archaeological research. The region has copious cave sites along its south and western coasts such as Klasies River, Sibudu Cave, Blombos Cave, Nelson Bay Cave, Die Kelders Cave 1, Pinnacle Point 13B, Sibudu and Diepkloof often characterized by deep archeological sequences with excellent preservation of the organic materials mostly encouraged by the geologies. The archaeological sites from the region have also yielded thousands of MSA lithic artefacts, large faunal assemblages and over 40 fossilized fragmentary *Homo sapiens* skeletal remains, which have collectively played a significant role in the reconstructions of the evolution of modern human behaviour (Singer and Wymer 1982; Clark 1989; Deacon 1989; Bräuer 1989, 2008; Klein 2009; Grine 2016). The region also has numerous chronometrically securely dated MSA deposits and has provided the earliest unambiguous evidence of symbolic mediated behaviour, and personal adornment from some MSA assemblages (Henshilwood et al. 2002, 2009; d’Errico et al. 2005).

Studies of the faunal assemblage from Klasies River in South Africa have featured prominently in the discussions over the emergence of modern human behaviour and have stimulated much debate. Richard G. Klein analyzed faunal assemblages from a number of MSA sites: Klasies River (KR) Cave 1, Die Kelders Cave 1 (DK1), Eland’s Bay Cave, Sibudu Cave, Blombos Cave and at a number of LSA sites such as Byneskranskop Cave 1 (BNK1), Blooplaas Cave (BPA) and Nelson Bay Cave (NBC) and identified a number of marked contrasts in ungulate mortality profiles and overall subsistence strategies between the MSA and LSA sites originating from the same environmental settings. From the MSA sites, he noted greater number of relatively docile eland (*Taurotragus oryx*), a scarcity of the large-sized, dangerous and aggressive prey such as the African buffalo (*Syncerus caffer),* bush pig *(Potamocherus porcus)* and warthog *(Phacochoerus africanus),* few prime-adults, rare evidence for specialized hunting strategies and sporadic, rather than systematic exploitation of the marine and avian resources. This is what he collectively dubbed as the "Klasies Pattern" (Klein 1975, 1976, 1977, 1978, 1979, 1981, 1982, 1987, 1992, 1995, 2000, 2008; Klein and Cruz-Uribe 1984, 1996, 2000). On the other hand, he noted fewer eland, more large-sized, dangerous animals, prime-adults, and intensive exploitation of the aquatic and avian resources from the LSA sites from similar environmental regimes. Klein concluded that the MSA hominins were ineffective hunters and less fully modern in their behaviour compared to their LSA successors. He also suggested that the abundance of the large-sized and dangerous animals in the LSA faunal assemblages reflected the introduction of projectile weaponry hunting technology that permitted them to hunt prey from safer distance.

Lewis R. Binford later also re-interpreted the MSA faunal assemblages from Klasies River and from several other Plio-Pleistocene and MP sites in Africa and Europe including from FLK 22 *Zinj* (Tanzania), Combe-Grenal, Grotte Vaufrey levels VII-VIII (France), Swanscombe, and Torralba-Ambrona (Spain). Binford diagnosed a "head-and-foot" (horns, skulls, maxillae, mandibles, teeth, metapodials and phalanges typically with little amount of flesh) dominated the skeletal part profiles relative to the meatier limb bones (humeri, radii, femora, tibiae typically the high-meat bearing elements). He also noted overall low proportions of cut marks inflicted on the fossil bone fragments of the large-sized animals in comparison to the tooth marks (Binford 1981, 1984, 1985, 1987, 1991; Binford et al. 1988). Besides, noting comparisons to what modern hunter-gatherers leave behind at the kill sites of the large-sized animals, accordingly, Binford concluded the early hominins and MSA/MP hominins of Africa and Europe were mostly obligate scavengers of the large-sized animals who came last to the feast of the carnivore ravaged carcasses, only to enjoy the scraps of flesh that survived and bone marrow i.e. also dubbed as the "Klasies Pattern" (Binford 1984, 1987, 1988, 1991; Binford et al. 1988).

According to Binford, the MSA/MP foragers were primitive and behaviourally archaic comparable to the early *Homo* who only managed to hunt the weak and small-sized animals. By implications, they had limited predatory ability to hunt the large-sized prey given the apparent limitations of their technology, and cooperative hunting was almost entirely not part of their behavioural repertoire. This view dominated much of the 1980s and continued into the 1990s. Blumenschine (1986a, b, 1987, 1988, 1991, 1995), Cavallo and Blumenschine (1989), Selvaggio (1994a, b, 1998), Capaldo (1995, 1997, 1998), Pobiner (2007) and Pante and colleagues (2012) also share the view that the early hominins at FLK 22 *Zinj* site at Olduvai Gorge in Tanzania were passive scavengers but of the felids (lions) defleshed carcasses only to retrieve the marginal scraps of meat and bone marrow surviving (but Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo et al. 2007a-c, 2014; Bunn 1981, 1982, 1986, 1996, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Potts and Shipman 1981; Oliver 1994, 2015; Pickering and

Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014 have different explanations).

Richard G. Klein and Lewis R. Binford characterization of the early hominins and MSA/MP hominins subsistence behaviour were later extrapolated to a global scale to serve as an interpretive scheme for their archaeological faunal assemblages i.e. the "standard argument" as Binford (1985:308) dubbed it. Consequently, it became broadly accepted that the carnivores (especially hyenas) generated many of the Plio-Pleistocene and MSA/MP faunal assemblages (Binford 1984, 1985, 1987, 1991; Binford et al. 1988). This pattern is not necessarily universal and many archaeologists do not share the view on both the early hominins and MSA/MP hominins and have different explanations (see Bunn 1981, 1982, 1986, 1996, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Chase 1983, 1986, 1989; Oliver 1994, 2015; Milo 1994, 1998; Marean 1998; Marean and Frey 1997; Marean and Kim 1998; Marean and Assefa 1999, 2005; Marean et al. 2000, 2004; Grayson and Delpech 1994; Bartram and Marean 1999; Assefa 2002, 2006; Domínguez-Rodrigo et al. 2007a-c, 2014; Faith 2008, 2011a, b; Thompson 2008, 2010; Clark 2009; Thompson and Henshilwood 2011; Dusseldorp 2010, 2012).

As remarked above, the models commonly used in the reconstructions of the MSA hominin foraging ecology are mostly based on southern Africa coastal sites and MP sites from Eurasia. However, over the past five decades, the number of the discovered and excavated MSA faunal assemblages in sub-Saharan Africa has expanded, and it is now feasible to test the validity of Klein's and Binford's hypotheses using much-expanded samples and sites that originate from different ecological settings (Marean and Assefa 1999, 2005; Faith 2008, 2011a, b; Hublin and McPherron 2009; Hublin and Richards

2009; Lombard 2012; Clark and Speth 2013). As of late Marean and Kim (1998:S79) have summarized the way forward “many researchers have begun to explore the possibility that most fundamental tactics of faunal exploitation may have varied over time and space during this period”. Besides, Hutson (2016:1) is also of the view that “from an ecological perspective, MSA subsistence was a product of behavioural adaptations to environmental factors and resource availability, the influences of which were likely different between interior and coastal ecosystems”. With regards to the new research directions and where in Africa, Steele and Klein (2009:123) suggest that “the most likely place to find faunal assemblages that span the MSA to LSA ‘transition’ is in East Africa. However, until recently few zooarchaeological studies have been conducted, in part because few suitable assemblages from the relevant site are known. One exception is Porc-Epic, Ethiopia, where Assefa (2006) recently completed a detailed analysis of the MSA faunal remains”.

Since the early-1930s, the East African region has been recognized as an important area for the study of hominin evolution and has yielded the largest and most continuous record of their cultural evolution and achievements (Clark 1988; Shaw 1989; Robertshaw 1990b; Phillipson 2005). The region is well known for extensive paleontological and archaeological sites such as Olduvai Gorge and Laetoli in Tanzania and Koobi Fora in Kenya (Leakey 1971, Bunn 1986, 1994; Leakey and Harris 1987). The region also has produced some of the oldest *Homo sapiens* remains, dated to around 200 kya and aspects of their technological development in the stone tool industries (Clark 1988; White et al. 2003; Deino and McBrearty 2002; McDougall et al. 2005; Sahle et al. 2014; Grine 2016). There is also evidence that some pockets in the region could have supported anatomically modern humans through a number of glacial cycles (Cohen et al. 2007; Scholz et al. 2007; Basell 2008; Mumbi et al. 2008; Finch et al. 2009, 2016; Blome et al. 2012; Maslin et al. 2014). The region also possesses one of the most diverse vertebrate communities of the large, medium, and small-sized mammalian species. The most common and abundant mammals in East Africa are the ungulates and carnivores (Walker 1985; Estes 1991; Owen-Smith 2006).

Middle Stone Age (MSA) sites are also present in relatively large numbers in East Africa region and sample a broad range of ecological settings across time and space (Clark 1988; Basell 2008; Tryon and Faith 2013; Sahle et al. 2014). The sites are well distributed along the East African Rift Valley, forested areas, grasslands, lake margins, and river valleys and thus offer a better chance to study the MSA hominins behaviour. In addition, there are also numerous rockshelters in the region, results from which can be compared to those from the southern Africa region and Eurasia (Mehlman 1977, 1989; Clark 1988; Basell 2008; Tryon and Faith 2013). However, MSA sites with relatively long continuous archaeological sequence are often pretty rare in the region. The majority of MSA sites are characterized by poor preservation of the faunal remains (Clark 1988; Assefa 2002, 2006; Marean and Assefa 2005; Steele and Klein 2009; Klein 2009; Willoughby 2007, 2012b). According to Assefa (2006:51), our understanding of the foraging strategies adopted by the MSA hominins in East Africa region is also still marginal.

This study mainly focused on two MSA faunal assemblages located far away from the Indian Ocean in Tanzania (Figure 1.2). Loiyangalani is an open-air site while

Magubike is a rockshelter and both have yielded large fossilized faunal assemblages from their MSA deposits from the new rounds of research (Tables 5.1, 5.2 and 8.2).

1.6. Research Objectives

The major objective of this study is to understand MSA hominin foraging ecology in Tanzania. The faunal remains that form part of this study came from the excavations conducted in 2003, 2004 and 2005 at Loiyangalani. These were carried out by the Serengeti Genesis Project under the direction of Professor John F.R. Bower of the University of California at Davis, USA, and Professor Audax Z.P. Mabulla, then of the University of Dar es Salaam, but now of the National Museums of Tanzania. The Magubike faunal assemblage came from the new excavations conducted in 2012 by the members of the Iringa Archaeological Project (IRAP) directed by Professor Pamela R. Willoughby of the University of Alberta, Canada.

In the light of the above the main objective, specific objectives of this study are as follows:

a) To conduct comprehensive taphonomic and zooarchaeological analyses of the faunal assemblages;
b) To reconstruct depositional histories and to establish the role of the anthropogenic and non-anthropogenic agents in the formation of the faunal assemblages; and
c) To reconstruct animal prey procurement strategy, carcass parts transport and processing intensity of the carcasses.

This study specifically intended to answer the following related questions: What patterns of faunal resources exploitation characterized the MSA hominins in Tanzania?

And do the MSA faunal assemblages from the Loiyangalani site and Magubike rockshelter contrast appreciably with those of their LSA successors in terms of the prey choices, carcass transport strategies, and processing intensity? In order to answer the above fundamental questions, this study integrated datasets from the skeletal part representation, mortality profile, bone surface modifications, and bone fragmentation patterns. The optimal foraging theory, experimental, and ethnoarchaeological interpretive frameworks guided the interpretations of the results, which also permitted the evaluation of both MSA hominin foraging ecology and predatory behaviour.

1.7. Study Sites and Rationale for their Selection

The two sites were selected for the following reasons. Both sites have been carefully excavated with recent techniques (including piece plotting in 3D of the artefacts recovered at Loiyangalani) and have yielded a wide array of cultural materials from their relatively long archaeological sequences of up to 2 m deep. These generally span the time period from the MSA to the historical period (Figures 3.5 and 3.8). Cultural materials recovered include thousands of MSA and LSA lithic artefacts, fossilized animal bones, fish bone fragments, isolated hominin remains, land snail shells, ochre fragments, as well as ostrich eggshell fragments and beads. The unearthed archaeological assemblages also offer an unprecedented opportunity to investigate a wide repertoire of MSA hominin foraging behaviour including their technology and sociality.

Loiyangalani and Magubike sample two distinct ecological settings namely the grassland and the highlands of Tanzania respectively as emphasized in Chapter 3. The straight distance between the two sites is about 600 km (Figure 1.2). The difference in the ecological nature of the faunal assemblages studied can also shed light on whether the MSA hominins subsistence strategies varied in different ecological settings.

Based on the typo-technological studies of the lithic assemblages, the faunal assemblages considered for this study are broadly similar in age (pending harmonization of the chronometric dates by different dating techniques at Magubike rockshelter and results from the new samples from Loiyangalani submitted for ESR dating). Nonetheless, radiocarbon and OSL dates from both sites indicate that the MSA deposits are broadly in excess of 50 kya (Feathers and Fusch 2005; Feathers 2016; Miller and Willoughby 2014; Bower et al. 2012). Finally, the two archaeological sites offer chances to fulfill my deep and long-term interests in them that grew mainly from participation in excavations as an undergraduate and graduate student at the University of Dar es Salaam and University of Alberta.

1.8. Dissertation Organization

The dissertation is organized into nine chapters covering different aspects of the present study. Chapter 1 serves as a general background to the present study and outlines the major models on the origin of anatomically modern humans. It also summarizes the current MSA/MP hominin subsistence strategies understanding in the light of the ongoing debate on the emergence of modern human behaviour. Chapter 2 defines the MSA concept with a specific focus on its characteristics and chronology. A review of MSA research in Tanzania is also presented, and particular emphasis is given to the finds from the known sites.

Chapter 3 introduces the two sites, and summarizes the findings from the previous archaeological research. Chapter 4 specifically outlines the optimal foraging theory, diet breadth, and the interpretive frameworks through which the faunal assemblages were analyzed and interpreted in the current study.

Excavations, taphonomic, and zooarchaeological methods employed, as well as the recording procedures used in this work, are all described in Chapter 5. Chapters 6 and 7 present results on the Loiyangalani and Magubike faunal assemblages respectively. Chapter 8 is on the discussions and interpretation of the results. Chapter 9 summarizes the research findings, offers conclusions, recommendations, and suggestions for future MSA research directions.

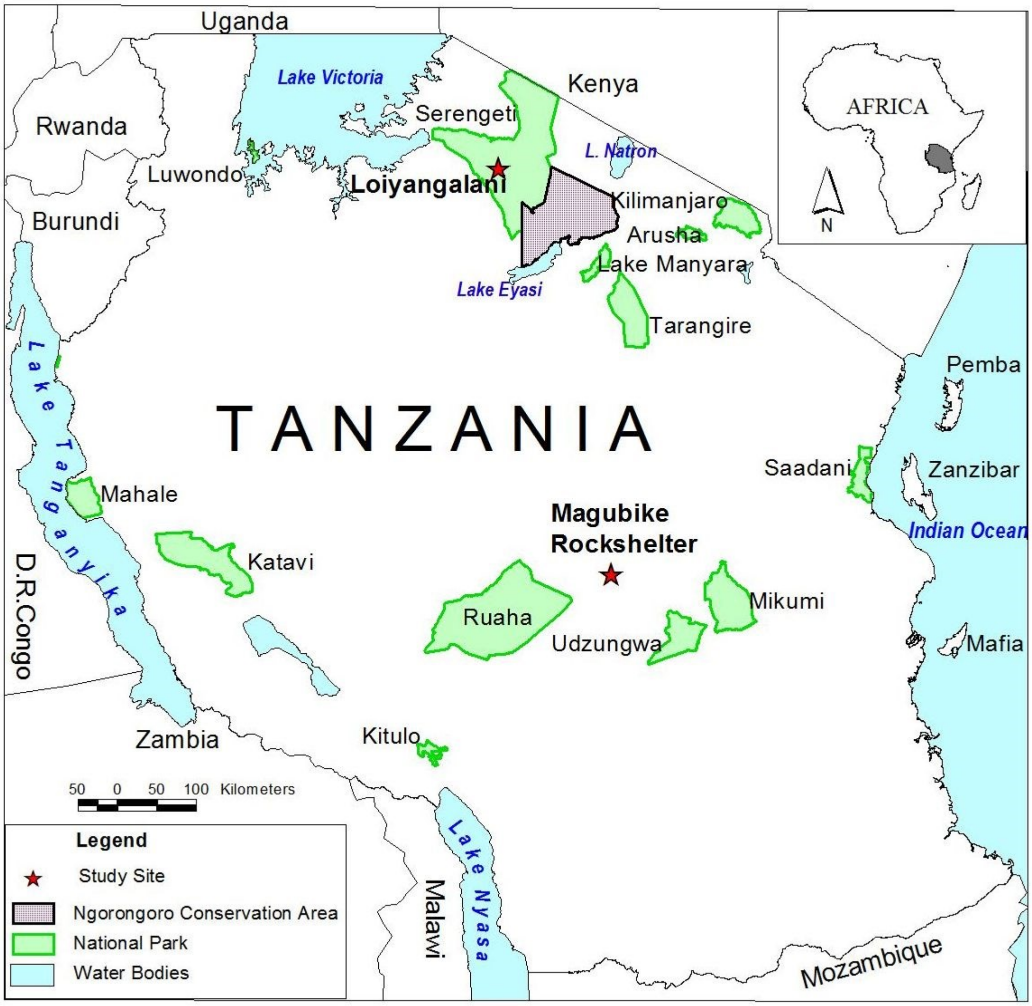


Figure 1.2. Map of Tanzania Showing the Loiyangalani Site and Magubike Rockshelter.

CHAPTER 2

MIDDLE STONE AGE ARCHAEOLOGICAL RESEARCH IN TANZANIA

2.1. Introduction

This chapter traces the development of Middle Stone Age archaeological research in Tanzania from the beginning of the 20th century to the present with a particular reference to the known sites, finds and aspects that are relevant to culture-historical reconstruction (see Figure 2.1; Appendix 1). The review broadly mirrors the archaeological research development trend in the country. Comprehensive reviews of the MSA finds from sub-Saharan African sites are discussed in McBrearty and Brooks (2000), and Willoughby (2007), and specifically from the East Africa region are provided in Clark (1988), Basell (2008) and Gliganic (2011). For the purpose of this chapter, the review is organized geographically starting with the MSA sites from northern Tanzania (from Lake Eyasi basin, Olduvai Gorge, Lake Natron and Lake Manyara basins), then sites from the southern highlands of Tanzania, and concludes with isolated MSA discoveries from the rest of the country (Figure 2.1). The coverage of the MSA sites is not essentially comprehensive as it is broadly based on published and/or unpublished literature and collections curated in the National Museums of Tanzania in Dar es Salaam.

2.2. The African MSA Industrial Complex, Technology and Chronology

A.J.H. Goodwin and C. van Riet Lowe initially defined the Middle Stone Age (MSA) Industrial-Complex for South Africa mainly based on a distinctive shift in lithic technology from core to flake tools mostly including scrapers and points made on retouched flakes and/or Levalloisian pieces (Goodwin 1928, 1931; Goodwin and Lowe

1929). The MSA represents a technologically and chronologically intermediate industry between the Early Stone Age (ESA) and LSA (Goodwin 1928, 1931; Goodwin and van Riet Lowe 1929). The third Pan-African Congress of Prehistory, held in 1955 in Livingstone, Zambia, approved Goodwin's MSA definition and a version of it is now widely used all over sub-Saharan Africa. The MSA tools are often distinguished from the antecedent ESA by an absence of large bifacial tools such as hand axes, choppers, and cleavers and from the LSA by the absence of microliths and backed blades or bladelets (McBrearty and Brooks 2000). Of note, for a long time in North Africa, there has been a tendency to use the European term Middle Paleolithic (MP). However, recently many North African archaeologists have started to use the term MSA routinely (for example, Aouadi-Abdeljaouad and Belhouchet 2009; Hublin et al. 2017; Richter et al. 2017).

The MSA denotes an archaeological entity characterized by the use of more complex Levalloisian technique, derived from the preceding Late Acheulean to make flakes of predetermined size and shape including scrapers and points that were probably hafted to handles to be used as projectiles (Knetch 1997; Shea 2006, 2009). The essential characteristics of the Levalloisian flakes are the convergent dorsal scars and faceted butts. They also sometimes have single or double platforms made from the disc-shaped cores (Goodwin and Lowe 1929). Retouched stone tools that include flake, scrapers (end, side, and convergent), notches, denticulates, bifacial pieces, and simple piercing or grooving tools (becs and burins) characterize the MSA toolkit (McBrearty and Brooks 2000). Points are usually considered to be the hallmark of the MSA Industrial-Complex.

The MSA in sub-Saharan Africa is commonly characterized by the uniformity in stone-tool technology, but there is also a considerable high degree of regional technological and stylistic variability across the continent frequently attributed to long-term ecological adaptations to specific habitats (Clark 1988; Mehlman 1989; McBrearty and Brooks 2000; Hovers and Kuhn 2006; Willoughby 2007; Basell 2008; Tryon and Faith 2013). African MSA lithic assemblages range in age from around 300 kya to as recently as 30 kya. Some of the oldest MSA lithic assemblages in Africa are now from Jebel Irhoud in Morocco recently re-dated to 315 kya (Hublin et al. 2017; Richter et al. 2017). The site has also yielded abundant remains of *Homo sapiens* and fossilized animal bones. MSA lithic assemblage from the Kapthurin Formation in Kenya date to more than 285 kya, finds from Gademotta in Ethiopia are dated to 276 kya and from Twin Rivers in Zambia to 265 kya (Barham 2002; Deino and McBrearty 2002; Tryon and McBrearty 2006; Sahle et al. 2014). The MSA lithic assemblages from Herto site in Ethiopia are dated to between 160 and 154 kya (Morgan and Renne 2008).

MSA assemblages have been recovered in numerous sediments frequently associated with *Homo sapiens* remains, or alternatively, those of the archaic *Homo sapiens/Homo heidelbergensis* (Clark 1989; Bräuer 1989; White et al. 2003; McDougall et al. 2005; Grine 2016; Hublin et al. 2017; Richter et al. 2017).

The LSA replaced the MSA between 50 and 30 kya and is mainly characterized by microliths and backed tools (McBrearty and Brooks 2000) as well as blades or bladelets struck from prepared and parallel-sided cores. Associated hominin fossil remains always belong to *Homo sapiens*. During this time, we also find unequivocal evidence of durable art, such as cave paintings and carvings on bone, as well as beads and other evidence of personal adornment (Klein 2009). In East Africa region, the LSA assemblages often date from about 40 kya and continue until the arrival of the pastoralists and farmers between 5,000 and 3,000 BP (Ambrose 1998; Phillipson 2005).

2.3. General Overview of Archaeological Research in Tanzania

Tanzania is privileged to contain paleoanthropological and archaeological materials that begin in the Pliocene period and extend into historical times. Together, they document long record of hominin evolution and their cultural achievements. An extensive review of published and unpublished literature on Tanzanian archaeology conspicuously unveils the archaeological research has been mostly shaped by individual initiatives with archaeologists selecting the archaeological period coverage (e.g. Early Stone Age, Middle Stone Age, Later Stone Age, Pastoral Neolithic, Iron Age or historical archaeology), and the areas of research and research themes (e.g. Stone Age, heritage sites management and rock paintings). Foreign researchers and teams mainly from Europe, North America, and some other African countries have conducted much of the sustained archaeological research in the country. These include members of the former Center for Prehistory and Palaeontology based in Nairobi, Kenya and led by Dr. Louis Seymour Bazett Leakey, the British Institute for Eastern Africa, the Olduvai Landscape Paleoanthropology Project, the Olduvai Paleoanthropology and Paleoecology Project, the Serengeti Genesis Project and the Iringa Region Archaeology Project to mention a few (Mturi 1978, 1998; Robertshaw 1990b; Chami 2005; Masao 2005; Willoughby 2012b). The contributions of the local archaeologists and institutions, including members of the Department of Archaeology and Heritage Studies of the University of Dar es Salaam, the Tanzanian National Museums, and Antiquities Division, though noteworthy, seem marginal when compared to the research conducted by foreign archaeologists and teams (Mturi 1978; Mehari et al. 2014). This has been attributed to a complex web of factors including the late pedagogical introduction of archaeology in the country (Karoma 1990; Mturi 2005; Schmidt 2005), the dearth of local professional archaeologists until the late-1990s (Mturi 1978, 2005; Robertshaw 1990b; Schmidt 2005), and lack of local sustainable research funding for large-scale archaeological research and field schools (Mehari et al. 2014). Until the early-1990s, there were notably few trained Tanzanian archaeologists, yet this case also prevailed in other African countries (see Musonda 2012). Equally, this could also be related to lack of interest in training local archaeologists by the colonial governments, international funding agencies and foreigner researchers working in Africa (Robertshaw 1990b). However, the number of archaeologists over the past three decades has increased and international research teams and projects working in the country have supported the majority of the first and second-generation Tanzanian archaeologists for graduate studies in Europe and America. Even so, the number of Tanzanian archaeologists with Masters and doctoral degrees in archaeology is still small.

The bulk of the archaeological research in Tanzania has mainly concerted on the paleoanthropological sites in the north which have yielded numerous fossilized hominin remains, and in the spectacular ruins of the Medieval and Swahili settlements along the Indian Ocean coast and its islands (Mturi 1978, 1998; Chami 1998, 2005, 2006). Compared to the rest of the country, the two designated archaeological zones have remarkably benefited from a long history of archaeological research. Archaeological sites from the two zones such as Olduvai Gorge, Laetoli, Mumba rockshelter, Nasera rockshelter, Kilwa and Songo Mnara islands have received by far the most intensive attention.

Archaeological research elsewhere in the country has a rather “Cinderella status” meaning is mostly ignored and/or remain unknown (see Figure 2.1). This is attributed to both external and internal factors, including research funding agency priorities, academic interest variability among archaeologists, good visibility of sites (especially exposed sequences rich in archaeological materials in primary, dateable, geological contexts and spectacular architectural monuments), national political influence (policy on archaeological research zones and research topics instituted from the mid-1970s), interdisciplinary influence (mainly from history and ethnography) and the proximity of the archaeological sites to the earliest established archaeological research facilities in the country (including artefact storage facilities, museums and designated laboratories) such as the National Museum of Kenya in Nairobi, Arusha Natural Science Museum, Olduvai Gorge and the National Museum of Tanzania in Dar es Salaam Tanzania (Karoma 1990; Robertshaw 1990a, b; Mturi 1978, 1998; Schmidt 2005). Rivalries between big research teams working in Tanzania who are allied with local archaeologists have also recently played a part especially on access to some areas, sites, and collections in custody of the government heritage institutions (see also Dalton 2007; Domínguez-Rodrigo et al. 2007a: xiii; Domínguez-Rodrigo et al. 2007e; Egeland 2007:1).

Growing archaeological research into unexplored areas especially those championed by the local archaeologists has demonstrated the potential to address a broad range of research topics and to address the research bias remarked above (Mehari et al. 2014). Unfortunately, majority of the new research projects significantly overlap and appear to be biased to the LSA, Iron Age, rock paintings, historical archaeology and heritage sites management. By comparison, MSA research has noticeably gained little popularity amongst the local archaeologists (for notable exceptions see Mabulla 1990a, b; 1996; Masao 1992; Bushozi 2003, 2011).

Below, MSA research in Tanzania is reviewed. For the purpose of this chapter, MSA research in Tanzania is loosely divided into two main phases that also correspond roughly to the general development of archaeological research in the country: the Pre-1960s phase and Post-1960s phase (Mturi 1978, 1998; Chami 2005; Masao 2005). The arbitrary division into two is essentially based on the main features that characterized each phase.

2.4. Pre-1960s Middle Stone Age Archaeological Research

The second part of the 19th C saw European expansion into Africa whose prevailing attitude towards the continent before the invasion was that "Africa has no history" (see Shaw 1989; Robertshaw 1990a; Willoughby 2007). Colonial explorers, administrators, missionaries and foreign enthusiasts, however, intermittently reported isolated finds of stone artefacts mainly of the Early Stone Age (ESA) bifacial tools that initially had little scientific interest to foreign archaeologists (Robertshaw 1990a, b; Gowlett 1990). Normally, reports were descriptions of the archaeological surface finds, frequently anecdotal in nature and with very limited useful archaeological information by modern standards (Robertshaw 1990a). However, gradually the archaeological finds from different parts of the continent eventually forced themselves upon the attention of foreign archaeologists and consequently the recognition of a richer African Stone Age heritage that later became the focus of future investigations (Shaw 1989; Robertshaw 1990a:4; Phillipson 2005).

Although the presence of stone tools in East Africa region were initially recognized by Professor J.W. Gregory, for whom the Gregory Rift was named, as far back as 1893, systematic Stone Age archaeology had its roots in the early 20th C beginning with the work of E.J. Wayland in 1919 in Uganda, and Dr. Louis S.B. Leakey in 1926 in Kenya. They both extensively explored the eastern African Rift Valley mainly to understand its geology and search for remains of the early hominins (Wayland 1924, 1929; Leakey 1929, 1931, 1936b; Cole 1954:46-52). Dr. Louis S.B. Leakey, later in 1931, shifted his attention to Olduvai Gorge in Tanzania where and his second wife Mary D. Leakey were involved for several decades in the excavations and detailed analyses of the archaeological materials (Leakey 1971, 1994). Mary Leakey also later became known for her documentation of the rock paintings from central Tanzania (Leakey 1983). The Leakey family is also globally well known for its contribution in the discoveries of early hominin remains at Olduvai Gorge in Tanzania and elsewhere in East Africa region, and their descendants continue to make contribution today.

Describing Stone Age cultures and how they change through time and space, along with discovering early hominin remains and reconstructing their way of life continued to be the main focuses of the archaeological research until the end of the 1960s (Leakey 1971, 1994; Clark 1988). This attitude is plainly seen in the prevailing key theme of the books published during the phase such as *The Stone Age Cultures of Kenya Colony* (Leakey 1931), *Stone Age in Africa: An Outline of Prehistory in Africa* (Leakey 1936b), *The Prehistory of Uganda Protectorate* (O'Brien 1939), *Prehistory of East Africa* (Cole

1954), and elsewhere *The Stone Culture of Northern Rhodesia* (Clark 1950). In absence of reliable chronometric dating techniques, the early archaeological research in East Africa were mostly aimed at establishing the relative chronology of the Stone Age sequences, which were, then broadly compared to the already established European Stone Age industries (Leakey 1936b; Cole 1954; Robertshaw 1990a, b). Characteristic artefact types, what the French labelled *"fossiles directeurs"* frequently defined cultural phases or periods. Diffusion theory dominated the realm to explain the cultural changes observed in the archaeological record and changes were mostly ascribed as the result of the influences of outside cultures (Chami 2006, 2007; Trigger 2008; Johnson 2010).

There was remarkably little general interest in the Middle Stone Age (MSA) research when compared to that of the Early Stone Age (ESA) until the mid-1970s. Different explanations can account for the marked lack of interest. The ESA sites were the earliest in the world, as dated through potassium-argon (Robertshaw 1990a). On the other hand, MSA finds in Africa were frequently assumed to be recent and were regularly attributed to the historic or modern hunter-gatherer authorships (Wendorf et al. 1975; Clark 1988). Conventional radiocarbon dates, a key and widely used chronometric dating technique starting in the early-1950s frequently suggested the MSA assemblages to be very young (Klein 2009:644). The lack of interest was also due to the long held view that the MSA period was relatively static in human behaviour mostly characterized by slow changes at best and unlikely contained anything of great interest for the investigation of prehistoric human behaviour (see Klein 2009 for a detailed discussions; and McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Shea 2011a, b for contra views). Again at that time, there was no evidence that the anatomically modern humans (i.e. *Homo sapiens*) could have evolved during the MSA period (Clark 1988:243). Another reason for the lack of interest in the MSA was the apparently limited visibility of the evidence for MSA hominin activities over the landscape (Binford 1962; Bower 1986:24). Besides, MSA faunal assemblages were also quite limited in number and were also not considered as an important avenue of research on prehistoric human behaviour (Thompson and Henshilwood 2011; Clark and Kandel 2013). True to the MSA research orientation of the time, reports on fossilized faunal remains were not published in detail and were often relegated to appendices in field reports and monographs. The palaeontologists used the archaeological faunal assemblages as relative chronological markers and as paleoenvironmental indicators (Vrba 1980; Gowlett 1990; Robertshaw 1990b).

MSA research in Tanzania began late in the early-1930s, when isolated finds were reported from some rockshelters and open-air sites. Dr. Louis S.B. Leakey excavated Nasera rockshelter in 1932 and discovered a long and rich stratified cultural sequence of MSA and LSA materials. This appears to be the first documented MSA research in the country (Leakey 1936b:59). Ludwig and Margit Kohl-Larsen anthropological expedition along the shore of Lake Eyasi basin between 1934 and 1938 resulted in a serendipitous discovery of the artefacts of an early MSA tradition (Sangoan/Njarasa) in direct association with fossilized hominin and animal remains (Kohl-Larsen 1943; Mehlman 1989). The excavations at Kisese II rockshelter in the late-1950s by Dr. Ray Inskeep also exposed deep cultural deposits comprising of the MSA and LSA lithic artefacts below and Iron Age materials from the top levels (Inskeep 1962). These pioneering MSA research in Tanzania later attracted archaeologists to the Eyasi basin, the Serengeti

National Park and central Tanzania (Mturi 1998; Chami 2005; Masao 2005). However, Mumba and Nasera rockshelters remained unstudied for up to four decades until Michael J. Mehlman re-excavated them in the late-1970s and early-1980s (Mehlman 1977, 1979, 1989). After seven decades, there is also ongoing work on the original collections from Kisese II rockshelter being done by Jason Lewis and Christopher Tryon (Willoughby pers.com 2017).

2.5. Post-1960s Middle Stone Archaeological Age Research

Post-1960s Tanzania witnessed major shift in archaeological research focus from the ESA to the MSA, and to other later archaeological periods including the Pastoral Neolithic (PN) and Iron Age (Robertshaw 1990b; Mturi 1998; Chami 2005, 2006; Masao 2005; Phillipson 2005). This was mainly propelled by the wide-ranging changes in the African political environment, new development in theories and practice, and by the impact of the new chronometric dating methods capable of the dating the archaeological remains beyond the upper practicable limit of the radiocarbon dating technique (Shaw 1989; Robertshaw 1990a, b; Aitken et al. 1992; Wintle 1996).

Newly emerging African nations started to view archaeology within their territories has huge contribution towards the reconstructions of national identities (Trigger 1984, 2008; Robertshaw 1990b). The New Archaeology or processual paradigm from the early-1960s, mainly inspired by American archaeologists, also championed developments in theory, emphasized rigorous problem-oriented investigations, and improved data collection methods, and attempted to establish cross-cultural laws governing prehistoric human behaviour (Binford 1962; Binford and Binford 1968). Lewis R. Binford was one of the key architects of the paradigm and passionately advocated the shift of the archaeology discipline towards more application of the scientific methods. These developments afforded archaeologists with new theoretical frameworks and models as well as with the analytical tools that were mostly borrowed from sister disciplines like anthropology and geography (Harris 1968; Barrett 2000). The use of diffusion theory to explain the cultural changes noted in the archaeological record was largely deserted and replaced by the more ecologically based models, which explained the variability in terms of functional, cultural and technological adaptations (Harris 1968; Trigger 2008; Johnson 2010).

The association of the MSA assemblages with the emergence of the anatomically modern humans in Africa prompted new flowering research interest post-1960s (Clark 1988, 1989; Mellars and Stringer 1989; Aitken et al. 1992; Grine 2016). Dating of the archaeological sites and deposits in sub-Saharan Africa also got tremendous boost from the use of the newly discovered chronometric dating techniques such as Uranium series, Electron Spin Resonance (ESR), Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) which collectively underscored a greater antiquity for the MSA assemblages as far back as 200 kya (Wendorf et al. 1975; McDougal et al. 2005). By extension, this also suggested a greater antiquity for the Middle Paleolithic (MP) in Europe and Near East (Wintle 1996; Hovers and Kuhn 2006). For instance, re-dating of the MP deposits associated with the remains of anatomically modern humans at Qafzeh and Skhul caves turned to be much older than the Neanderthal-bearing deposits from the nearby sites of Kebara and Amud (Valladas et al. 1998). In general, the new dating methods permitted better precision in the chronological estimation of the archaeological deposits and provided a new platform for a steady move towards a more behaviourally oriented research (Harris 1968; Barrett 2000; Trigger 2008; Johnson 2010). The flowering interests into the MSA research also gained an extra impetus in the mid-1980s from the impact of the Mitochondrial Eve model that consequently led to the acceptance of the Out of Africa 2 model (Cann et al. 1987; Stringer and Andrews 1988). The Mitochondrial Eve also provided sound accounts for the bedevilling problem on MSA artefacts association with the remains of anatomically modern humans in numerous sites in Africa and outside the continent. It is also during the relatively same time that we see the beginning of an invigorated research interest in the MSA/MP faunal remains in sub-Saharan Africa and Eurasia mostly due to their relevance to the emergence of modern human behaviour debate (Binford 1984; Klein and Uribe 1984; Mellars and Stringer 1989).

As already remarked above, MSA research in Tanzania went into limbo until the mid-1970s, despite the earlier promising MSA finds from the Nasera, Mumba and Kisese II rockshelters. The period from the mid-1970s marked the beginning of extensive and intensive archaeological reconnaissance surveys. The broad objectives of the surveys were the discovery of new MSA sites worthy of excavations, determining spatial-temporal distributions of the archaeological materials, recovery of hominin remains and the understanding of their technology, subsistence and culture changes over the past 200 kya (Bower 1986:27; Clark 1988; Mehlman 1989; Phillipson 2005; Willoughby 2007).

Middle Stone Age research expanded into new areas such as into the southern highlands of Tanzania and resulted in the discovery of new MSA sites. J.D. Clark surveyed along the Songwe Valley in Mbeya in 1960 and G. Smolla in 1961 at

Tendaguru, near the famous dinosaur site in Lindi Region (Smolla 1962; Clark 1970, 1988). The pioneering work of J.D. Clark later attracted the attention of Sally McBrearty and her colleagues, T. Wynn and T. Chadderdon in the mid-1980s, and later Pamela R. Willoughby from the early-1990s who have collectively reconnoitered the entire Songwe Valleys and Rukwa Region (Wynn and Chadderdon 1982; McBrearty et al. 1982, 1984; Willoughby 1990, 1992, 1996).

Other notable MSA research conducted during the period under review include works of Mary D. Leakey and her colleagues in the Ndutu Beds in 1968, and Professor John F.R. Bower's large-scale surveys within the Serengeti National Park beginning in 1977. Glynn L1. Isaac also analysed the MSA findings from Kilwa in 1974 and Michael J. Mehlman's re-excavated the Nasera and Mumba rockshelters in 1977 and 1981 respectively (Leakey et al. 1972; Isaac 1974; Bower 1977; Mehlman 1977, 1989). Many archaeologists consider Mehlman's work at Mumba and Nasera rockshelters to be the milestone of MSA and LSA research in East Africa region (Clark 1988; Tryon and Faith 2013). Other research includes the work conducted by Audax Z.P. Mabulla in the Ndutu Beds in 1989 and the Eyasi basin in the mid-1990s (Mabulla 1990a, b, 1996). Other isolated MSA research conducted post-1960s including those highlighted above, and many recent works are described in details in the review below.

Post-1960s MSA research phase also saw general amplified interest in the fossil faunal assemblages from the paleontological and archaeological sites, unlike in the earlier phase reviewed above. The Man the Hunter paradigm chiefly influenced this, as did the new hominin behavioural models developed afterward in the late-1960s and beginning of the 1970s based on the faunal materials from Olduvai Gorge, Tanzania (Lee and DeVore

1968; Leakey 1971). Concepts such as “kill sites or butchering sites”, “living floor”, “home base or central foraging place”, or “stone caches” were introduced on basis of the large and well-preserved faunal remains from FLK 22 *Zinj*, DK 3 and FLK NN3 sites at Olduvai Gorge in association with dense clustering of stone tools (Leakey 1971; Isaac 1971, 1978; Bunn 1981, 1982, 1986; Potts 1988; O’Connell 1997). Consequently, fossil faunal assemblages were later mainly collected under the assumptions that were accumulated mostly by the early hominins and were routinely interpreted as being the direct result of active hunting of ungulates. Cut marks and percussion marks inflicted on fossilized animal bones were interpreted as results of hominin butchering activities (Bunn 1981, 1982, 1986; Bunn and Kroll 1986; Bunn and Ezzo 1993; Potts and Shipman 1981; Potts 1988). Early hominins were also considered as successful hunters at the top of the trophic pyramid who also engaged in cooperative hunting activities (Isaac 1971, 1978). According to Manuel Domínguez-Rodrigo, this inferential association stems from what could be collectively labeled as the “*Zinj* effect” (Domínguez-Rodrigo 2009).

By the late 1970s, paleoanthropologists started to focus on the reconstructions of the discrete hominin activities and independent depositional events that created the Plio-Pliocene sites (see Schick 1984, 1987; Shipman 1986; Potts 1982, 1988). The taphonomic revisionist studies of the Plio-Pleistocene faunal assemblages at Olduvai Gorge have recently shown with exception of the FLK 22 *Zinj* site, a variety of processes and agents were responsible for their formation including hominins, carnivores, rodents and birds (see Domínguez-Rodrigo et al. 2007a; Egeland 2007 for the details).

Studies of the archaeological faunal remains also broadened in scope starting in the early-1980s, largely in reaction to Lewis R. Binford provoking arguments about scavenging mode of meat acquisition by the early hominins and MSA/MP hominins in Africa and Eurasia (Binford 1981, 1984, 1985, 1987, 1991; Binford et al. 1988). Concurrently, Charles K. Brain also casted the debate wide and articulated the importance of meticulous taphonomic studies of the fossil faunal assemblages in the reconstructions of the early hominins subsistence behaviour. The publication of the *Nunamiut Ethnoarchaeology* and *Bones: Ancient Men and Modern Myths* both by Lewis R. Binford (Binford 1978, 1981); *The Hunters or the Hunted: An Introduction to African Cave Taphonomy* by Charles K. Brain (Brain 1981) as well as *Life History of a Fossil: An Introduction to Taphonomy and Paleoecology* by Pat Shipman (Shipman 1981), tremendously transformed the knowledge regarding the faunal remains recovered from the Plio-Pleistocene sites. The books collectively illustrated the importance of rigorous taphonomic studies and raised a number of issues and questions for the academic generation of paleoanthropologists and archaeologists to wrestle with several of them have been addressed through experimental and ethnoarchaeological studies (see Clutton-Brook and Grison 1983; LeMoine and MacEachern 1983; Kroll and Price 1991; Hudson 1993).

Binford's groundbreaking ethnographic work with the Nunamiut of Alaska came up with a list of quantification units (NISP, MNI, MNE, GUI, and MGUI), to quantity meat, marrow and grease yields of different skeletal parts. These were largely based on the anatomical characteristics of the domestic sheep (*Ovis aries*) and caribou (*Rangifer tarandus*). Binford's work also illustrated the basic aspects of field carcass processing and transport strategies of the carcass parts from the kill to consumption sites that are collectively referred to as the utility indices (Binford 1978, 1981). Archaeologists commonly use the quantification units and utility indices to interpret patterning in the fossil faunal assemblages ranging from the Plio-Pleistocene to historical times (Klein and Cruz-Uribe 1984; Grayson 1984; Metcalfe and Jones 1988; Jones and Metcalfe 1988; Lyman 1994, 2008; Reitz and Wing 1999).

A number of experimental simulations to critically scrutinize the fossil faunal assemblages are also currently available (Blumenschine 1986a, b, 1988, 1995; Blumenschine and Selvaggio 1988, 1991; Blumenschine and Marean 1993; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Capaldo and Blumenschine 1994; Marean 1991; Marean and Spencer 1991; Marean et al. 1992; Domínguez-Rodrigo 1997a-c, 1999a; Pobiner 2007; Pante et al. 2012; Parkinson 2013; Gidna et al. 2014; Organista et al. 2016). In addition, extensive ethnoarchaeological datasets are also available as a bridge to understand patterning in the archaeological faunal assemblages (Clutton-Brook and Grison 1983; Bunn and Kroll 1986; Bunn et al. 1988, 1991; O'Connell 1988, 1990, 1992; Kroll and Price 1991; Hudson 1993; Oliver 1993; Lupo 2001, 2006; Lupo and O'Connell 2002; Monahan 1998). These have generated robust interpretive and referential frameworks to strengthen inferences made regarding the prehistoric human behaviour and zooarchaeologists can now explore different research questions with greater certainty (Marean et al. 2000; Lupo and O'Connell 2002; Domínguez-Rodrigo et al. 2014).

Taphonomic studies and innovative analytical tools have also extensively developed over the past four decades (Fernández-Jalvo and Andrews 2016). Analysts also continue to refine the methods to improve accuracy in the reconstructions of prehistoric human behaviour (Behrensmeyer 1991; Gifford 1991; Lyman 1994; Bar-Oz and Munro

2004; Domínguez-Rodrigo et al. 2007a). Numerous newer zooarchaeological studies regularly incorporate meticulous taphonomic analyses, and have re-examined many of the classical sites once studied by Klein and Binford. Both the methodology and theoretical frameworks used to reach the early interpretations on fossil faunal assemblages also have been critically re-examined (see Chase 1989; Milo 1994, 1998; Marean and Kim 1998; Bartram and Marean 1999; Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2006, 2007a-c; Domínguez-Rodrigo et al. 2007a, 2014; Grayson and Delpech 2003, 2004). New studies also have illuminated several shortcomings on earlier interpretations of some faunal assemblages. Earlier faunal studies have been critiqued on excavation techniques employed, analytical methodological biases, retention of the identified specimens and on the sample sizes used to reach the conclusions frequently without supporting taphonomic studies (Klein 1976; Turner 1989; Marean 1998; Marean and Kim 1998; Marean and Assefa 1999; Marean et al. 2000, 2004; Bartram and Marean 1999; Faith 2008).

2.6. The Present Status of Middle Stone Age Archaeological Research

Tanzania has a fairly large number of MSA sites with the majority of them discovered during the search for early hominins and through large-scale archaeological reconnaissance surveys (Mturi 1978, 1998). A few MSA sites have also been discovered through limited contract archaeology such as Kizimbani I & II in Kilwa (Karoma 1982), Seronera and Makundusi within the Serengeti National Park (Bower 1973; Bower and Chadderdon 1986; Lyaya 2016) and Buzwagi in Shinyanga (Masao 2009). Appendix 1, summarizes the known MSA sites in Tanzania, provides an account of their nature, finds and whether or not a site has yielded faunal remains from its MSA deposits. Some of the sites listed have never been thoroughly published, and/or they are just infrequently mentioned in literature.

Taken together, a comprehensive overview of the MSA research in Tanzania demonstrates the following features. Notable is the fact that, MSA sites are best known from the northern and southern highlands of Tanzania (see Figure 2.1). With regards to the nature of the MSA findings, the majority are surface scatters frequently in association with other archaeological materials sometimes of mixed archaeological cultures of which their stratigraphic position in sealed archaeological deposits cannot be securely established. The majority of the recorded MSA sites are open-air sites and rockshelters are relatively few (Appendix 1). MSA research archaeological in Tanzania over the past nine decades has concentrated heavily on rockshelters that usually contain stratified deposits of organic remains in their relatively sheltered contexts. Open-air sites such as Loiyangalani with rich and well-preserved faunal remains, are notably rare (Figure 1.2). Another salient aspect is that many of the known MSA sites are not securely dated (Gliganic 2011). The situation is somewhat better in a few sites from the northern and southern Tanzania including Mumba rockshelter, Nasera rockshelter, Ngaloba Beds, Ndutu Beds, Loiyangalani, Magubike, and Mlambalasi rockshelters. Attempts have been made to date them with various chronometric dating techniques (Feathers and Fusch 2005; Gliganic 2011; Miller and Willoughby 2014; Spiller et al. 2014; Feathers 2016; Werner and Willoughby 2017).

The majority of the studies on the MSA assemblages in Tanzania are mostly lithocentric broadly meant to draw some parallels with the European Paleolithic ones

(Leakey 1936b; Masao 1992; Mturi 1998). Detailed aspects of their manufacturing processes, typological variability, and technological organization are the main focuses of the MSA lithic assemblages studies (Clark 1988; Mehlman 1989; Mturi 1998; Willoughby 2007; Tryon and Faith 2013). In order to facilitate comparisons of the MSA assemblages, archaeological sites and levels, virtually every archaeologist working in East Africa region makes use of Mehlman's classification scheme which includes a list of four main stone tools groups: retouched pieces, cores, debitage and none-core flake stone (Mehlman 1989:117). Besides, raw material sourcing, mineralogical examinations and morphometric studies of the stone tools also have been recently explored (Adelsberger et al. 2011; Biittner 2011; Bushozi 2011).

When compared to the amount of research conducted in the country, studies of MSA faunal remains are notably few. This may reflect rarity of sites that preserve them. The majority of the MSA sites have yielded few faunal specimens that are frequently poorly preserved. Only a few sites have yielded large faunal assemblages, and hominin remains that are both informative on prehistoric human dietary choices and which might also provide samples for chronometric dating (Clark 1988; Marean 1990a). Unfortunately, reported MSA faunal assemblages are also mostly presented in terms of present or absent basis and/or by lists of species found from the archaeological sites and units with little or no information on relative species abundance, skeletal part representation, mortality profile and bone surface modifications that consequently make comparisons among sites difficult. The MSA faunal assemblages from Loiyangalani as well as from Mumba, Sonai, Magubike, and Mlambalasi rockshelters are among the best available.

In the subsections below, MSA sites and their findings in Tanzania are reviewed. Sites with limited published information are not thoroughly covered, but they are listed in Appendix 1. As a matter of convenience, each site is treated separately.

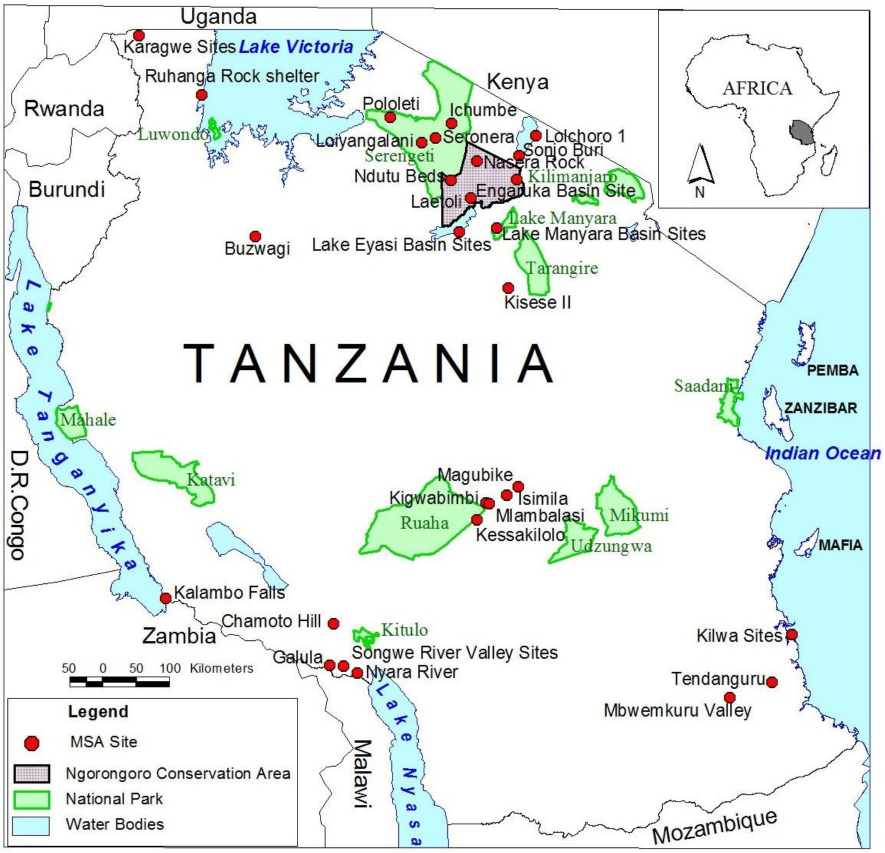


Figure 2.1. Some MSA Sites in Tanzania Mentioned in this Dissertation.

2.7. Middle Stone Age Sites from Northern Tanzania

Northern Tanzania is rich in archaeological remains representing humankind's cultural and evolutionary history. The region also preserves numerous rich archaeological sites spanning the period from the Early Stone Age (ESA) to Iron Age (IA), offering opportunities to study the entire hominin biological and cultural evolution (Figure 2.1).

Copious open-air sites and rockshelters from the region have produced the largest samples of lithics, well-preserved animal bones and hominin remains in primary geological contexts (Figure 2.1, Appendix 1). The best-known and intensively researched sites from this designated archaeological zone include Olduvai Gorge, Laetoli, Mumba rockshelter, Nasera rockshelter and Peninj.

2.7.1. Mumba Rockshelter

Mumba rockshelter (7°17’47’’E, 3°32’26’’S) is located about 3.5 km east of the edge of Lake Eyasi and approximately 70 and 30 kms due south of Olduvai Gorge and Laetoli respectively (Figure 2.1). The rockshelter has a long and rich archaeological sequence ranging from the MSA to Iron Age. Mumba currently represents a yardstick for organizing the MSA and LSA local variability in East Africa region (Mehlman 1989; Clark 1988; Tryon and Faith 2013).

Mumba has been a focus of repeated archaeological excavation since the early-1930s. Kohl-Larsen’s research in the Lake Eyasi basin discovered hominin fossil remains consisting of three individuals (Eyasi I, II & III) in association with MSA artefacts and fossilized mammal remains. They are now attributed to archaic *Homo sapiens* and are dated to over 200 kya. However, due to lack of chronological control and stratigraphic integrity of the finds are often ignored in the discussions of the emergence of *Homo sapiens* (Leakey 1936a; Kohl-Larsen 1943; Domínguez-Rodrigo et al. 2008). Mabulla (1996), during his doctoral archaeological research around Lake Eyasi basin, also discovered an occipital bone fragment of *Homo sapiens* from approximately 100 km south of Kohl-Larsen’s skull site.

Margit Kohl-Larsen first test excavated Mumba rockshelter between 1934 and 1938 and recovered an archaeological sequence ranging from the MSA to the IA. Later, Michael J. Mehlman re-excavated it in 1977 (Mehlman 1979, 1989). Mary E. Prendergast and her colleagues also re-excavated the rockshelter in 2005 along the border of the area excavated by Kohl-Larsen (Prendergast et al. 2007; Prendergast 2008).

Mumba rockshelter archaeological sequence is divided into six Beds based on the sediment characteristics ranging from Bed I at the top to Bed VI at the bottom. According to Mehlman also based on the cultural materials recovered, Beds I and II represent the Iron Age deposits. Bed III is classified as LSA and Bed V to VI as MSA deposits (Mehlman 1989). Bed IV, roughly 26 m above the modern lake level, is archaeologically sterile and its sediments are suggestive of a rise in the water level of the Lake Eyasi, which flooded the rockshelter (Mehlman 1989). Nowadays, Lake Eyasi shore is approximately 4 km away from Mumba rockshelter.

Based on stone tool typologies, technological differences, and spatial distribution, Mehlman described the over 12 m long archaeological sequence from the MSA to the LSA for Mumba and Nasera rockshelters. In an order of age, from oldest to the most recent include three typical MSA (Njarasan, Sanzako, and Kisele), two MSA/LSA (Mumba, Naseran) and two fully developed LSA industries (Lemuta and Silale). These are named after the local geophysical features in the Lake Eyasi basin and Serengeti National Park (Mehlman 1989).

The Njarasan Industry is a local variant of an early MSA-Sangoan Industry. The Sangoan was first described by E.J. Wayland based on surface finds from the hills and lake flats surrounding Sango Bay in Uganda now dated to over 200 kya (Wayland 1923, 1924). Sangoan stone tools have been also reported at Tendaguru, Kilwa, and Nyara in Tanzania and Muguruk in Kenya (Clark 1988; McBrearty 1988). The diagnostic features of the Sangoan Industry are the heavy-duty stone tools such as picks, choppers, core scrapers, and core-axes (Wayland 1923, 1924). The Sangoan Industry geographic distribution in East Africa region initially was mainly ascribed to the more closed vegetation, but new evidence at Simbi has suggested was also more common in the open grassland habitat settings (McBrearty 1988).

The Sanzako Industry is an early MSA and is present in Bed VI-B at the base of the archaeological sequence. It is dated between 131 and 109 kya and contains high proportions of scrapers (side, notched, concave), bifacially modified pieces, and heavy-duty tools such as small bifaces and choppers. The use of Levalloisian technology and production of points are both rare. The dominant raw material for the Sanzako artefacts is quartz (approximately 95%), others occur in low proportions including quartzite, nephelinite, chert, and obsidian. Obsidian sourced from Lake Naivasha in central Kenya about 320 km suggests an existence of an extensive network of long-distance trade and exchange (Mehlman 1989). Mehlman also recovered three isolated hominin molars (small in size but morphologically modern) belonging to a single individual from Bed VI-B. These are believed to be of an early *Homo sapien*s and are dated between 132 and 109 kya (Mehlman 1984, 1987, Bräuer and Mehlman 1988). Numerous fossilized remains of zebra, warthog, kudu, chimpanzee, giraffe, buffalo, rhino (both white and black), hippopotamus, wildebeest, waterbuck, reedbuck, bush pig, and impala were also recovered from Bed VI-B (Mehlman 1989).

The Kisele Industry is present in Bed VI-A at Mumba and has been re-dated by Optically Simulated Luminescence, and Infrared Stimulated Luminescence (OSL and IRSL) to 63.4 ± 5.7 and 73.6 ± 3.8 respectively (Gliganic 2011; Gliganic et al. 2012). The Kisele Industry is also present in the lower levels (level 12 to 25) at Nasera rockshelter (Mehlman 1977). High proportions of disc and part peripheral cores, as well as a few radial and Levallois cores characterize the Kisele Industry. A few bifacial and unifacial points are also present, but scrapers (side and notched) make up the bulk of the retouched tools and mainly manufactured from quartz. Backed tools and burins are both rare, and microliths are totally absent (Mabulla 1996; Mehlman 1989).

The Mumba Industry is mostly present from the middle and upper Bed-V and is considered as a transitional Industry between the MSA and LSA. This is mainly based on the proportions of points (typical MSA) and the absence of microliths (typical LSA). Large backed flakes, blades, trapezes, unifacial points, and bipolar cores mostly characterize the Mumba Industry (Mehlman 1989). However, a recent study by Diez-Martin and colleagues (2009) has also noted it does not contain any retouched points or knives. Nevertheless, the difference between Mehlman and Diez-Martin and colleagues findings may largely reflect spatial variation across the same site. The Mumba Industry also has been recently re-dated to 57 kya (Gliganic 2011).

The Nasera Industry dated to 23.3 kya mainly comes from level 6 and 7 at Nasera rockshelter. It is also present in lower Bed III at Mumba rockshelter, recently re-dated to 39 kya (Gliganic 2011). The Nasera Industry mainly includes small convex end scrapers primarily manufactured from white quartz and chert. Points increase down the archaeological sequence and backed pieces are infrequent (Mehlman 1989).

The Lemuta Industry from levels 4 and 5, overlies the Nasera Industry at Nasera rockshelter and is completely absent at Mumba rockshelter. It is dated between 21.6 and 14.8 kya (Mehlman 1989). Bipolar cores dominate and scrapers (end and convex) mostly are made from locally sourced quartz, obsidian, and chert. Backed tools are also present but in relatively low proportions.

The Silale Industry is found in the upper Bed III. However, according to Mehlman, the industry is too small to provide an adequate definition, other than an observation that small convex end scrapers dominate the lithic assemblage (Mehlman 1989).

2.7.2. Nasera Rockshelter

Nasera rockshelter is situated on the eastern peripheries of the Serengeti plains approximately 34 km due north of Olduvai Gorge and 90 km north of Mumba rockshelter (Leakey 1936b; Mehlman 1977, 1989). In prehistoric times, its occupants along a wildlife migration route that link the Serengeti and Salei Plains strategically occupied the rockshelter (Figure 2.1). However, an absence of a permanent freshwater source nearby, and lack of wildlife especially during the dry seasons, led Mehlman (1977, 1989) to suggest the site was mainly used as a seasonal hunting and/or scavenging base.

Dr. Louis S.B. Leakey first test excavated the eastern and western parts of the rockshelter in 1932 and uncovered a succession of artefacts belonging to the Middle and Later Stone Age (Leakey 1936b: 63-66). He also collected about 2,534 stone artefacts, 852 ostrich eggshell fragments, and about 47 potsherds (Mehlman 1989). Between 1975 and 1976, Mehlman re-excavated about 75 m^2 of sediments along the eastern half of the rockshelter. A long continuous cultural sequence with archaeological materials from the MSA to IA was recovered. Thousands of stone artefacts, potsherds (more than 500 of the Kansyore, Narosura and Akira wares) as well as more than 168,000 pieces of fossilized animal bones, so far no comprehensive account of them has been published were unearthed. The faunal remains from the Leakey and Mehlman's excavations are thought either to be curated in a storage facility at Olduvai Gorge or are probably currently in the National Museum of Tanzania in Dar es Salaam (see also Prendergast 2008:216).

2.7.3. Sonai Rockshelter and Lake Eyasi Lakebed Site

Middle Stone Age tools are also reported at Sonai rockshelter on the slopes of mount Oldeani about 4.2 km northeast of Lake Eyasi (Prendergast 2008; Prendergast et al. 2007) According to the oral traditions of the Hadza, a modern hunter-gatherer group living in the Eyasi basin, their ancestors has occupied it for at least the past three generations (Marlowe 2010). Excavations by Mary E. Prendergast between 2005 and 2006 yielded numerous fossilized animal bones and lithic assemblage, of which a large proportion belonged to the LSA. Other finds recovered included numerous ostrich eggshell beads and fragments as well as one cowry shell from the top levels, the latter probably suggestive of an existence of long-distance exchange networks reaching the Indian Ocean coast (Prendergast 2008).

Sonai is divided into three main archaeological horizons (designated by Prendergast as levels I to III). Level I on top of the archaeological sequence mostly yielded ceramics, fragmentary animal bones and isolated human remains belonging to two individuals, one of them a robust adult. Remains of a juvenile are considered intrusive. Level II has mainly yielded large quartz flakes characteristically with minimal retouch, cores, and a few comminuted animal bones attributed to the LSA or PN archaeological cultural phases. Finally, Level III at the bottom of the archaeological sequence mostly yielded numerous larger flakes, some discoidal cores, side-scrapers, burins and a few points with an MSA affinity predominantly manufactured of quartz along with a few fossilized animal bone fragments (mainly size 1-2 bovids).

The Eyasi Basin lakebed (approximately 70 km long and 25 km wide) is another site where MSA tools have been reported in association with a cluster of fossilized small and large-sized animal bones (Domínguez-Rodrigo et al. 2008). Cranial fragments (mainly horn cores and isolated teeth) dominated the skeletal part representation. Other elements identified included vertebrae and scapulae. Taphonomically, state of preservation of the MSA faunal assemblage was good with no traces of abrasion and polishing typical of the water-rolled bone fragments (Shipman and Rose 1983). The MSA assemblage from the site was also associated with a cranial fragment of *Homo sapiens* (Domínguez-Rodrigo et al. 2008).

2.7.4. Ngaloba Beds (Laetoli)

Laetoli is a Pliocene site located about 36 km south of the Olduvai Gorge. The site is famously known for the discovery of the trails of the *Australopithecus afarensis* footprints. These represent three individuals and are dated to 3.7 mya (Leakey and Harris 1987). Paleoanthropologists and archaeologists consider the footprints as one of the undisputable line of evidence for hominin habitual bipedalism. Different animal and avian tracks are also preserved in the volcanic tuff.

Middle Stone Age tools dominated by scrapers and cores, apparently with affinity to those recovered in the Eyasi basin and Upper Ndutu Beds at Olduvai Gorge, were also recovered in 1976 *in situ* from the Upper Ngaloba Beds (Figure 2.2). The MSA lithics were directly associated with the Ngaloba skull (LH 18) (Day et al. 1980; Magori and Day 1983). Recent petrographic and geochemical studies of the MSA lithic assemblages from different localities and exposures of the Ngaloba Beds have shown that basaltic rocks were mostly used in stone tool manufacture. These were mainly sourced from the Ogol lavas, Olmoti, Ngorongoro, Satiman, Lemagrut, and Endonyo Empusikiyaa (Adelsberger et al. 2011). Faunal remains recovered from the Ngaloba Beds include fossilized mammals, birds, and reptiles (Day et al. 1980).

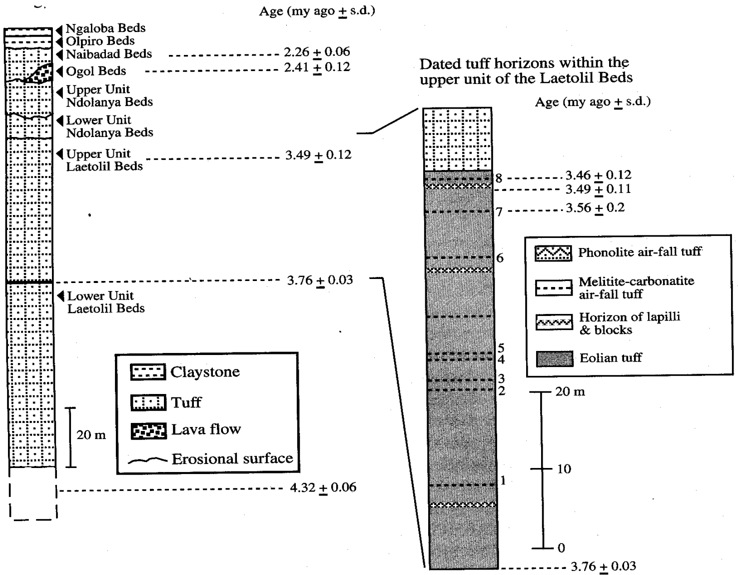


Figure 2.2. Schematic Stratigraphy of Laetoli Geological Beds (Adapted from Klein 2009).

2.7.5. Ndutu Beds (Olduvai Gorge)

The Ndutu and Masek Beds form the upper part of the Olduvai Gorge sequence, which as a whole spans the last 2 mya (Figure 2.3). The Ndutu Beds are commonly divided into the Upper and Lower Units (Hay 1976). The Upper Ndutu Beds mainly consist of aeolian tuff and are estimated to be about 50 kya old. The Lower Ndutu Beds are made up of conglomerate and sandstones that are dated to about 56 kya (Skinner et al. 2003). Paleoclimatic reconstructions of the deposits have suggested the Ndutu Beds were laid down during period of hot and dry conditions analogous to what now present at Olduvai Gorge (Hay 1976; Cerling and Hay 1986).

MSA tools typically with faceted striking platforms and convergent dorsal scar patterns including flakes, scrapers, discoid and Levallois cores as well a few modified pieces were reported by Mary D. Leakey and her colleagues in the early-1970s from the Upper Ndutu Beds (Leakey et al. 1972). Olivine basalt (93%) mainly sourced from the Lemagrut volcanic hill south of Olduvai Gorge dominated the raw materials used in stone tools manufacture followed distantly by phonolite (6%) and quartz (1%). Hay (1976:159) also reported surface scatters of MSA artefacts from two localities (49b and 49c) just east of the Olduvai Gorge second fault. The Naisiusiu Beds overlying the Ndutu Beds have mainly yielded LSA lithic assemblages mainly dominated by backed blades (42%) and geometric microliths (30%) mostly made from obsidian and chert (Clark 1988). The obsidian sourced from the Sonanchi site in southern Kenya suggests the LSA people at Olduvai Gorge probably also involved themselves in long-distance trade and exchange.

Mabulla's (1990a, b) archaeological surveys of the Ndutu Beds in the late-1980s recorded five new MSA sites: three from the Main Gorge (HcJe-1 through 3) and two from the Side Gorge (HcJe-4 and 5). The new sites mostly consisted of clusters of MSA artefacts and fossilized fragmentary bones in direct association. From the Main Gorge, the dominant raw materials used in stone tools manufacture were mainly quartz and quartzite sourced from Naibor Soit, a hill which is the only known source close to Olduvai Gorge. Other raw materials represented in low proportions are phonolite sourced from the Sadiman volcanic hill near the Ngorongoro crater approximately 22 km away and olivine basalt from the Englosen hill approximately 10 km away due north of Olduvai Gorge (Mabulla 1990b). The dominant raw material in the Side Gorge for the MSA sites is exclusively olivine basalt sourced from the Lemagrut hill about 21 km south of Olduvai Gorge. According to Mabulla (1990a, b), scrapers typologically dominate the MSA lithic assemblages from the Ndutu Beds and retouched points are generally rare.

Marean (1990a) conducted the taphonomic studies of the MSA faunal assemblage collected from surface by Audax Z.P. Mabulla in 1989. He also identified specimens to skeletal parts, assessed bone surface modifications, and also considered the species present. The faunal assemblage associated with the MSA artefacts demonstrated a noticeable mixture of both fossil and sub-fossil specimens conceivably from two different Beds. Species represented were mainly open habitat ungulates including some size 1 (Thompson’s gazelle), size 3 (hartebeest, topi and an extinct form of antelope), size 4 (Grevi zebra, a giant cape zebra) and size 5 (hippopotamus) as well as fish remains mainly represented by their diagnostic cranial bones. Mammalian skeletal parts identified included horn cores, mandibles, isolated teeth, tibiae, pelves, metatarsals, metacarpals, astragali, and phalanges, the bulk heavily cemented by concretions. The majority of the specimens were also noted in weathering stage 2. Carnivores tooth marks were preserved on the majority of the identified skeletal parts. No definite hominin-induced surface modifications (either cut or percussion marks) were documented in the faunal assemblage.

Recent archaeological surveys of the Ndutu Beds by Metin I. Eren and his colleagues have resulted in recording of a total of 72 new MSA find-spots characterized by different lithic artefact densities. The majority of the artefacts exhibited characteristics typical of the MSA Industrial-Complex. Levallois and discoidal cores comprised the bulk along with the triangular flakes that might have used to tip thrusting or throwing spears and/or may have served as cutting implements (Knetch 1997; Shea 2006, 2009). In general terms, the raw materials used in stone tools manufacture differ markedly from those reported by Mary D. Leakey and her colleagues who earlier found the olivine basalt to dominate the lithic assemblage (Leakey et al. 1972). Results from the recent MSA assemblage analysis, quartz (40%) are the most common raw material and others such as basalt and phonolite were also used in small proportions in stone tools manufacture (Eren et al. 2014). A small sample of fossilized faunal remains was also collected typically in different states of preservation (Only 37 specimens of which 25 were identified to skeletal parts) belonging to the small and large-sized animals including Thompson’s gazelle, Grant’s gazelle, topi, zebra, rhinoceros and buffalo.

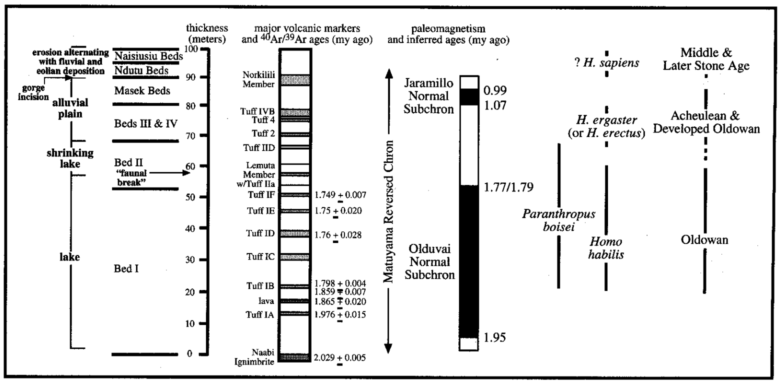


Figure 2.3. Schematic Stratigraphy of Olduvai Gorge Geological Beds (Adapted from Klein 2009).

2.7.6. Serengeti National Park Sites

The Serengeti National Park ecosystem is also a home to a diversity of the major archaeological culture stages known in East Africa and represents an excellent field laboratory for the study of the long-term interactions between humans and animals as well as with their environment (Sinclair and Norton-Griffiths 1979; Sinclair and Arcese 1995a; Sinclair et al. 2008; Bower and Gogan-Porter 1981; Jager 1982). Archaeological research within park has located cultural materials spanning the ESA, MSA, LSA, Pastoral Neolithic, Iron Age, and rock paintings (Bower 1973, 1977, 1981, 1985; Bower and Gogan-Porter 1981; Bower and Chadderdon 1986; Bower et al. 2012; Mabulla 2014).

An ESA site (HcJd-2) containing a few bifaces tools has been reported just north of the shore of Lake Magadi (Bower and Gogan-Porter 1981:6). Extensive archaeological surveys within the park by Professor John F.R. Bower in the mid-1970s and the early-1980s also reported a total of eight MSA sites that appear to be the oldest known evidence of hominin adaptations to the grassland plains in Tanzania (Bower and Gogan-Porter 1981:7-8; Clark 1988:276). From the Moru Kopjes, MSA sites included a total of four sites (HcJd-1, HcJd1-2, HcJd1-4 and HcJd1-5), one from Gol Kopjes (HcJd-3), two from the northern of the park (HaJe-1 and HbJa-2), and two from the western corridor (HaJa-1 and HcJe-1). Efforts to relocate MSA sites from the western corridor near Handajega Gate along with Professor John F.R. Bower in 2005 were not successful. Reported LSA sites within the park include Naabi Hill (HdJd-1) and others from the Serengeti plains (HcJd-3 to 5, 7 and 8). Numerous LSA sites can also be found from almost everywhere within the park (Bower and Gogan-Porter 1981:30).

Numerous rock paintings also exist in the Moru Kopjes area and in the Maswa Game Reserve. The majority of the paintings are ascribed to the LSA (Bower and Gogan-Porter 1981:34; TANAPA 2006; Mabulla 2014). The paintings often portray shield designs and forms as well as some display narrative contents such as hunting scenes and warfare and/or raiding (Bower and Gogan-Porter 1981:36). According to Mabulla (2014) recent documentation of the rock paintings, have shown the majorities were mainly executed in monochrome (black or red), some in biochrome (red and white, red and black) and a few in polychrome (red, black and white; red, orange, black and white colors).

During the 2004 excavations at Loiyangalani, the park rangers informed our research team of an ochre source (famously known in Maasai word as *Lokaria*) located southwest of the Moru Kopje Rangers Post. With their guidance, we subsequently toured and confirmed its presence. The straight distance between the ochre source and the Loiyangalani site is < 20 kilometers. Conceivably, prehistoric humans who resided the Serengeti National Park certainly used this particular source to get the pigmentaceous materials for rock paintings and for personal decorations. Ochre fragments have been reported at several archaeological sites within the park including Loiyangalani, Seronera, SWRI, and Gol Kopjes (Bower 1973; Bower and Chadderdon 1986). The Moru Kopjes south of the Loiyangalani site is also the site of a famous rock gong that echoes profound sound when hit and is believed to be used by the Maasai ethnic group to summon tribal members for ritual and cultural ceremonies (TANAPA 2006).

Makundusi and Mbono are new MSA sites recently reported within the Serengeti National Park by Edwinus C. Lyaya and by Serengeti National Park Ecologist respectively. Makundusi, which has been recorded through contract archaeology, is located along the Gurumeti River. The site constitutes surface scatter of several hundred MSA artefacts, unfortunately, not in association with fossilized bones (Lyaya 2016). The analysis of the MSA lithic assemblage from the site is not yet complete. Mbono MSA site is located near the boundary of the Serengeti National Park and Maswa Game Reserve, and near the source of the Mbono River, which is a tributary of the Simiyu River that flow west to empties its water into Lake Victoria (Figure 3.1). The site contains MSA tools and fossilized animal bones eroding out from the riverbanks and there are also countless fossilized bones on surface in its floodplain.

2.7.7. Engaruka, Lake Manyara and Lake Natron Basins Sites

The Lake Manyara and Lake Natron basins are also home to the vast majority of the paleontological and archaeological sites. Charles Keller and colleagues (1975) reported isolated MSA artefacts from the western and eastern flanks of the Engaruka and Manyara basins during the reconnaissance surveys conducted between 1969 and 1970 (Figure 2.1). Unfortunately, local name of the places were not recorded. The MSA assemblages included mainly flakes with faceted platforms, Levallois cores, scrapers and bifacial points manufactured predominantly of basalt. Other raw materials used in the stone tools manufacture mainly include quartz and chert but in small proportions.

A total of six open-air sites with artefacts attributed to the MSA period are also reported from the Manyara Basin terraces (Keller et al. 1975:374). Levallois cores are numerous in the lithic assemblages and are manufactured exclusively of chert. Flakes were also present but numerically infrequent. Recently reported MSA finds are from the hilltops on both sides of the Engaruka River. At Lolchoro 1 site include flakes and tools with faceted striking platforms and radial preparation on their dorsal side mainly manufactured of chert, quartz and volcanic rocks (Seitsonen 2005, 2006; Seitsonen 2007).

Bushozi's (2003) archaeological surveys of the lowland areas and the western Lake Natron escarpment exposures also reported a total of five new MSA sites (Figure 2.1). Subsequent excavations of the sites yielded MSA artefacts, animal bones (many unidentifiable pieces), and land snail fragments. The MSA tools from the sites mainly included scrapers, flakes, and retouched flakes and points were notably few. The makers of the MSA tools appear to have preferentially used the high quality and locally sourced chert. Other raw materials also locally sourced including basalt, quartz and quartzite were rarely used.

University of Stockholm research team has also recently reported numerous MSA find spots at Sonjo Buri village west of Lake Natron near the Tanzania and Kenya border (Figure 2.1). The excavations at the site yielded flake tools, various types of scrapers (side, end-side, end, notched), burins, and blade debitage unfortunately, not associated with fossilized faunal remains (Seitsonen 2005, 2006, 2007). Quartz (92%) sourced from the vicinity of the site dominated the raw materials used in stone tools manufacture followed distantly by chert (8%). The latter was regularly preferred in the manufacture of points and was mainly sourced from long distance (Seitsonen 2007).

MSA artefacts exposed by sheet erosion have been also reported by the ACM-UDSM field schools conducted within the Tarangire National Park and at Olasiti village just 7 km out of the park main gate. The MSA finds within the park mainly include a variety of scrapers and unifacial points. Points and scrapers made of chert mainly dominate the MSA scatter at Olasiti village. Unfortunately, many of the MSA sites within and outside the Tarangire National Park are mostly being lost to erosion and human activities expansion.

2.8. Middle Stone Age Sites from Southern Highlands of Tanzania

For a long time, the archaeology of whole of southern highlands of Tanzania has been best known from Isimila Stone Age near Iringa town and from Kalambo Falls on the border between Tanzania and Zambia (Mturi 1978, 1998; Msemwa 2002; Chami 2005; Masao 2005). However, archaeological research conducted since the mid-1950s, have also resulted into discoveries of other new archaeological sites spanning from the ESA to Iron Age as well as rock paintings (Figure 2.1). Unfortunately, a few archaeological sites from this area have been excavated and intensively studied.

2.8.1. Sites in the Songwe River Valley

In the early-1960s, J.D. Clark and his team conducted a pioneering archaeological survey in Mbeya and reported two MSA sites at Nyara River and Galula (Clark 1970). The Nyara River site is located near the limestone works west of Mbeya city (Figure 2.1). The site yielded abraded Sangoan-like lithic artefacts including core-axes, cleaver-flake, choppers, unifacial and bifaces, polyhedrons and unmodified flakes, Levallois pieces and core-axes from its Unit G (Clark 1988). The majority of the stone tools were large and mostly manufactured on cobbles of gneiss, quartzite, and chalcedony. At Galula, several heavily abraded discoidal cores and small flakes with radial and faceted platforms mainly manufactured of quartz were also recovered and numerous others on the northern Songwe River terraces.

Archaeological surveys expedition conducted by Sally McBrearty and her team beginning in the mid-1970s into the early-1980s have also reported six more MSA sites (IdIu-1, 3, 4, 7, 9 & 10), one mixed MSA/LSA site (IdIu-6) and two LSA sites (IdIu-2 & 5) in the Songwe River Valley west of Mbeya city (McBrearty et al. 1982, 1984). The majorities of the stone tools collected were typically MSA and mostly manufactured from chert and quartz. Typologically, flakes and core scrapers dominated, whereas bifacially modified flakes were less frequent (McBrearty et al. 1982, 1984). Bipolar reduction technology and disc cores were common, but a few Levallois cores also existed. The only evidence of Early Stone Age (ESA) so far documented in Mbeya Region is evidenced by the presence of a few isolated axes and cleavers in secondary context near the Mbeya-Tunduma road (McBrearty et al. 1982).

Excavations at Kiwira River that flow south to empties its water into Lake Nyasa yielded a broad variety of stone tools including numerous flakes with facetted platforms, discs, bipolar as well as irregular cores (McBrearty et al. 1982:18). Judging from the techno-typological aspects of the lithic assemblage, prepared core technology and small irregular scrapers, mainly manufactured of quartz characterize the Kiwira Industry. Formal tools are few and burins and Levallois pieces are totally absent. Of note, very little is known regarding the origin of the Kiwira Industry, its chronology, and geographical extension. The LSA artefacts, mainly made of quartz, were also recovered from the top levels. The LSA tools at Kiwira are typologically similar to what has been reported by Mehlman at Mumba and Nasera rockshelters (Mehlman 1989). Scrapers (41%), followed distantly by becs (19%), backed pieces and microliths (6%) and finely worked points dominated the formal tools (Wynn and Chadderdon 1982:137).

Extensive archaeological surveys from the early-1990s by Professor Pamela R. Willoughby of the Songwe and Lake Rukwa basins resulted in discovery of a total of 33 new archaeological sites, of these 17 were open-air MSA mostly located on the ancient terraces, and the rest belonged to the LSA (Willoughby 1990). A significant number of the MSA and LSA bearing sites later became her focus of subsequent excavations starting from the early-1990s (Willoughby 1992, 2007). According to Willoughby (1993:32), the MSA assemblages in Mbeya Region are mostly made from quartz (50%), followed distantly by chert (18%), volcanic rocks (16%) and quartzite (12%) and are largely dominated by scrapers, points, backed pieces, awls, crescent, burins, bifacially modified pieces, and a few bifacial tools. The LSA lithic assemblages exhibit a preference of white quartz and are mainly dominated by geometric microliths (crescents, triangles, and trapezes). LSA sites are located ubiquitously throughout the Songwe River Valley, in the ancient river terraces and have been also recovered at Mapogoro and Milanzi rockshelters (Willoughby 2007).

2.8.2. Sites in Iringa Region

The Iringa Region Archaeological Project (IRAP) officially organized in 2006 has conducted a much recent extensive archaeological reconnaissance surveys in Iringa Region. The long-term objectives of the IRAP include to document and understand patterns of technology, subsistence, and adaptation during both the Middle and Later Stone Age. IRAP has also recorded numerous new ESA, MSA, LSA, IA, and historical period sites (Table 2.1). Numerous granitic rockshelters deep-stratified with MSA, LSA and IA deposits including Magubike, Mlambalasi, Kitelewasi, and Lutona as well as numerous open-air sites have been also recorded (Figures 2.1 and 3.6). Intensive archaeological excavations at Magubike and Mlambalasi rockshelters over the past decade have yielded abundant lithics along with fossilized animal and isolated hominin remains (Alexander 2010; Biitner 2011; Bushozi 2011; Collins 2009; Collins and Willoughby 2010; Miller and Willoughby 2014; Sawchuk and Willoughby 2015; Werner and Willoughby 2017; Biitner et al. 2017). Despite these accomplishments, the full archaeological potential of the Iringa Region is far from complete known. There is certainly a very great deal of the ESA, MSA, LSA, and IA sites awaiting discovery (Willoughby 2016). Magubike rockshelter is subject of this study is extensively described in the next chapter.

Table 2.1. New Sites Discovered in Iringa Region.

Site	Nature of the Site	Cultural Phase
Isimila	Open-air	ESA/MSA
Isimila River	Open-air	ESA
Mgongo	Open-air	ESA
Kigwambimbi	Open-air	MSA
Magubike	Rockshelter	MSA to IA
Mlambalasi	Rockshelter	MSA to IA
Kessakilolo	Rockshelter	MSA to IA
Nyamihuu	Open-air	MSA to IA
Malunde	Open-air	LSA & IA
Kigongoma	Open-air	LSA & IA
Kibebe Gully	Open-air	LSA
Kalenga	Open-air	IA
Utinde	Open-air	MSA to IA
Songambele	Rockshelter	MSA to IA
Kwa Yoweli	Rockshelter	MSA to IA
Kitesengwa	Open-air	ESA

2.8.3. Mlambalasi Rockshelter

Mlambalasi (7°35’ S; 35°30’ E) is a large granitic rockshelter located roughly 60 km west of Iringa town (Figure 2.1). It is just about 500 m west of Chief Mkwawa’s grave, the former leader of the *wa*-Hehe ethnic group who committed suicide on June 19th, 1899 to avoid arrest by the German colonial forces (Crema 1987:20). The *wa*-Hehe, who are the fourth largest amongst about 130 ethnic groups in Tanzania, currently inhabit most of the southern highlands.

Dr. Paul Msemwa initially test-excavated Mlambalasi in 2002 (Msemwa 2002) and later the IRAP in 2006 and 2010 re-excavated it as part of the ongoing archaeological works in Iringa Region. Excavations conducted inside and on the slope just outside the main rockshelter have uncovered a stratified archaeological sequence mainly spanning from the LSA to Iron Age/historic period. The upper deposits inside the rockshelter mainly have yielded historic and Iron Age (IA) materials (decorated and undecorated potsherds, iron metal, iron slag, grindstones, land snail shells, fossilized animal bones, beads, and charcoal) followed in sequence by a microlithic LSA. The LSA industry at Mlambalasi is mainly dominated by microlithic backed tools, and geometric tools struck from bipolar cores mainly manufactured of quartz (Willoughby 2012b; Biitner et al. 2017). Fragmentary fossilized commingled human remains (two adults one nearly complete attributed to the LSA and juveniles from the Iron Age/historic period) also have been recovered. Calibrated radiocarbon date place the LSA assemblage and the human burial at Mlambalasi rockshelter between 13 and 12 kya (Sawchuck and Willoughby 2015).

MSA deposits are also present (but mixed) at Mlambalasi. A big rock boulder weighing several tons on the slope in front of the main rockshelter appears to cover the large part of the MSA deposits that are not mixed. The large piece appears to fit well back onto the break off the rockshelter overhang, and its cross section of fracture match perfectly.

2.9. Middle Stone Age Sites from the Rest of Tanzania

The area under review covers the rest of Tanzania where isolated MSA sites have been reported including sites from the central, Lake Victoria basin and the southeastern coast of Tanzania (Figure 2.1). The MSA research from these areas is comparatively limited and poorly understood. However, this does not imply the areas are totally devoid of the MSA sites and occurrences (see Kessy 2009). Nonetheless, this may mostly reflect an artefact of archaeological research bias remarked above.

2.9.1. Kisese II Rockshelter

Kisese II is a spectacular granitic rockshelter located in the Irangi hills overlooking the Maasai Steppe about 64.4 km north of Kondoa town in central Tanzania (Figure 2.1). Dr. Louis S.B. Leakey and his wife Mary initially test excavated the rockshelter in 1951 to a depth of up to 4.2 m (Leakey 1983). Dr. Ray Inskeep later re-excavated it in 1956 to a depth of 6 m below the modern surface (Inskeep 1962).

Kisese II rockshelter preserves Iron Age, LSA and MSA deposits from the lower levels. Iron slag and broken tuyeres are numerous from the first few top levels, and pieces of ochre have been recovered throughout the archaeological deposits. LSA microliths and small convex scrapers are also numerous from level 9 to 11, and are radiocarbon dated 41,031-33 (calibrated) (Deacon 1966). Faunal remains recovered from the rockshelter include remains of the small-sized alcelaphine that went extinct during the early Holocene. The same species has also been reported at GvJm-46 (in Kenya) suggesting its widespread nature in East Africa region. According to Mehlman (1989:365 and 452), Mumba Industry is present at Kisese II rockshelter below level 11.

Kisese II rockshelter also has impressive rock paintings mostly executed in monochromes (dark red, yellow, or orange) portraying human figures, animals, hunting scenes and abstract markings mainly ascribed to the pastoralist and agriculturalist communities (Leakey 1983). Kisese II rockshelter which together with Kisese I, Kwa Mtea, Kolo, Itololo, Kandaga, and Masange rock paintings now forms the nucleus of the Kondoa Rock Art World Heritage Site bestowed in 2006.

Other MSA finds from central Tanzania are reported from DKB 11 and 12 in Msia south of Kondoa (Masao 1992:106). Unfortunately, MSA assemblages from these sites have not been fully analyzed and never described in details (Masao pers.com 2016).

2.9.2. The Lake Victoria Basin

Although the western part of the Lake Victoria Basin has occupied a critical position in Africa's later prehistory, surprisingly, is one of the least archaeologically known areas in Tanzania and has not seen sustained archaeological research (Phillipson 1986; Mturi 1978, 1998; Chami 2005, 2006; Masao 2005). Some specific reasons for this include the absence of rockshelters with deep stratified deposits and the overall absence of information on prehistoric foragers who inhabited the basin (O'Brien 1939; Phillipson 1986, 2005). Archaeological studies in the Lake Victoria Basin, much like in central Tanzania, have been mostly overshadowed by the documentation of the rock paintings and ethnoarchaeological studies of the iron-smelting technology (Mturi 1998). However, a few isolated archaeological materials belonging to the ESA, MSA, LSA, Pastoral Neolithic, and Iron Age have been reported from the Lake Victoria Basin, in Tanzania and Uganda (Soper and Golden 1969; Chami 2006; Prendergast 2008).

2.9.3. Ruhanga Rockshelter

Ruhanga is a large granitic rockshelter overlooking the western shore of Lake Victoria, about 2 km inland southeast of Muleba town (Figure 2.1). Discovered in 2002 by the University of Dar es Salaam archaeology field school was subsequently excavated in the same year under the direction of Professor Felix A. Chami. The rockshelter also has impressive paintings on its walls. The archaeological surveys in Muleba District also resulted in the discovery of numerous scatters of LSA, over 60 Iron Age sites and rockshelters the majority with paintings (Chami 2006).

Three archaeological layers have been identified inside the rockshelter based on the types of the cultural materials recovered (Kwekason and Chami 2003). The upper levels between 20 and 75 cm are mainly assigned to the Iron Age deposits and typically with numerous undecorated and decorated potsherds of the "roulette" and "Kansyore" traditions. This is followed by a microlithic LSA between 75 and 90 cm below the modern surface. Other materials from the LSA deposits included a few abraded ochre fragments conceivably used to paint the walls of the rockshelter. A fairy large lithic assemblage of MSA artefacts was also recovered from 90 to 150 cm below the modern surface. The MSA artefacts comprised of points, scrapers, and blades mainly manufactured with Levallois technology. The rockshelter currently represents the only known site near the shore of Lake Victoria in Tanzania that has yielded MSA artefacts from stratified deposits careful excavated.

The proximity of Ruhanga rockshelter to the Lake Victoria shoreline means fish would have been also within the reach. Unfortunately, no fish remains were recovered from its IA, LSA, or MSA deposits. Recent excavations of other rockshelters in Muleba District have also failed to recover faunal remains perhaps due to extreme acidic nature of the soils along the western arm of the East African Rift Valley in Tanzania that is less ideal for the preservation of the organic materials. Fish bones are typical very sensitive to the acidic soils and particularly when are boiled or burned (Wheeler and Jones 1989; Steffen and Mackie 2005).

2.9.4. The Kagera River Basin

Reid and Njau (1994) recent archaeological surveys along the Kagera River Basin in Karagwe District have reported numerous isolated open-air sites from erosion-exposed deposits some of them belong to the MSA. Open-air sites with ESA, LSA and Iron Age materials were also recorded. The ESA find spots are reported at Rwambaizi, Igurwa and Bwera villages from the eastern escarpment of Karagwe District with a high concentration documented at Kayanga village. The ESA tools mainly include bifaces, picks, core scrapers, and large flakes (Reid and Njau 1994). During the surveys, three new MSA sites from eroding stratified deposits were reported from the lowland areas of the Kagera River as well as at Rwambaizi and Kibwera villages (Reid and Njau 1994:69). The MSA assemblage mainly included small bifaces, points, and core scrapers some with very fine retouch. Extensive surface scatters of LSA sites are also recorded mostly from the lowland floodplain areas along the lower Mwisa River, Bugara, Kibwera, and Byenturege villages. No excavations of these sites so far have been conducted to evaluate their full potential below.

2.10. Sites in Lindi and Mtwara Regions

Ingram (1933) was the first scholar to hint that some stone using people could have settled the Tanzanian coast and possibly its immediate hinterland areas (cited in Kessy 2009). While this area is one of the areas to receive the first archaeological research attention in Tanzania, unfortunately, little is known of its Stone Age archaeology. Stone Age accounts from this part of the country often appear as addenda to monographs and archaeological reports rather than reports of their own (see Chittick

1974; Isaac 1974). There is also remarkably very little Stone Age archaeological research conducted and finds reported from Lindi and Mtwara Regions (Karoma 1982:1). This situation has been mainly attributed to the rugged mountainous topography, poor infrastructure, low visibility and accessibility of sites in the forested areas and also to the present-day Indian Ocean rise in level that may have flooded the paleocoastlines and drowned many of the coastal MSA sites (Isaac 1974:255; Basell 2008:2485; Kwekason 2011:2). Besides, for many decades Stone Age archaeological research along the Tanzanian coast and its immediate hinterland has been very much a secondary undertaking to the study of the artefacts from the ruined Swahili settlements (Chami 1998). Swahili is a culture which emerged in the first millennium AD and is mainly found along the eastern African coast and its islands extending north from Somalia and to Mozambique archipelago to the south covering an expanse of about 2,500 km (Kusimba 1999). Ruined Swahili settlements regularly exhibit mosques, spectacular tombs with Arabic epitaphs on tombstones with Chinese porcelain and celadon concentrated around and sometimes built into structures (Masele 2012).

2.10.1. Tendaguru, Mbwemkuru River Valley and Sites in Mtwara Region

A relatively small collection of MSA surface finds comprising of flakes, bifacial scrapers, core-axes with Levallois preparation like those reported from around Lake Victoria Basin manufactured from local sourced sandstone are reported at Tendaguru near a world famous dinosaur site in Lindi Region (Smolla 1962). Later archaeological survey undertaken by Felix A. Chami and Remigius A. Chami (2001) about 2 km southwest of the Tendaguru site have also reported typical MSA artefacts mainly including core scrapers (Chami and Chami 2001:29). However, this site has not been excavated.

Kwekason (Kwekason 2011:138) has recently reported new isolated MSA finds from the surveys along the Mbwemkuru River Valley down to the Indian Ocean shore at Nchinjidi and Mtarika villages. The MSA assemblages mainly include scrapers of Sangoan affinity, nicely trimmed points analogous to what have been reported by Glynn Isaac from the Kilwa sites (Isaac 1974). Kwekason (2011) considers this area was the core of the MSA technology along the Tanzanian southeast coast. Isolated MSA have been also collected from Kimbilimu, Kipili, Mandawa, Chikotwa, Kiliamanda, and Mikadi in Newala District. These are so far unstudied and are curated in the Tanzanian National Museum in Dar es Salaam. The MSA lithic assemblages suggest that the Tanzanian coastal areas still have many more MSA sites yet to be discovered (Kwekason 2011:148).

Ranhorn and her colleagues (2013) have also recently reported ten MSA sites (9 open-air and 1 rockshelter) from the Makonde Plateau in Mtwara, Lindi, and Ruvuma Regions of Tanzania near the border with Mozambique. The new-recorded MSA sites include Mto Komwene, Ligunga, Nyangao, Cherenga, Fini Nkungu, and Chilonji. Preliminary analysis of the lithic assemblages have demonstrated the MSA tools are mostly represented by single and multi-platform cores including the classic Levallois cores, flake blades, points and scrapers mostly made from quartzite and chert. The MSA sites are mostly found in association with quartzite outcrops or near water channels margins. Unfortunately many of the new MSA lithic assemblages from Lindi and Mtwara

Regions have not yet been full analyzed and detailed accounts of the materials have not been published.

2.10.2. Kilwa Sites

Kilwa is perhaps the best extensively and intensively researched than any other known archaeological site along the Tanzanian coast and its islands. The Island of Kilwa in Lindi Region is also known as Kilwa Kisiwani and is located opposite to Kilwa Masoko town on the mainland, which together with Songo Mnara Island to the south form the nucleus of the Ruins of Kilwa and Songo Mnara World Heritage Site bestowed in 1981 (Figure 2.1). Kilwa was the biggest commercial city along the eastern African coast before the arrival of the Europeans and has been reported to control the coast as far as Sofala in present-day Mozambique (Figure 2.1). Neville H. Chittick intensively and extensively excavated Kilwa Kisiwani from 1958 until the mid-1970s (Chittick 1965, 1974). Since then the Kilwa Kisiwani and Songo Mnara Island have been also sporadically excavated by numerous archaeologists (Mturi 1978, 1998; Chami 1998, 2005, 2006; Masao 2005).

From Kilwa, MSA artefacts have been reported from the northern section of the island at Nguruni and Masakasa as well as from Mpara Hill on the mainland (Isaac 1974; Karoma 1982). The Nguruni site is located to the west of *Husuni Kubwa* and the reported surface MSA stone tools from the site appear to be of the Sangoan type with no signs of rolling. The lithic assemblage mainly comprises of the unretouched scrapers of various forms, blades, unifacial points and backed pieces made of quartz and sandstone similar to those reported at Tendaguru (Smolla 1962; Isaac 1974:254-256). The Masakasa site located to the east of *Husuni Kubwa* has yielded a variety of artefacts of Sangoan affinity.

Stratified MSA and LSA artefacts also have been reported by the University of Dar es Salaam archaeology field school conducted in the early-1980s at Mpara Hill in Kilwa Masoko on the mainland results of which are still not published (Karoma 1982). The MSA lithic assemblage reported from surface exposures at Kizimbani mostly includes modified pieces, scrapers, Levallois flakes and discoidal cores made of quartzite and chert.

CHAPTER 3

PREVIOUS RESEARCH AND DESCRIPTION OF SITES EXAMINED

3.1. Introduction

This chapter highlights general background of the study areas. Accordingly, it also presents a fuller account of the previous archaeological research within the Serengeti National Park and in Iringa Region (Figures 3.1 and 3.6). This is followed by detailed description of the Loiyangalani site and Magubike rockshelter. The findings from the previous excavations are also summarized. The primary purpose is to place the two sites within their regional contexts and provide some detailed background from which the studied faunal assemblages originated. Detailed results for the present study are presented in Chapter 6 and 7 for the Loiyangalani site and Magubike rockshelter respectively.

3.2. Serengeti National Park

Serengeti National Park, within which the Loiyangalani site is located, has been a protected area since 1940, was nominated as a national park in 1959 and as a World Heritage site in 1981 (Sinclair 1995; Sinclair and Arcese 1995a, b). The National Park takes its name from a Maasai word "*Siringet*" which means "endless plains". It covers an area of approximately 14,763 km^2, which make it the second largest after Ruaha National Park from southern Tanzania (Figure 2.1). The park lies between the eastern African Great Rift Valley to the east and Lake Victoria to the west in Tanzania (TANAPA 2006). It is bordered to the north by the Loita and Mara plains of Kenya, to the south by the Lake Eyasi escarpment of Tanzania (Sinclair and Arcese 1995a, b).

3.2.1. Serengeti National Park - Modern and Past Ecologies

The climate of the Serengeti National Park is mainly governed by the position of the Intertropical Convergence Zone (ITCZ), monsoon winds and by the influence of Lake Victoria (Figure 3.1). Topography such as the Ngorongoro, Sadiman and Lemagrut volcanic highlands to its south and the Gol mountains chain to the eastern border modify the climate locally. These intersect moisture-laden winds blowing from the Indian Ocean prompting a rain shadow effect especially across the southern part of the park (Norton-Griffiths et al. 1975; Sinclair 1979a, b, 1995).

Overall temperatures are relatively stable with an annual mean of 20°C. Monthly mean temperatures also exhibit some minor variation and the average fluctuation often ranges between 3 to 4°C, while closer to Lake Victoria is frequently below 2°C (Figure 3.1). Temperature variation within the park is also locally regulated by altitude (Norton-Griffiths et al. 1975; Sinclair 1979a, b, 1995).

The Serengeti National Park mostly gets rainfall between November and May with recorded peaks in December and March/April. Rainfall tends to drop towards the eastern and increases towards the northern part of the park. The annual rainfall is also influenced by the shift of the ITCZ and ranges from 500 mm in the southeast, to 1200 mm in the northwest and to the western part of the park near Lake Victoria reaches 950 mm (Kendal 1969; Norton-Griffiths et al. 1975; Sinclair 1979a, b, 1995). January and February often tend to be dry and July is the driest month with rainfall dropping to zero (Jager 1982).

Paleo-ecological datasets of the Serengeti National Park have been reconstructed mostly from the Laetoli, Olduvai Gorge, and Lake Victoria sediment studies and can be summarized as a succession of wet-dry-wet cycles (Kendall 1969; Hay 1976; Sinclair

1979b, 1995). Paleoecological reconstructions from Laetoli on the southern edge of the Serengeti plains have ranged from a more densely to moderate wooded to forested habitats between 3.8 and 3.5 mya and more semi-arid open grasslands at around 2.66 mya (Hay 1987; Peters et al. 2008).

Recent paleoecological reconstructions from the Upper Laetolil Beds (dated between 3.8 and 3.5 mya) and the Upper Ndolanya Beds (dated 2.66 mya) have illuminated new paleoecological conditions present during their formation (Figure 2.2). Initial reconstructions suggested the Laetolil Beds represented a mosaic of more open habitats and the Ndolanya Beds were characterized by much more arid and semi-arid bushland analogous to the modern day Serengeti plains (Leakey and Harris 1987). Nonetheless, more recent paleoecological reconstructions of the Laetolil Beds show evidence that had a thick woodland cover with some lighter trees scatters that were also of greater significance to the adaptations and survival of the *Australopithecus afarensis* (Kovarovic 2004; Kovarovic et al. 2002).

At Olduvai Gorge site between 2.1 and 1.7 mya, the climate was much moister, and a paleolake of 10 km long and 5 km wide existed as evidenced by the diversity of the fossil remains including mammals, crocodiles, tortoises, and flamingo remains along with papyrus rhizomes (Leakey 1971; Hay 1976; Sikes 1994). According to Hay (1976), the paleolake peripheries supported a mosaic of habitats of permanently flooded marshes to riverine woodlands. Away from the paleolake the open grasslands, dominated similar to what is present in Lake Manyara National Park (Sinclair 1979b). Between 1.75 and 1.5 mya the climate was drier, the annual rainfall dropped as low as 350 mm and the paleolake water level significantly dropped (Bonnefille 1984). During the Last Glacial

Maximum (LGM) around 19 kya, the climate was relatively cooler and moister again. Kendal's (1969) paleoenvironmental reconstructions of the Lake Victoria sediments for over the past 15 kya have also identified the periods between 12.5 and 10.5 kya and between 9.5 and 6.5 kya were mostly wetter than today (Figure 3.1). According to Sinclair (1979b:41-44), the paleoenvironment and ecology of the Serengeti National Park overall appears to have been relatively similar to the present day.

3.2.2. Vegetation and Fauna

Overall Serengeti National Park is grassland and woodland dominated ecosystem with some few variation regarding plant species composition and coverage. The vegetation is spatially heterogeneous, wooded savannah and a denser cover of tall grasses mostly characterizes the northern portion of the park. The short grass plains dominate the southeastern portion, whereas further to the east of the park is more forested (Sinclair 1979b; Jager 1982). The western part of the park is predominantly wooded and extends up to the perimeter of the Lake Victoria, but also occasionally feature patches of grassy plains. The high concentrations of wooded grassland are also located near the edges of the major rivers that drain the park including the Grumeti, Balangeti and Mara and along the margins of their floodplains (Figure 3.1). The Loiyangalani site, which forms part of this study and described in detail below, is predominantly vegetated by sedges and reeds or tall grasses (Figure 3.1).

Serengeti National Park houses a wide range of animals including about 30 ungulates species, and 13 species of large carnivores that makes it one of the richest national parks in Africa (Sinclair 1979b, 1995). Animal species ubiquitously found within the park include elephant (*Loxodonta africana),* buffalo (*Syncerus caffer*), giraffe (*Giraffa camelopardalis)*, zebra *(Equus burchellii),* Grant's gazelle *(Nanger granti)*, Thompson's gazelle *(Eudorcas thomsoni)*, impala *(Aepycerous melampus),* wildebeest *(Connochaetes taurinus)*, topi *(Damaliscus korrigum),* eland *(Taurotragus oryx)*, bushbuck *(Tragelaphus sylvaticus*), waterbuck *(Kobus ellipsiprymnus*) and warthog *(Phacochoerus africanus).* White rhino (*Ceratotherium simum)* and black rhino (*Diceros bicornis*) are also present. The rhinos are currently listed as endangered species due to severe poaching with only around 40 individuals remaining. Tanzania had an estimate of about 10,000 black rhinos in the 1960s, by 1984 were reduced to around 3,000 and by 1990s the number declined to less than 100 animals. Common carnivores in the Serengeti National Park include lion (*Panthera leo)*, leopard *(Panthera pardus)*, cheetah *(Acinonyx jubatus)* and spotted hyena (*Crocuta crocuta*). Crocodiles *(Crocodylus niloticus)* also infest the major rivers that drain the Serengeti National Park (Schaller 1972).

Wildebeests *(Connochaetes taurinus)*, zebras *(Equus burchellii)*, Grant's gazelles *(Nanger granti)* and Thompson's gazelles *(Eudorcas thomsoni)* extensively populate the Serengeti plains during the rainy season especially around the Moru Kopjes and the areas near the Loiyangalani and Mbalangeti rivers. This is prior to their migration into the western corridor in May and June (Maddock 1979; McNaughton 1988, 1990; Holdo et al. 2011). The quality of forage in tropical grazing ecosystems like the Serengeti National Park usually declines progressively with the advancing dry season and force the ungulates to migrate to meet their nutritional requirements. The wildlife migration within the Serengeti National Park comprises of about 1.3 million wildebeest *(Connochaetes taurinus),* 200,000 zebra *(Equus burchellii),* and more than 400,000 Thompson's gazelles

(Eudorcas thomsoni) (Sinclair 1995; Packer et al. 2005). The wildlife migration resembles “a giant, live, nature operated mowing machine tending the vast 14,763 km^2 of the park” affording the most scintillating game viewing (Wakibara 2012:26). The ungulates habitually tend to stay in the western corridor of the Serengeti National Park as long as food and water persist. The wildlife migration is usually dictated by the fluctuations in food supply as a result of rainfall gradient (Maddock 1979; McNaughton 1988, 1990), search for water quality (Wolanski and Gereta 2001) and predation risk from the large carnivores such as lions *(Panthera leo)* and hyenas *(Crocuta crocuta)* (Hanby et al. 1995; Hoffer et al. 1993). Natural barriers and terrain complexities frequently dictate the routes and movement of the large herds of the migrating ungulates (Holdo et al. 2011).

Many of the same ungulate species listed above might have been available at the Loiyangalani site during the Middle Stone Age. Resident species, which also would have been also potentially available all year round at the site for hunting, includes Grant’s gazelle *(Nanger granti),* warthog *(Phacochoerus africanus*), impala *(Aepycerous melampus)*, topi *(Damaliscus korrigum),* giraffe (*Giraffa camelopardalis)* and buffalo (*Syncerus caffer*) (Sinclair 1995). Fish from the Mbalangeti and Loiyangalani rivers would also have been an additional seasonal hominin attraction at the Loiyangalani site (Figures 3.1 and 6.3).

Fossilized bones belonging to the small and large-sized wild ungulates have been reported from numerous archaeological sites within the park. There is also ample evidence that they were exploited by hominin as attested by the cut marks and percussion marks inflicted on their bones (Gifford-Gonzalez 1985; Marean 1996; Thompson et al.

2004; Thompson 2005). Domesticated species also have been reported mostly from the Pastoral Neolithic sites (see Bower 1973; Bower and Chadderdon 1986). Rock paintings within the park also display diverse wild animal drawings and hunting scenes (Bower and Gogan-Porter 1981; TANAPA 2006; Mabulla 2014).

3.2.3. Physical Features and Drainage Patterns

Serengeti National Park lies between 1,780 m on the eastern plains and slopes down to about 1,230 m near Lake Victoria. It rises to 2,090 m above the sea level in the extreme northeastern part (Sinclair 1979b). The average altitude is about 1,500 m, and abundant granitic rock outcrops such the Moru, Simba and Gol Kopjes are among the most visually striking features of the southeastern part of the park (Jager 1982). Kopjes are granitic-gneiss boulders rising abruptly from the surrounding grassland. The Kopjes within the national park typically have dense vegetation cover and habitually also support a variety of the small and medium-sized animals as well as avian species (TANAPA 2006).

The Grumeti, Mbalangeti, and Mara rivers that flow west to empty their water into Lake Victoria mainly drain the Serengeti National Park (Figure 3.1). During the dry season, their water discharge often drops or wholly ceases. The drainage pattern of the Serengeti National Park is predominantly dendritic, and flooding sometimes occurs when the major rivers overflow their banks (Jager 1982). Marshes, waterholes, pools are also present, particularly where the bottom consists of impermeable bedrock. Magadi, a small saline Lake also exists near the Loiyangalani site (Figure 3.1).

3.3. Previous Archaeological Research in Serengeti National Park

For more than nine decades, the Serengeti National Park has been a site of copious studies considering the conservation of its ecosystem and the wildlife (Sinclair and Norton-Griffiths 1979; Sinclair and Arcese 1995b; Sinclair et al. 2008). Professor John F.R. Bower conducted the earliest recorded archaeological research within the park in 1971 at Seronera site (HbJd-1). This was part of a salvage/rescue excavation during the construction of the Seronera Game Lodge (Bower 1973). During the excavations of the lodge's foundation in 1970, three complete stone bowls were recovered and were brought to the attention of both the architect and construction consultant who subsequently notified the National Museum of Kenya. The British Institute of Eastern Africa based in Nairobi hired Professor Bower to undertake the rescue excavations of the site (Bower 1973).

Starting in 1977, Professor John F.R. Bower in collaboration with the Tanzanian Antiquities Division also conducted an extensive archaeological reconnaissance surveys within the Serengeti National Park. This was mainly aimed at determining the range and spatial-temporal distribution of the prehistoric sites relative to the environment, topography, vegetation zones and wildlife migration routes (Bower 1977:25). The areas covered included the Moru Kopjes, Gol Kopjes, western and northern parts of the park. A total of new 33 Middle Stone Age (MSA) find spots were recorded (Bower and Gogan-Porter 1981:7-8). Numerous LSA, Pastoral Neolithic, and Iron Age sites were also recorded. Results of the surveys exhibited the park is endowed with diverse archaeological assemblages with the potential to address diverse research questions on the ecology, hominin adaptations and evolution of their culture (Bower 1981: 53; Bower and Gogan-Porter 1981: 3).

Between 1977 and 1983, Professor John F.R. Bower excavated three Pastoral Neolithic (PN) sites from the central part of the park at the Serengeti Wildlife Research Institute (hereafter SWRI) (HbJd-3), Gol Kopjes (HcJe-1) and Seronera (HbJd-1). The SWRI rockshelter yielded a total of 6,300 comminuted bones (mainly belonging to the PN period), almost 200,000 lithic pieces and bits of ochre. The Gol Kopjes stone cairns yielded about 1,237 potsherds (including culturally and diagnostically decorated Nderit and Akira wares). Faunal remains from the site mostly included several thousands of fragmented and taxonomically identifiable pieces. Other finds included stone artefacts and bits of ochre as well as fragments of iron, including a complete spear tip, spear butt and a handful shell and glass beads (Bower and Chadderdon 1986). Rare remains of domesticated species including cattle (*Bos indicus*), goat (*Capra hircus*) and sheep (*Ovis aries*) were also recovered from this site. The Seronera site yielded a ground stone axe, pestle-rubber, decorated potsherds as well as surface artefacts of possible MSA affinity (Bower 1973:73).

More recent archaeological surveys along the Grumeti River carried out by Fidelis T. Masao and colleagues between 2000 and 2002 have also reported scatters of stone artefacts belonging to the Late Acheulean, Sangoan, MSA and LSA at Pololeti and at Kirawira. But, no archaeological excavations have yet been conducted at these sites (Masao et al. 2003). Of note, the full archaeology potential of the Serengeti National Park has not yet been fully explored.

3.4. Iringa Region

Iringa Region forms part of the southern highlands of Tanzania and covers a total area of about 43,935 km^2 (Figure 3.6). Rolling highlands and mountains ranges such as the Kipengere and Udzungwa cover the large part of the Iringa Region. The average altitude is around 1,450 m above sea level (Crema 1987). The highlands also contain numerous Precambrian granitic rockshelters and overhang some of them potentially provided prehistoric humans with both naturally ready-made shelters and suitable surfaces for rock paintings (Itambu 2013). Some rockshelters including Magubike, Mlambalasi, Kitelewasi, Kessakilolo and Rutona rockshelters also preserve anthropogenic deposits (Willoughby 2005, 2012b).

Magubike rockshelter, which is also part of this study, is located about 40 km east of the Ruaha National Park established in 1964 (Figures 2.1, 3.6 and 3.7). The park takes its name from the Great Ruaha River that flows through it and is the main source of water for the park as well as provides about 56% of the water supply to the Mtera reservoir and hydroelectric plant (Mwakalila 2005). Ruaha National Park covers an area of approximately 20,226 km^2 following its boundary expansion in the last decade making it currently the largest in the country (Figures 2.1 and 3.6).

3.4.1. Iringa Region - Modern and Past Ecologies

Altitude and wind movements mostly influence the Iringa Region climate, and temperatures often vary with altitude (Figure 3.6). The areas which lie between 1,800 and 3,000 m above sea level, experience annual temperature of below 15°C with extremes recorded in June and July (NEMC 1995). The lowland areas that mainly cover the northern part of Iringa Region experience annual temperatures of between 25 and 30°C with the warmest months being December and January.

Iringa Region receives an average annual rainfall of between 1,000 and 1,600 mm and mostly gets rainfall from November through May with the highest amount recorded between March and May. February often receives less rainfall and a typical long dry season lasts from June to October often with rainfall below 500 mm. The highlands areas between 1,600 and 2,700 m above sea level mainly found on the southeast and eastern fringe of the Iringa Region where mist also occurs get higher rainfall that ranges between 1,000 and 1,600 mm annually (NEMC 1995). The mid-altitude areas between 1,200 and 1,600 m above sea level, which receive moderate rainfall ranging between 600 and 1,000 mm annually, form the main watershed for the Great Ruaha River (Figure 3.6). The lowland areas between 700 and 1,100 m above sea level mostly cover the northwest, and western parts of the Iringa Region usually get low rainfall that ranges between 500 and 550 annually (NEMC 1995).

Unfortunately, Iringa Region paleoenvironmental datasets are scarce. The available datasets were collected in the early-1960s and early-1970s mainly from an ancient lake and exposed gully at the Isimila Stone Age site (Howell et al. 1961; Hansen and Keller 1971; Cole and Kleindienst 1974). Geological and sediments analyses suggest Isimila Old Stone Age site was formed in a deltaic setting mainly dominated by the alluvial sands, silt-clay, mudstone and claycrete laid down in a small lake or swamp over a relatively short span of time (Hansen and Keller 1971). Much recent paleoenvironmental datasets come from the Dama swamp core drillings in the Udzungwa highlands (Mumbi et al. 2008) and can be also extrapolated from core drillings from Lake Nyasa about 300 km south of Iringa town (Cohen et al. 2007; Scholz et al. 2007). Archaeological evidence from some of the excavated rockshelters indicates continuous hominin occupations of the southern highlands of Tanzania from at least the late Acheulian to the historical period (Willoughby 2012b).

3.4.2. Vegetation and Fauna

Topography, drainage, soil, rainfall and human activities account for the diversity of the vegetation types in Iringa Region (Magembe 2007). Although a substantial part of the Iringa Region landscape is now engaged with agricultural activities, a large proportion of the land is still covered by natural vegetation of different composition and plant species (Ndangalasi 1999).

Three major natural vegetation types characterize the Iringa Region including the woodlands, grasslands and riverine/valley bottom wetlands/riparian forests (Magembe 2007). Tropical woodlands are mainly found in the high altitude areas and within and near river catchment areas and are primarily dominated by the miombo forests with the genus *Brachystegia* being the most dominant species. Miombo is a broad term referring to the vegetation dominated by the *Brachystegia julbernardia*. According to the national land covers and land use reconnaissance surveys conducted in 1996, the miombo woodlands cover about 93.2% of total forested area in Tanzania. Miombo woodlands are also the key source of wood fuel, construction poles, fruits, and traditional medicines (Isango 2007). They also support agriculture especially tobacco currying. The miombo trees typically dominate the vegetation around Magubike rockshelter at present and

Albizia petersiana bushland occupy the low-lying areas, and the valley nearby where the soils are also remarkably fertile (Ndangalasi 1999).

The northern part of Iringa Region mainly supports wooded grasslands and bushlands mainly consisting of the dense thickest with the acacias and other thorny trees that typically withstand long periods of droughts as the dominant trees species (Kashaigili et al. 2007).

Valley bottom/riverine/riparian vegetation types are found mainly in the lowland, along stream and gullies and in wetland areas (Magembe 2007). These areas are normally very rich in plant species compared to the woodlands and grasslands because of their persistent wetter conditions. They also act as the refuge for different animal species especially during the heightened dry seasons. The most dominant species in these areas include *Ficus lutea, Prunus africana* and *Syzygium cordatum* (Magembe 2007).

Ruaha National Park hosts a wide diversity of wildlife such, elephant (*Loxodonta Africana)*, buffalo (*Syncerus caffer*), giraffe (*Giraffa camelopardalis)*, zebra *(Equus burchellii)*, lions (*Panthera leo)*, spotted hyena *(Crocuta crocuta),* leopard *(Panthera pardus)*, cheetah *(Acinonyx jubatus)*, waterbuck *(Kobus ellipsiprymnus*), impala *(Aepycerous melampus),* lesser and greater kudu *(Tragelaphus imberbis),* Grant's gazelle *(Nanger granti)*, eland *(Taurotragus oryx)*, warthog *(Phacochoerus africanus)* and sable antelope *(Hippotragus niger)*. Crocodiles *(Crocodylus niloticus)* also infest the Great and Little Ruaha Rivers. There are also more than 500 bird species both endemic and migratory amongst them is the conspicuous ostrich (*Struthio camelus*). Ruaha National Park was also once well known for its rhinos, but poachers made them locally extinct with the last sighting within the park reported in 1982 (Newmark 1996). Wildlife concentrations in Iringa Region are also found in the Udzungwa National Park (Figures 2.1 and 3.6). The Great and Little Ruaha Rivers and other numerous small rivers are also rich in fish especially catfish (*Clarias* sp.).

According to the historical sources, various small and large-sized animal species including hares *(Lepus capensis),* dik dik *(Madoquar kirki),* sable antelope *(Hippotragus niger),* Thompson's gazelle *(Eudorcas thomsoni),* warthog *(Phacochoerus africanus)*, zebra (*Equus burchellii)*, buffalo *(Syncerus caffer*) and elephant (*Loxodonta africana)* were abundant on the landscape near the Magubike rockshelter until the mid-1940s (Crema 1987). The *wa*-Hehe ethnic group continued to hunt them using a variety of techniques including stalking, ambush, and drives. For the extremely large-sized and potentially dangerous animals, bows and arrows (poisoned) were used (Crema 1987:130-133). Hunting of the small-sized and fast-running prey involved the use of traps and nets.

Remains of the wild animals both extinct and present forms are also reported from some open-air archaeological sites and rockshelters in Iringa Region (Coryndon et al. 1972; Collins 2009; Collins and Willoughby 2010). Rock paintings on some rockshelters also depict a rich ungulate profile that inhabited the Iringa Region landscape in ancient times (Itambu 2013).

3.4.3. Physical Features and Drainage Patterns

On the basis of relief, Iringa Region can be broadly divided into two geographically regions: the highlands and lowlands areas. The highland areas, which rise from 1,000 above the sea level, are often characterized by thin and low fertility soils that are typically not suitable for agricultural activities. Soils tend to be thicker and fertile in the lowland areas and most of the agricultural activities in Iringa Region take place here (Magembe 2007).

The central plateau has a vast network of small rivers and divides the Iringa Region into the northern and southern drainage parts (Figure 3.6). The northern part is the major sources of water for the Great Ruaha River. Small rivers and their tributaries draining the northern part all merge into the Great Ruaha River outside Iringa Region to form part of the Rufiji River basin (Figure 3.6). Most of the southern part of Iringa Region drains into Lake Nyasa, which through the Shire and Zambezi Rivers is connected to the Indian Ocean (Figures 2.1 and 3.6).

3.5. Previous Archaeological Research in Iringa Region

For more than seven decades the archaeology of Iringa Region has been virtually known from Isimila Stone Age site (35°36’12’’E, 7°53’48’’) located about 20 km from Iringa town (Hansen and Keller 1971; Howell et al. 1972; Cole and Kleindienst 1974). Discovered in the early-1950s by D.A. Maclennan, Isimila was initially test excavated by Howell in 1954 and later by the research teams of the University of Chicago in the 1957/1958 and of the University of Illinois in 1969/70 (Hansen and Keller 1971; Howell et al. 1972; Cole and Kleindienst 1974). The site has yielded Acheulean stone artefacts dated to 260 kya by uranium series (Howell et al. 1972). Various extinct forms of animals including hippopotamus, elephants, rhinoceros, equids, suids, bovids and amphibians also have been recovered from the site (see Coryndon et al. 1972).

Archaeological materials attributed to different post-Acheulean periods also have been reported from the Isimila Stone Age site landscape particularly from the northern and western part suggesting the site has been inhabited by different prehistoric human groups (Willoughby 2007; Kimaro 2008). They include of MSA, LSA, PN and IA archaeological materials. The PN and IA cultural materials mainly comprise of beads, iron slag, decorated and undecorated potsherds and animal bones with the majority poor preserved and taxonomically unidentifiable due to extreme fragmentation.

The archaeology of Iringa Region is also known from sporadic archaeological surveys and excavations of some rockshelters and open-air sites and ethnoarchaeological studies of iron-smelting technology of the Bena ethnic group (Mturi 1998; Msemwa 2002). IRAP has recently conducted a relatively comprehensive archaeological survey of the Iringa Region and has intensively test-excavated Magubike and Mlambalasi rockshelters (see Willoughby 2012b for the summary of the findings). Magubike rockshelter is a subject of this study and is described in more details below.

3.6. The Loiyangalani-Open-Air Site

3.6.1. The Geographic and Ecological Setting of the Loiyangalani Site

Loiyangalani (34°48’10’’E, 2°35’18’’) is an open-air MSA site situated along the middle reaches of the Loiyangalani River in the Serengeti National Park, Tanzania (Bower 1977, 1981, 1985). The river is a branch of the Mbalangeti River, which flows westward to eventually emptying its water into Lake Victoria (Figure 3.1). The Loiyangalani River also flows west to join the Mbalangeti River near the Makati hills just about 3 km west of the archaeological site. The site is registered as Standardized African Site Enumeration System (SASES) as HcJd-1 (Nelson 1971). It lies about approximately 2 km north of Lake Magadi. The site is also located just east of the quartzite Makati hills, which border the western edge of the Serengeti plains (Figures 3.1 and 3.2).

Ecologically, the site is located in a floodplain and along the western margins of the Serengeti plains as well as between the grassland and woodland ecotones. The site is also strategically located at one of the corridors that separate the Serengeti National Park into the eastern and western main corridors commonly used by migrating wildlife to reach the west that covers most of the areas west of the park as far as to the Lake Victoria (Holdo et al. 2011). In both an ecological and archaeological sense the site is located in undisturbed Serengeti National Park ecosystem (Sinclair 1979a, b, 1995; Sinclair et al. 2008; Bower and Gogan-Porter 1981). The Loiyangalani River floodplain also retains several seasonal depressions frequently flooded during the wet season and some drowned by rising ground water table that slowly dries during the summer. The depressions often join to form a through flowing Loiyangalani River during the rainy season. Seasonally flooded marshes and waterholes also exist within the Loiyangalani River floodplain. These conditions habitually encourage growth of sedges, reeds or tall grasses that also attract a diversity of grassland and woodland ungulates as well as aquatic life at the same location even during the heightened dry seasons. This type of landscape and topographic setting is also an exceptionally well desirable location for animal prey hunting (Behrensmeyer 1987; Hayness 1988; Driver 1990, 1995; O’Connell et al. 1992; O’Connell 1997; Lupo 1994; Lupo and O'Connell 2002). Gregarious grazing and mixed feeding ungulates frequently congregate near the Loiyangalani site during the dry seasons. During the archaeological excavations between 2003 and 2005, the most commonly observed animals near the site included impala (*Aepycerous melampus*), Grant’s gazelles (*Nanger granti*), buffaloes (*Syncerus caffer*), giraffe (*Giraffa* *camelopardalis*) and occasionally elephant (*Loxodonta africana*). These were frequently observed to come to drink water and graze for fresh grasses. It was also noted the swamps in the vicinity of the Loiyangalani site and Mbalangeti River nearby also supported hippopotamus (*Hippopotamus amphibius*).

3.6.2. Previous Archaeological Excavations at the Loiyangalani Site

An American archaeologist, Professor John F.R. Bower discovered Loiyangalani in 1977 in the course of the archaeological surveys within the Serengeti National Park (Bower 1977). Initial test excavations were conducted in 1979, and further excavations were undertaken in 2000. From the previous excavations, Loiyangalani has yielded abundant, diverse archaeological materials from its stratified series of alluvial deposits of about 2.5 m deep. These include numerous stone tools assigned to the MSA and LSA, well-preserved faunal remains of the small and large-sized bovids, equids, carnivores, crocodiles, fish, and tortoises (Tables 5.1, 6.3, 6.8; Figures 3.3, 6.4 and 6.5). The archaeological assemblage also comprises of ochre fragments and pencils (some abraded on one or more surfaces). Numerous ostrich eggshell fragments, three complete (see Figures 3.3 and 3.4), as well as two fragmentary beads indicative of symbolic mediated behaviour, also have been recovered from Unit 1, which is generally ascribed to the MSA (Thompson et al. 2004; Thompson 2005; Bower and Mabulla 2013; Bower et al. 2012). This signifies the occupants of the Loiyangalani site conceivably exploited a wide repertoire of the faunal resources, transported ochre chunks to the site for pigment making and probably may have also decorated themselves with ostrich eggshell beads.

The archaeological assemblage uncovered generated great interest, which led to the official organization of the Serengeti Genesis Project starting from 2003.

Stone artefacts stand out among the most well represented archaeological materials at the Loiyangalani site. The lithic assemblage is mainly typologically classified as MSA and mainly come from Unit 1, whereas the LSA artefacts are sparse. Pointed pieces including becs, borers, burins and various forms of scrapers (side, end, irregular, notched, nosed, convergent) comprise the bulk of the formal tools. Scrapers are also the numerically ubiquitous among the formal MSA tools, along with a small number of bifaces or pointy discs. Levalloisian cores are rare (Bower et al. 2012). The majority of the stone artefacts also exhibit little evidence for fluvial abrasion (Thompson et al. 2004).

The MSA and LSA lithic assemblages at Loiyangalani site differ strikingly with regards to artefact size, raw materials used in stone tools manufacture and on the aspects of inclusion of other cultural materials (Bower et al. 2012; Bower and Mabulla 2013). Considerably larger flakes (average length of 3-5 cm) mostly made by Levalloisian core-reduction technology characterize the MSA assemblage, whereas the LSA ones are commonly geometric microlithic (1-2 cm). Vein quartz is the most common raw material in the LSA used for stone tools manufacture, whereas dark or red to white, fine-grained, quartzite predominates in the MSA. Obsidian pieces are present in the LSA assemblage suggesting the existence of a long-distance exchange network, but these are entirely absent in the MSA lithic assemblage (Mehlman 1989; Bower et al. 2012).

Analyses of the Loiyangalani MSA lithic assemblage have also superficially noted some notable regional similarities and differences in terms of techno-typological features with the Mumba and Nasera rockshelters, approximately 100 km to the south and about 70 km to the east of the Loiyangalani site (Bower and Gogan-Porter 1981:9; Bower and Mabulla 2013; Bower et al. 2012). The MSA lithic assemblage from the Loiyangalani site is roughly contemporaneous with the Kisele Industry, a local MSA manifestation at the Mumba and Nasera rockshelters (Mehlman 1989). At Mumba, the Kisele Industry is dated to about 63.5 kya whereas the Loiyangalani MSA dates to 65 kya (Mehlman 1989; Gliganic 2011; Gliganic et al. 2012; Bower et al. 2012).

Some features also distinguish the Loiyangalani MSA industry from the Kisele Industry. First, are the aspects related to the raw materials used in the stone tools manufacture and those related to the forms of stone tools. The principal raw material in the Kisele Industry is quartz rather than quartzite and also includes infrequent obsidian pieces, which are totally absent in the Loiyangalani MSA lithic assemblage (Mehlman 1989; Bower and Mabulla 2013). Regarding the stone tool forms, the Kisele Industry mainly includes scrapers, as well as bifacial and unifacial points (Mehlman 1989). A few bifacial and unifacial points and non-descript "pointy" pieces such as becs, borers dominate the Loiyangalani MSA lithic assemblage (Bower 1985).

The striking differences in terms of techno-typological and raw materials used in the stone tools manufacture between the Loiyangalani MSA with other well-documented MSA sites from northern Tanzania remarked above, broadly may appear to represent a context-specific MSA hominin adaptation to the grassland plains (Clark 1988:277), or may be attributed to the Loiyangalani MSA hominin group being isolated (Bower et al. 2012; Bower and Mabulla 2013). Alternatively, it may reflect a possibility that the MSA hominin group at the Loiyangalani site differed somewhat in resources use strategies available over the landscape or systems of cooperation (Stiner 2005:4). According to

Bower and colleagues (2012), Loiyangalani site was mainly an ephemeral hominin occupation site primarily used for reshaping the stone tools.

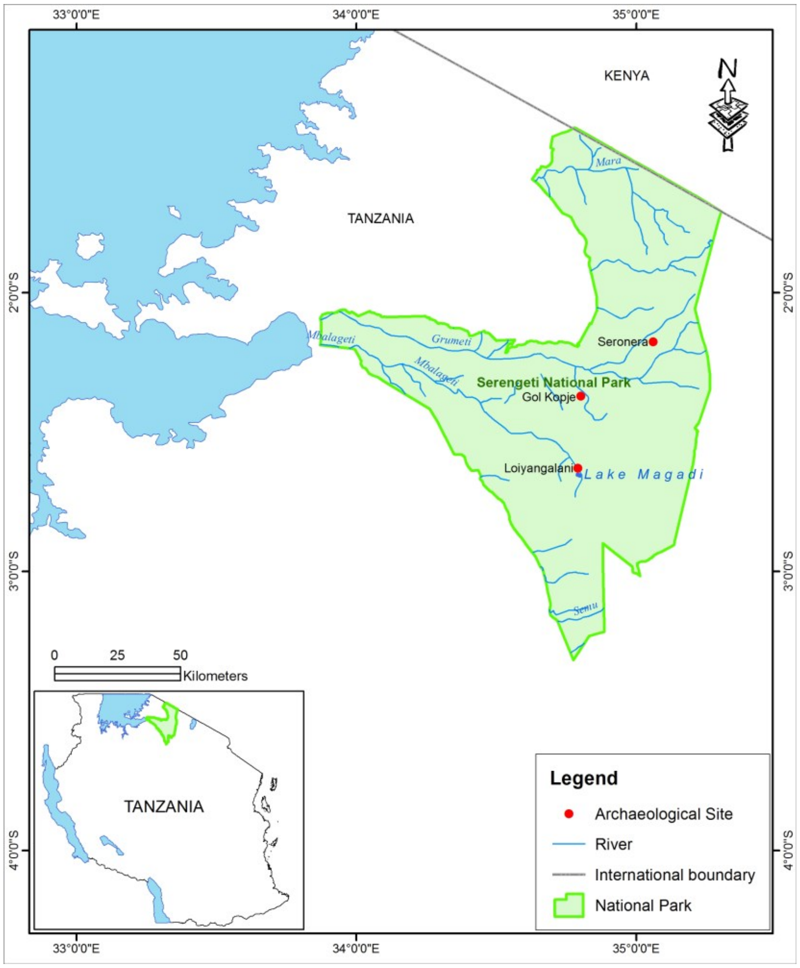


Figure 3.1. Map of Serengeti National Park Showing the Loiyangalani Site.

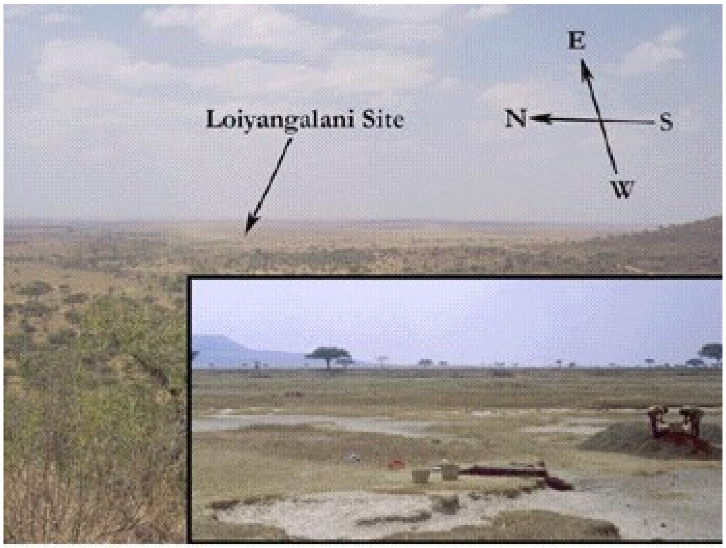


Figure 3.2. Photo Showing Loiyangalani within the Serengeti National Park.

Figure 3.3. Some Middle Stone Age finds from the Loiyangalani Site.

Figure 3.4. Ostrich Eggshell Beads from the Loiyangalani Site.

3.6.3. Previous Studies of Faunal Remains from Loiyangalani Site

Diane P. Gifford-Gonzalez, Curtis W. Marean, and Jessica C. Thompson have all studied the approximately 2,400 faunal specimens from the previous excavations at the Loiyangalani site. These studies have illuminated the taphonomic profile, depositional history and foraging economic aspects of the occupants of the site (Gifford-Gonzalez 1985; Marean 1996; Thompson 2005).

Studies of the faunal assemblages have demonstrated different bone weathering stages, which suggest some specimens were exposed up to 4 years before being covered by sediments (Behrensmeyer 1978; Gifford-Gonzalez 1985; Marean 1996; Thompson 2005). Some specimens exhibited slight to moderately abraded edges that could reflect rolling in the river currents or repeated trampling against a gritty substrate by ungulates (Potts and Shipman 1981; Behrensmeyer et al. 1986). A considerable portion of the specimens is also reported to display a great deal of post-depositional alterations (sheen, smoothing, pocking and exfoliation/sheeting) through breakage, transport, and diagenesis (see Thompson 2005 for the details). However, mechanical refitting and bone fragmentation patterns of the faunal assemblage overall point to a rapid burial with little re-deposition (Marean 1996:2).

Of the mammalian remains, size 2 bovids dominated the faunal remains by both the number of identified specimens (NISP) and minimal number of individual (MNI) counts. Other small and large-sized animals have also been reported at the site but generally in notably very low proportions. Gifford-Gonzalez studies of the faunal assemblage unearthed in 1979 from several localities at the Loiyangalani mainly identified a number of terrestrial mammals including herbivore such as Burchell's zebra (*Equus burchellii)* and Grevy's zebra *(Equus grevyi)* that both weigh up to 450 kg and carnivore remains were also identified (Gifford-Gonzalez 1985; Bower 1985:48; Estes 1991). Extinct forms of equids and bovids were also recognized (Bower and Gogan-Porter 1981:29). Overall, no marked difference in species representations between the LSA and MSA assemblages was noted (Gifford-Gonzalez 1985:48). Micromammals identified mostly included rodents *(Thryonomys swinderianus)* that were considered to result from the natural incorporation by the Loiyangalani River system and/or they could have also been a human prey since they weigh up to 7 kg. Rodents are frequently found in areas with dense tall grasses, riverine and near water sources. Fossilized remains of fish (mainly *Clarias*), tortoise, land snail, crocodile, and bird are also reported from the site (Marean 1996; Thompson 2005; Thompson et al. 2004).

Regarding surface modifications inflicted on the bone fragments, some exhibited hominin damage (cut marks and percussion marks) and/or carnivore tooth marks resulting from processing of the carcasses to retrieve meat and marrow (Gifford-

Gonzalez 1985; Marean 1996; Thompson et al. 2004; Thompson 2005). According to Thompson (2005) the overall percentages of cut marks, percussion marks and tooth marks in the faunal assemblage recovered in 2000, are relatively low when compared to published experimental and ethnoarchaeological datasets summarized in Marean and colleagues (2000), Lupo and O'Connell (2002) and Domínguez-Rodrigo and colleagues (2014). The results also suggested the faunal remains at the site were not subjected to significant bone modifications from both hominin and carnivore while still in their nutritive state. Previous analyses of the faunal assemblages, however, have implicated hominin as the key taphonomic agent in both modification and accumulation of the faunal assemblage. Carnivore involvement in the manipulation of the bones at the site also have been reported is relatively minimal.

3.6.4. Loiyangalani Stratigraphy and Chronology

Professor Carl F. Vondler of the Iowa State University, USA, studied the Loiyangalani site geology and sedimentology for this study. The stratigraphy across the test pits at the site appear to be similar and is vertically divided into four archaeostratigraphic layers designated as Units (Unit 1 through 4 from bottom to the top), which both reflect variation in hydrological and ground cover and is characterized as follows (Figure 3.5).

- Unit 1 is the lowermost and is interpreted as proximal overbank alluvial floodplain deposits that range from an upper limit to about 90 to 100 cm and the lower limit 250 cm below the modern surface (see also Bower et al. 2012). Unit 1 is very rich in faunal remains that are also well-preserved (see Figures 3.3, 3.5, 6.4, 6.5, 6.15 and 6.16).

- Unit 2 overlies Unit 1 and is about 50 to 100 cm thick and is composed of more distal floodplain deposits marked with prismatic to the blocky structure and is virtually archaeologically sterile (Bower et al. 2012). It represents a poorly drained distal floodplain environment, probably a temporary pond as suggested by sediment texture and color as well as by the presence of desiccation cracks, especially from the upper part of the Unit (Figure 3.5).
- On top of Unit 2, is Unit 3 that consists mostly of well-developed soils that supports the long grasses of the Serengeti plains. Unit 3 has yielded a few undiagnostic LSA stone artefacts and animal bone fragments per unit volume of sediments (Figure 3.5).
- Unit 4 consists essentially of sediments derived from the erosion of Unit 3 mixed with flood sediments from the Loiyangalani River such are evident on the modern surface, aeolian sediments and volcanic ash. Unit 4 has also yielded a light scatter of LSA stone artefacts and a few fossilized faunal remains.

Dating the Loiyangalani archaeological deposits has shown considerable variation in previous attempts, which is also a common case for the majority of the open-air archaeological sites (Bower and Gogan-Porter 1981:54). Summaries of previous chronometric dating results are provided in Table 3.1 below. An Electron Spin Resonance (ESR) date on bone collagen from a 1979 excavation sample collected from 120-130 cm below the surface surprisingly provided a date of 10,765 BP for Unit 1, which is too recent. Another radiocarbon dates by CSIR and Beta Analytic on material thought to have been recovered in 1979 from the uppermost Unit 1 gave an uncalibrated date of 13,920 ± 70 BP (Woodbourne 2004).

More recent application of Optical Stimulated Luminescence (OSL) dating that measures how much time has elapsed since the materials were last exposed to light provided a different age of 65,000 ± 4.4 for sediments from near the top of Unit 1 that correspond well with the MSA lithic assemblage from the site and place it firmly into the known MSA chronological time range in East Africa (Deino and McBrearty 2002; Feathers and Fusch 2005; Morgan and Renne 2008; Bower et al. 2012; Sahle et al. 2014). However, no single dating sample for an archaeological site can be considered decisive. Given the disparity of the results by different chronometric dating methods, dating Unit 1 obviously still require further investigations. New ESR samples collected between 2003 and 2005 excavations have been submitted to Professor Anne Skinner to get finer chronological resolutions. Results are not yet out.

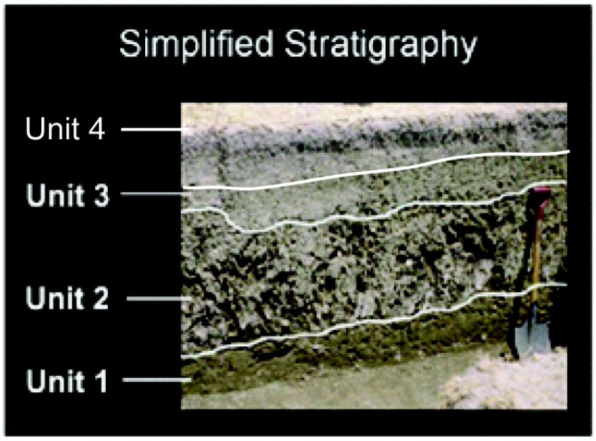


Figure 3.5. Simplified Loiyangalani Site Stratigraphy.

Table 3.1. Summary of Chronometric Dating at Loiyangalani.

Age	Stratum	Method	Laboratory
65 kya ±4.4	Unit 1	OSL	University of Washington
*13,920 BP ±70	Unit 1	14 C (OES)	CSIR (Pretoria)
**10,765 BP	Unit 1 (?)	14 C (Bone)	Beta Analytic
8.6 kya	Unit 2	OSL	University of Washington

*Sample obtained from the top of Unit 1

** Sample obtained from 1979 excavations, whose stratigraphy sequence does not exactly march that of more recent excavations

3.7. Magubike Rockshelter

3.7.1. The Geographic and Ecological Setting of the Magubike Rockshelter

Magubike is a large granitic rockshelter (7°45.790’S, 35°28.399’E) located approximately 40 km west of Iringa town in the southern highlands of Tanzania (Figures 2.1, 3.6 and 3.7). The rockshelter takes its name of a village of the same name and is registered as HxJf-01. The roof of the rockshelter covers 535 m^2 with a maximum east-west linear dimension of 23.2 m and 5.9 m across the main shelter and the side chamber respectively (Figures 3.7 and 5.3). The ceiling is approximately 20 m above the ground at its highest point (Figure 5.7). Besides, no rock paintings have been noted anywhere on the rockshelter exposed walls.

Magubike rockshelter is located in an area typical of the landscape of the southern highlands of Tanzania mostly characterised with rolling topography and scatters of numerous rock outcrops (Figure 3.7). The areas neighbouring Magubike rockshelter get annual rainfall ranging between 600 and 1,000 mm and form the watershed for the Kalenga River, which is one of the tributaries of the Great Ruaha River. Numerous springs gushing fresh water throughout the year also exist near the rockshelter and in the valley east of the site. This type of ecological setting is ideal for hunting as could have supported a wide range of animal species and was regularly visited by herd or individual animals even during the heightened dry seasons (Behrensmeyer 1987; Hayness 1988; Driver 1990, 1995; O'Connell et al. 1992; Lupo and O'Connell 2002). Hunter-gatherers are reported in East African region to have tactically utilized the natural features such as the rock outcrops, springs, waterholes, rivers and lakes margins for successful hunting of ungulates at places such as at Nasera rockshelter, Lukenya Hill and Rusinga Island (Mehlman 1977, 1989; Marean 1997, 1990b).

Figure 3.6. Map of Iringa Region Showing Magubike Rockshelter.

5.2).

Figure 3.7. Photo Showing Magubike Rockshelter.

3.7.2. Previous Archaeological Excavations at Magubike Rockshelter

Professor Pamela R. Willoughby recorded Magubike rockshelter during an initial visit in the summer of 2005. The circumstances of the discovery of the rockshelter and others in Iringa Region are described in Willoughby (2005, 2012b). The rockshelter was initially test excavated in 2006, and further excavations were conducted in 2008. A total of 5 test pits were opened inside and outside of the rockshelter (Figure 5.3). A total of 4.5 m^2 and 3.4 m^2 of sediments were excavated in 2006 and 2008 respectively. Magubike has yielded a large suite of archaeological materials including isolated hominin teeth. Numerous iron implements, bits of tuyeres, iron slag, potsherds, glass and ostrich eggshell beads, land snails, charcoal fragments, microlithic artefacts and fossilized animal bones were recovered from its Iron Age deposits (Willoughby 2012b). From the MSA deposits the cultural materials recovered mostly included lithic artefacts, fossilized animal bones, land snail shells and a few ostrich eggshell beads and fragments (Table 5.2).

Techno-typological aspects of the lithic assemblages have shown that, Magubike contains typical MSA artefacts mainly manufactured from the white quartz, quartzite, cryptocrystalline silica and metamorphic rocks (Biittner 2011). Quartz appears to be the much-exploited raw material in stone tools manufacture at the site and was mainly locally sourced (Werner 2014). Initial archaeological surveys in Iringa Region with a geological focus failed to identify the sources for chert/flint and metamorphic rocks and it was suggested possibly were sourced from long distance places (see Biittner 2011). The largest nearby source for chert (7°53.070’S, 35°25.899’E) has been recently discovered through intensive archaeological surveys of the Isimila Stone Age site landscape by the University of Dar es Salaam archaeology field school conducted between July and August 2015. The straight distance between the chert source and Magubike rockshelter is less than 30 km. Besides, numerous new chert sources were also recorded in 2016 within a distance of less than 10 kilometers from Magubike and Mlambalasi rockshelters (Willoughby 2016).

The MSA tools at Magubike rockshelter are generally much larger in size when compared to the LSA ones. The majority of the formal tool types comprise of scrapers, backed pieces, points, burins, bifacial pieces and becs (Willoughby 2012b). Technological analyses of the lithic assemblage denote that bipolar technology was commonly used to manufacture the stone tools and a similar preference is also reported by Willoughby for the MSA sites in Mbeya Region (Willoughby 2007; Werner and Willoughby 2017).

3.7.3. Previous Studies of Faunal Remains from Magubike Rockshelter

Benjamin R. Collins analyzed the faunal assemblage from the 2006 excavations. A total of 3,377 specimens were recovered, of which provided a number of identified specimens (NISP) of 1,164 and MNI estimate of 18 individuals (Collins 2009). The majority of the specimens identified to skeletal parts came from the Iron Age and LSA deposits. Specimens were also well-preserved and less affected by the concretions in comparison to those from the MSA deposits. Surface modifications recorded mainly included a few cut marks, percussion marks, and trample marks (Collins 2009:134-136, 138-139).

Specimens identified to skeletal parts from the MSA deposits that bear a direct relationship to the present study were numerically very few, due to the high degree of fragmentation. Over 60% of the total sample measured < 2.5 cm in maximum dimension. Small-sized animals (size 1-2) represented the most common identified group (81%; NISP=496; MNI=6) and large-sized (size 3-4) accounted for the remaining 17% (NISP=107; MNI=1). The results broadly suggested MSA hominin preferentially foraged on small-sized (size 1-2) ungulates. Regarding the surface modifications in the MSA faunal assemblage, unfortunately, both hominin and carnivore traces were scarcely identified due to the overall poor preservation character with approximately 90% of the total sample being carbonate-affected (Collins 2009:142, 220-221). Collins (2009:198, Table 6.10), reports only two specimens preserved surface modifications (a percussion mark and a tooth mark) in the entire studied MSA faunal assemblage. However, green breakage accounted about 60% of the total long bone specimens analyzed with the remainder 40% being diagenetically fractured. Citing, skeletal part abundance, positive relationships between skeletal part abundance against their economic utility values (albeit weak), evenness indices, and the general mode of long bone fragmentation, led Collins (2009:226) to implicate hominin key authorship in the accumulation of the MSA faunal assemblage at Magubike rockshelter.

3.7.4. Magubike Rockshelter Stratigraphy and Chronology

The Magubike archaeological sequence mostly exhibits anthropogenic traces rather than a sequence of naturally deposited sediments. Descriptions of the stratigraphy are also anecdotally reported in several reports (see Collins 2009:91-93; Alexander 2010: 34-37; Biittner 2011:30-35; Bushozi 2011:198-203; Willoughby 2012b: 112).

In the main part of the site, under the roof, there are up to 2 m of cultural materials. These are broadly divided into two main units (see Figure 3.8 below). As clearly defined by soil texture, color, thickness of the deposits and artefact types the upper levels (0 to 50 cm below the modern surface) are assigned to the Iron Age (IA). The IA deposits are characterized by poorly to moderately sorted silty and sand to almost gravel-sized clasts often dark/blackish in color mostly resulting from the anthropogenic activities and iron smelting conducted within the rockshelter. Cultural materials from the IA levels mainly include a mixed composition of iron slag, decorated and undecorated potsherds, land snail shells, lithics and burnt bone fragments. Macroscopic analyses of the iron slag suggest traditional iron bloom refining process.

In this part of the site, MSA deposits occur directly below the IA deposits between 50 and 200 cm below the modern surface (Figures 3.8 and 5.3). Lithological properties of the deposits are characterized by moderately to poorly sorted silty, to gravel-sized and to cobble-sized clasts of which their proportion increases with depth. Soil colors range from red-brown to dark brown. Archaeological materials from the MSA deposits mainly include a mixed composition of lithics, beads, land snails shells isolated hominin and abundant comminuted fossilized animal bones.

Stratigraphy descriptions from the 2012 excavations are subdivided into six lithostratigraphic units of varying thicknesses and colors from the top down the archaeological sequence and are summarized below (see Figure 3.8).

- Unit 1 (0 to about 18 cm) and Munsell color chart of 10YR 2/1 – black.
- Unit 2 (18 to 41 cm) and Munsell color chart of 5YR 2.5/2 – dark reddish brown.
- Unit 3 (between 41 and 85 cm) and Munsell color chart of 5YR 4/4 reddish brown.
- Unit 4 (85 to 161 cm) and Munsell color chart of 7.5YR 4/5 - strong brown.
- Unit 5 (161 to 170 cm) and Munsell color chart of 7.5 YR 6/5 - reddish yellow.
- Unit 6 (170 to 200 cm) and the Munsell color chart is 10R 4/6 - red.
- Unit 7 (from 200 cm) is bedrock and is archaeologically sterile.

Initial attempts to date Magubike rockshelter archaeological deposits on the materials recovered in 2006 by radiocarbon dating on the *Achatina* shell fragments samples (from 20-30 cm below surface) yielded a calibrated date of 1,410-1,015 BC which falls within the range of the Iron Age. A sample from MSA deposits yielded a chronometric date of 41,100-42,480 BP (uncalibrated) and is of meticulous interest because it falls within the known MSA/LSA transition (Klein 2009). However, this date also can be at best treated as minimum, rather than an absolute date because it can be beyond the practical upper limit of radiocarbon dating method as a practice by most laboratories (Aitken et al. 1992; Wintle 1996).

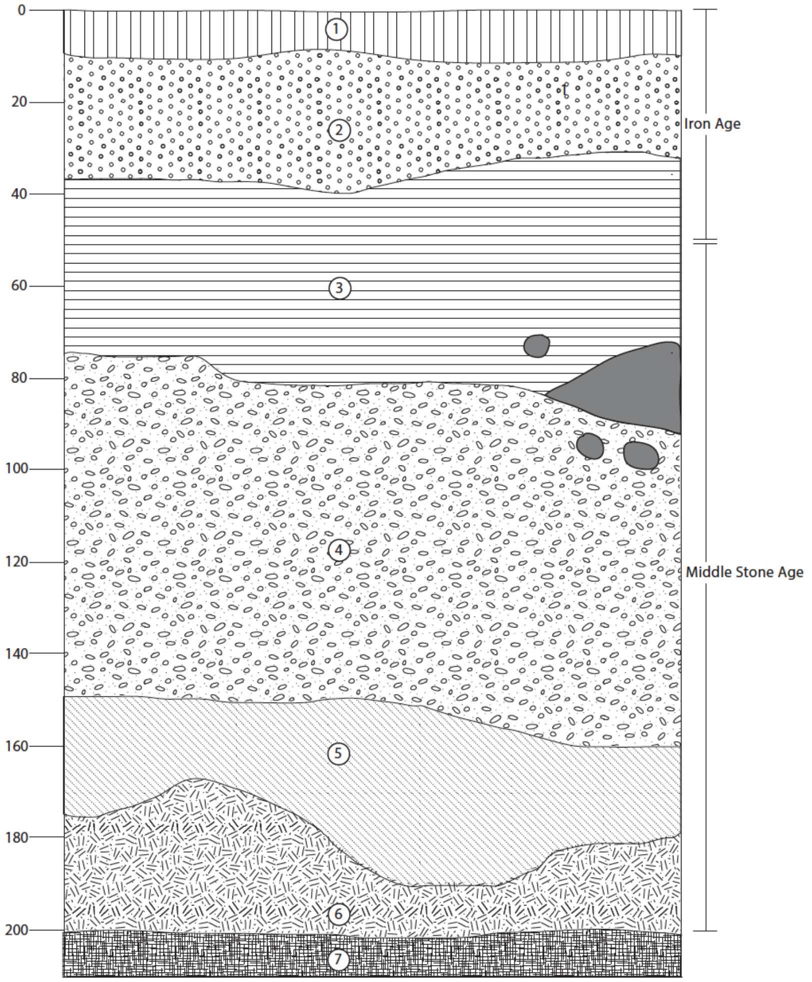


Figure 3.8. Magubike Stratigraphy from Western Wall of Test Pit 12.

CHAPTER 4

OPTIMAL FORAGING THEORY

4.1. Introduction

This chapter introduces optimal foraging theory and the diet breadth model, which in conjunction with published experimental and ethnoarchaeological datasets guided the interpretations of the results for the archaeological faunal assemblages considered for this study (Tables 5.5, 8.4; Figures 6.14, 6.18, 7.10 and 7.13). A brief summary of the diet breadth model is provided below followed by a discussion on how it serves to predict and generate quantitative datasets to answer the paleoanthropological research questions outlined in Chapter 1.

4.2. Optimal Foraging Theory

Since the birth of archaeology, its broad objective has been always to make inferences about the past based on material evidence of human activities (Trigger 2008; Johnson 2010). Like for all other disciplines, theories always shape our research designs to reach scholarly established reconstructions of the past human lifeways. Theoretical frameworks frequently guide us on what to record and inform us on what is possible (Binford and Binford 1968; Barrett 2000). One of the theoretical frameworks that have received wider use in archaeology is the optimal foraging theory, which is a subset of human behavioural ecology. This was developed in the 1970s by ecologists interested in the understanding and quantification of observable nonhuman foraging behaviours (Winterhalder and Smith 2000; Kelly 2007). Optimal foraging theory is mostly grounded in evolutionary neo-Darwinism and in economic principles of optimization and assumes that foragers tend to exploit resources in an efficient way within a set of constraints in terms of energy intake (usually calories per unit time spent foraging). Foragers also add resources into their diet spectrum from the highest to the lowest ranked until the net return rates per unit time spent foraging are maximized (MacArthur and Pianka 1966; Stephens and Krebs 1986; Bettinger 1991; Pianka 2000; Winterhalder and Smith 2000). In general natural selection always favour foragers that maximize their energy return rates, and consequently their reproductive success.

Optimal foraging theory comprises a number of models that explain diverse aspects of animal foraging and decision-making across space and time. These include what to forage (Diet Breadth/Prey Choice model) as well as where and when (Patch Choice/Marginal Value Theorem) (MacArthur and Pianka 1966; Stephens and Krebs 1986; Bettinger 1991; Kelly 2007). The Central Place model addresses how much and how far to transport the procured resources back to the consumption sites (Orians and Pearson 1979; Schoener 1979). The optimal foraging models are both broadly and tightly correlated, and researchers frequently use either independently or several of them in their studies. Shared traits in the models include a goal, decision, currency, set of constraints and set of options available to a forager (Kelly 2007).

Since the early-1980s, optimal foraging theory has been successfully applied in the study of different aspects of modern hunter-gatherers foraging economies including among the Hadza of Tanzania, the Nunamiut of Alaska, the Ache of Paraguay, the San of southern Africa, the Bofi of Central Africa and the Aka of Congo (Bettinger 1991; Lee and Daly 1999b; Winterhalder and Smith 2000; Kelly 2007). Consequently, results of such studies are widely applied in the reconstructions of early hominins foraging ecology and economy more particularly via the analysis of the archaeological faunal assemblages (Hudson 1993; Broughton 1999; Broughton and Grayson 1993a, b; Broughton et al. 2011; Winterhalder and Smith 2000; Ugan and Bright 2001; Smith and Winterhalder 2003; Bird and O'Connell 2006; Lupo 2007). They have been also used to create robust inferential frameworks to interpret patterning in the archaeological faunal assemblages (see Kroll and Price1991; Lupo and O'Connell 2002; Marean and Cleghorn 2003; Cleghorn and Marean 2004, 2007; Faith and Gordon 2007; Faith et al. 2009).

4.3. Diet Breadth Model

The diet breadth model, also known as prey choice model, is a widely used analytical framework in archaeology (Winterhalder and Smith 2000; Sheehan 2004; Bird and O'Connell 2006; Lupo 2007). It assumes that prey are encountered randomly over the landscape and predicts that the high-yield/high-ranked prey will be habitually taken into the diet spectrum on encounter based on their intrinsic high post encounter return rates (MacArthur and Pianka 1966; Stephens and Krebs 1986; Bettinger 1991; Pianka 2000; Winterhalder and Smith 2000; Kelly 2007). Low-yield/low-ranked prey, regardless of their abundance over the landscape, should be only included in the diet spectrum depending on the availability of the high-yield/high-ranked prey. When encounters of the high-yield/high-ranked prey decline, for whatsoever reasons, foragers are habitually expected to widen their diet spectrum to include the low-yield/low-ranked prey typically with relatively low nutritional post-encounter return rates to maximize their foraging return rates (Bird and O'Connell 2006; Kelly 2007; Lupo 2007). These are chosen sequentially in order of decreasing rank to compensate for the decline in the availability of the high-yield/high-ranked prey. The inclusion of more low-yield/small-sized prey often reflects an expansion in the diet breadth (Stiner and Munro 2002; Lupo and Schmitt 2005; Ugan 2005a, b; Bird et al. 2009; Broughton et al. 2011). Other factors that can also determine the selection of prey on encounter frequently noted among different modern hunter-gatherers groups include the composition of the foraging group (Hurtado et al. 1985; Jochim 1988; Hill et al. 1987; Bird and Bird-Bliege 2000; Lupo and Schmitt 2005), prestige (Hawkes 1991; Hawkes and Bliege-Bird 2002; O'Connell et al. 2002), cultural taboos and/or preferences for certain animal resources or parts such as the fat-rich bones (Binford 1978, 1981; Lupo and O'Connell 2002; Marlowe 2007; Morin 2007).

Post-encounter return rates may also vary as a function of prey anti-predatory defense behaviour and climatically propelled changes in the prey abundances over the landscape (Grayson and Delpech 1998, 2002, 2003; Madsen and Schmitt 1998; Ugan et al. 2003; Ugan 2005a; Bird et al. 2009). However, technology used in the procurement of prey such as adoption of shotguns, snowmobiles, dogs, and nets can also notably augment encounter, pursuit cost and post-encounter return rates for some type of prey such as fish and insects and their overall relative ranking in the diet spectrum available to a forager (Madsen and Schmitt 1998; Rick and Erlandson 2000). Inclusions of fish and birds may also indicate an expansion of the dietary breadth.

Ethnographic studies have demonstrated when procured individually large-sized animals often provide higher foraging returns per energy expenditure in terms of nutritional values (meat, marrow, and grease) as well as raw materials for tool making and clothing (Kelly 2007). However, an important exception to this generalization is for some of the very large-sized prey such as elephants and whales which often have higher handling costs that frequently outweigh their post-encounter returns (Ugan and Bright 2001; Byers and Ugan 2005; Ugan 2005b). Small-sized animals are usually considered to be of low ranked status. Accordingly, animal body size provides a precise proxy measure of post-encounter return rates (Bayham 1979; Broughton 1999; Broughton and Grayson 1993a, b; Broughton et al. 2011; Cannon 2000; Ugan 2005b).

The diet breadth model is commonly used to evaluate prehistoric human prey choices, transport decisions and processing intensity of the individual carcasses (see Winterhalder and Smith 2000; Smith and Winterhalder 2003; Bird and O'Connell 2006 and Lupo 2007 for recent detailed reviews). The diet breadth model has been commonly applied to African and European archaeological faunal assemblages to test the opposing hypotheses regarding subsistence behaviour between the MSA and LSA hominins or between the Middle and Upper Palaeolithic ones in Eurasia. Some of the examples in Africa include (Faith 2008; Faith and Gordon 2007; Faith et al. 2009; Clark 2009; Dusseldorf 2010, 2012) and in Europe (Grayson and Delpech 1998, 2002) and in America (Broughton 1999; Jenetski 1997; Butler 2000; Butler and Campbell 2004). It has been also commonly used to address questions related to the transition from hunting/gathering to an agricultural economy in the Near East (Bar-Oz 2004; Munro 2004; Adler and Bar-Oz 2009). Besides, it is also frequently used to test the hypotheses regarding the long-term foraging intensification and resources depression (Lupo 2007; Broughton 1999; Butler 2000; Butler and Campbell 2004; Cannon 2000; Nagaoka 2001, 2002a, b).

Applications of optimal foraging theory to the archaeological record, however, have not gone unchallenged. Major criticisms mostly have come from the assumptions behind the models. It has been argued, for example, that some of the assumptions fundamental to the classic optimal foraging models are simple and do not explain the often poorly preserved and time-averaged archaeological faunal assemblages (Behrensmeyer and Hill 1980; Behrensmeyer 1991; Shipman 1981; Klein and Cruz-Uribe 1984; Kidwell and Behrensmeyer 1993; Lyman 1994, 2003). Foraging models usually make some assumptions that are often too simple or may be wrong (Marlowe 2010:102). Of course, this is one of the best logical ways to build a model, first, test it and then let the results guide it to greater complexities (Smith 1983). The intense focus on the faunal component and neglect of the vegetal portion of the prehistoric human diet, as well as the behavioural dynamics such as imbued social goals are also not always considered (Hill et al. 1987; Hawkes 1991; O'Connell et al. 2002; Hawkes and Bliege-Bird 2002; Lupo 2007). Other criticisms include the problem in defining currency by ordering resources based on their energetic return rates commonly used to gauge the overall foraging efficiency (Lupo 2007). Ranking prey by body size has also been noted to be problematic especially for the highly sexually dimorphic species (see Lyman 2003; Stiner and Munro 2002; Munro 2004; Morin 2012 for the details) and always neglect the differential in handling costs among the animals of comparable body sizes (Lupo and Schmitt 2005; Stiner and Munro 2002). Equally problematic is that the available range of the foraging return rates datasets are mostly derived from a limited number of ethnographic studies and may not sufficiently represent the whole past (Lee and Daly 1999b; Kelly 2007; Bright et al. 2002; Broughton et al. 2011). Besides, documented ethnographically foraging return rates of the plant foods are also few (Hurtado et al. 1985; Bright et al. 2002; Cordain et al. 2002) and in particular are not available for the MSA/MP archaeological record (Kuhn and Stiner 2006). Criticisms of the optimal foraging theory are also extensively addressed elsewhere (in Martin 1983, 1985; Pyke 1984; Dwyer 1986; Broughton and O'Connell 1999; Joseph 2000; Lupo 2007). Some scholars, however, have vehemently defended both the theoretical and methodological foundations of optimal foraging theory and its applications in archaeology (see Winterhalder 1981a, b, 2002; Winterhalder and Smith 2000; Broughton et al. 2011).

4.4. Archaeological Indicators of Foraging Efficiency

The diet breadth predictions outlined above are critical to the understanding of the MSA hominin foraging ecology as reflected in archaeological faunal assemblages, which is the primary objective of this dissertation. The key is the assumptions that foragers usually seek to optimize their foraging by procuring the high-yield/high-ranked resources first, and then include the low-yield/low-ranked, which consequently make them fit and reproductively successful (MacArthur and Pianka 1966; Stephens and Krebs 1986; Bettinger 1991; Pianka 2000; Winterhalder and Smith 2000; Kelly 2007). Accordingly, this provides a robust analytical framework to probe the fundamental foraging decisions made by the MSA hominins at Loiyangalani and Magubike. Besides, it also permits to formulate quantitative and testable variables detailed below to evaluate the overall MSA hominins foraging strategies. In this dissertation, the diet breadth model is mainly used to investigate prey choices and carcasses processing intensity as reflected in a variety ways in the archaeological faunal assemblages. Indicators of foraging efficiency considered in this study are briefly reviewed below.

4.4.1. Abundance Index

The Abundance Index (AI) is a ratio of the small and large-sized prey and was developed by Bayham (1979). It figures prominently in the studies of animal exploitation patterns and is often simple to use. The Abundance Index (AI) assumes a positive correlation between the archaeological faunal abundances and post-encounter return rates of the prey over the landscape that is usually combined into a single measurement usually body size with the large-sized assumed to have higher post-encounter return rates than the small-sized prey. The relative abundance of the large-sized animals is calculated as the ratio of the large-sized to the sum of the large and small-sized ones:

$$AI = (\sum \text{large-sized}/(\sum \text{small-sized} + \sum \text{large-sized}) \ldots\ldots\ldots (1)$$

The relative abundance index is scaled from 0 to 1. A high index suggests higher foraging returns (i.e. hunting efficiency) and a lower index is an indicator of a decline in an overall foraging efficiency (i.e. resource stress) (Bayham 1979; Broughton 1999; Broughton et al. 2011; Butler 2000; Ugan 2005b; Nagaoka 2001, 2002a, b). In North America literature, the Abundance Index (AI) frequently takes the form of an Artiodactyls Index in which the relative proportions of the artiodactyls (representing large-game) and lagomorphs (representing small-game) are often compared (Ugan and Bright 2001). For the African case, (see Table 4.1 below) animals are usually assigned to body size classes representing small (<100 kg), medium (100-300 kg) and large animals (300-1,000 kg) and very large (>1,000 kg) following Brain's (1981) and Bunn's (1982) guidelines.

Table 4.1. Animal Body Size Classes by Body Weight.

Size	Mass (in Kg)	Common Name
Size 1	10-20	Hyrax, Hare, Rodent, Dik, Thompson's Gazelle
Size 2	20-100	Grant's Gazelle, Antelope, Reedbuck, Warthog, Impala, Springbuck
Size 3	100-300	Wildebeest, Hartebeest, Waterbuck, Topi, Kudu
Size 4	300-1,000	Zebra, African Buffalo, Eland
Size 5	>1,000kg	Giraffe, Hippopotamus, Rhinoceros, Elephant

4.4.2. Prey Diversity (Richness and Evenness)

Long-term archaeological sites often contain relatively large faunal assemblages often with more than one species or classes of animals while short-term sites are usually small and less diversified (Jones 2004). Richness is the number of species, taxa or class of animals in a defined sampling unit and is computed by the number of taxa (NTAXA) identified in the faunal assemblage under consideration (Magurran 1988). In order to gauge the degree of taxonomic richness in the archaeological faunal assemblage one of the most common measures used by zooarchaeologists is the Shannon-Wiener Index of heterogeneity, also frequently referred to as the Shannon Index calculated as follows:

$$H' = - \sum P_i * (\ln P_i) \text{ .... } (2)$$

where P_i is the proportion of taxon i in the faunal assemblage. H' is a number that commonly ranges between 1.5 and 3.5 (Magurran 1988:35). The higher the value is, the greater the degree of heterogeneity for the faunal assemblage (see Table 8.3). However, the use of NTAXA has been frequently criticized because it represents maximum rather than the average diet breadth over a given period (Madsen 1993; Lyman 1994, 2003, 2008). A number of factors also negatively mediate the NTAXA as measure of the dietary breadth including time-averaging, destructive taphonomic factors, bone fragmentation, differential hominin transport behaviour of the carcass parts, technology and climate-driven changes (Broughton and Grayson 1993a, b; Kidwell and Behrensmeyer 1993; Grayson and Delpech 1998; Grayson et al. 2001; Lyman 2003; Ugan et al. 2003). To circumvent the problems stated above, normally taxonomic richness is combined with other measures of the diet breadth such as evenness index to provide much clear information (Grayson and Delpech 1998; Broughton et al. 2011).

Evenness is the relative frequencies of each species, taxa or class of animals in a defined sampling unit within the archaeological faunal assemblage under consideration (Cruz-Uribe 1988; Lyman 2008). Changes in the Evenness Index (*E*) reflect a broadening of the dietary breadth; changes in prey encounter rates or decreasing availability of the preferred high-ranked prey (Jones 2004). Thus, the evenness index derived from the Shannon-Evenness Index *(E)* is calculated as:

$$E = H'/\ln(S) \ \ldots\ldots\ldots \ (3)$$

where H' is the Shannon Index, and S is the number of non-overlapping ungulate taxa, species or class of animals in the faunal assemblage under consideration. The Shannon Evenness Index *(E)* ranges between 0 and 1. The lower the value, the less even the faunal assemblage is (Magurran 1988). When the index equals 1, all taxa are equally abundant. For the same species are exploited, the NTAXA, *H,* and *E* are also higher (Grayson and Delpech 2002; Jones 2004; Lyman 2008). When the index is equal to 0 denotes only one class is represented i.e. dominated by one or few of the represented taxa (see Table 8.3). This often happens, when a faunal assemblage was accumulated by the highly specialized foragers or in relatively short-term sites i.e. NTAXA, *H'* and *E* are all typically low.

Likewise, the evenness index is plagued by same problems that affect the richness (NTAXA) remarked above. In addition, evenness index do not take into account the position of prey in a rank ordered set (Grayson and Delpech 1998; Grayson et al. 2001). It follows that an increasing evenness may reflect rising abundance of some high-ranked items rather than decreasing availability of one dominant prey and the value can remain unchanged even though resource exploitation is changing (Nagaoka 2001, 2002a, b, 2006). The consideration of only resources that are satisfactorily high-ranked and were always included in the diet spectrum can help to alleviate this problem (Jones 2004). The proportions of individual prey types can also be examined to determine the changes in the diet breadth (Nagaoka 2001, 2002a, b, 2006).

4.4.3. Analysis of Mortality Profile

Mortality profile is one of important avenues in zooarchaeological studies commonly used to examine a broad spectrum of early hominins and modern human behaviour including their overall foraging strategies (hunting or scavenging), seasonality, social organization and site formation processes. Tooth eruption, tooth wears stages, epiphyseal fusion, and cementum annuli are the common methods used in the reconstructions of the mortality profile in the archaeological faunal assemblages (Klein 1982; Klein and Cruz-Uribe 1983, 1984; Stiner 1990, 1991a, b, 1994; Steele 2005). Mortality profile data are usually grouped into three life-history stages as documented in wildlife ecology: juveniles, prime-adults, and old animals.

Hominins are selective and habitually hunt prime-aged adult prey whereas the carnivores frequently tend to kill the young, old or weak prey. A mortality profile dominated by prime-aged prey combined with a relatively complete skeletal part profile is indicative of hominin-generated faunal assemblage and by extension signal efficient hunting (Brain 1980, 1981; Vrba 1980; Klein 1982; Klein and Cruz-Uribe 1983, 1984; Stiner 1990, 1991a, b, 1994; Gaudzinski and Roebroeks 2000). On the other hand, juveniles and old individuals in conjunction with the skeletal part profile dominated by cranial and lower limb bones frequently characterize carnivore-generated faunal assemblages (Vrba 1980; Klein and Cruz-Uribe 1983, 1984; Stiner 1990, 1991a, b, 1994). Of note, the impact of post-discard carnivore ravaging and density-mediated attrition also can shape the mortality profile reconstructions (Binford 1978, 1981; Blumenschine 1986a, b, 1987; Blumenschine and Marean 1993; Marean and Spencer 1991; Marean et al. 1992; Capaldo 1995). Juveniles are frequently underrepresented in many archaeological faunal assemblages because their bones are more prone to carnivore ravaging and postdepositional attrition processes than those of the adults (Klein and Cruz-Uribe 1983, 1984; Lyman 1994). Small-sized and juveniles animals are also often practically consumed by large carnivore within short time following their death (Blumenschine 1986a, b, 1987). The teeth of juvenile animals are also typical small and are more likely to fall out of their mandibles and maxillae (Munson 2000; Munson and Marean 2003; Munson and Garniewicz 2003).

4.4.4. Skeletal Part Representation

Ethnoarchaeological studies have demonstrated that nutritional values of the carcass parts critically influence their transport from kill sites to consumption sites by hominins. Other inherent factors include the number and carcass size to be transported, carcass condition, size and strength of available carriers, hunger level, time of day, weather, hunting season, geographic features, perceived competition from carnivore and distance from the kill site to basecamp (Perkins and Daly 1968; Binford 1978, 1981; Brain 1981; Bunn 1981, 1982, 1983; Bunn et al. 1988; O'Connell et al. 1988, 1990, 1992; Stiner 1990, 1991a, b, 1994; Oliver 1993; Monahan 1998; Lupo 1994, 2001, 2006; Lupo and O’Connell 2002). Unfortunately, most of these factors are often hard to recognize in the archaeological faunal assemblage, but still, a possible hominin carcass transport behaviour can be broadly inferred based on the overall skeletal part representation (Stiner 1990, 1991a, b, 1994).

Notwithstanding, the existence of notable variability in hunted prey transport behaviour and carcasses processing intensity documented among the modern hunter-gatherer groups imbued by both tradition and heritage, a general coherent pattern of processing and transport of the carcass parts still exist (Binford 1978, 1981; Nilssen 2000; Burger et al. 2005). Hunter-gatherers preferentially process and transport the high-utility long bones (humerus, radius, femur, and tibia) first based on their overall high amount of nutrients (meat, marrow, and grease). Later, they process the low-utility elements including metacarpals, metatarsals, carpals, tarsals, cranial elements and phalanges (containing some marrow but little meat) as predicted by the diet breath model above (Binford 1978, 1981; Bunn et al. 1988; Bunn and Kroll 1986; Bunn and Ezzo

1993; O'Connell et al. 1988, 1990, 1992; Oliver 1993; Lupo 1994, 2001, 2006; Lupo and O’Connell 2002; Monahan 1998). The cranial and lower limb bones are also frequently abandoned at the kill sites.

Faunal assemblages generated by hominin and carnivore typically exhibit distinctive patterns, which by extension reflect their mode of foraging for those carcasses. The relative abundance of the high-and-low utility elements provides an index to evaluate foraging efficiency. An abundance of the high utility skeletal parts is frequently cited as an evidence of hominin effective hunting (Bunn 1981, 1982, 1986; Bunn and Kroll 1986; Bunn and Ezzo 1993; Bartram and Marean 1999; Marean and Kim 1998; Marean and Assefa 1999; Marean et al. 2000, 2004; Assefa 2002, 2006; Domínguez-Rodrigo 2002). On the other hand, an abundance of the low-utility skeletal parts (i.e. “head-and-foot dominated pattern”, “Klasies pattern” or also called “reverse-utility curve pattern”) is typical of the faunal assemblages generated by carnivore and by extension is often interpreted as an evidence of hominin passive scavenging (Brain 1980, 1981; Vrba 1980; Binford 1978, 1981, 1984, 1985, 1991; Grayson 1989; Marean and Frey 1991; Stiner 1990, 1991a, b, 1994).

Scholarly opinions frequently differ, and always there has been intense debate regarding the exclusive use of skeletal part profiles to infer prehistoric human subsistence behaviour (Domínguez-Rodrigo 1999b; Stiner 2002; Pickering et al. 2003). Some zooarchaeologists consider skeletal part profiles to be ambiguous sources of data that cannot be used exclusively to discriminate the actions of the hominin from those of the carnivore. According to Lupo (2001), high-resolution behavioural inferences on prehistoric human based on the skeletal part profiles are only valid at sites with typical simple taphonomic and deposition histories. The survivorship of the skeletal parts post-discard is frequently biased by a number of destructive taphonomic processes including, carnivore ravaging, weathering, sediment compaction, rockfall (for the case of caves and rockshelters), and density-mediated attrition (Behrensmeyer 1978, 1991; Brain 1981; Klein and Cruz-Uribe 1984; Marean 1991; Marean and Spencer 1991; Marean et al. 1992; Lyman 1994; Blumenschine and Marean 1993; Lam et al. 1999). According to Capaldo (1995, 1998), carnivore ravaging alone can lead to a deletion of more than 95% of the axial elements. In order to clearly discriminate the actions of the hominin and carnivore, many zooarchaeologists frequently incorporate bone surface modifications data to bolster the inferences drawn from the skeletal part profiles.

4.4.5. Bone Surface Modifications

One of the best ways to reconstruct the prehistoric human subsistence behaviour is through rigorous study of bone surface modifications. As Pante and colleagues (2012:395), have recently summarized it “bone surface modifications are often the basis of interpretation of Stone Age archaeological bone assemblages”. Besides, for Domínguez-Rodrigo and colleagues (2014:32), “little can be interpreted on prehistoric human behaviour without the analysis of the bone surface modifications in the archaeological faunal assemblages”.

Over the past four decades studies of the bone surface modifications have played prominent role in the reconstructions of foraging ecology of the early hominins in the Plio-Pleistocene sites in East Africa (Bunn 1981, 1982, 1983; Bunn and Kroll 1986; Bunn and Ezzo 1993; Binford 1985, 1988; Blumenschine 1986a, b, 1988, 1995;

Blumenschine and Selvaggio 1988, 1991; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Domínguez-Rodrigo 1997a-c, 2002, 2009). They have been also widely used in resolving the hunting versus scavenging debate by the early hominins (Domínguez-Rodrigo and Barba 2005, 2006, 2007a-c; Domínguez-Rodrigo and Pickering 2003). Bone surface modifications have also frequently featured in the reconstructions of the MSA/MP hominin foraging economy and predatory behaviour (Klein and Cruz-Uribe 1984; Binford 1981, 1984, 1991; Chase 1983, 1988, 1989; Milo 1994, 1998; Grayson and Delpech 1994; Marean 1998; Marean and Kim 1998; Speth and Tchernov 1998, 2001, 2002; Assefa 2002, 2006; Stiner 2005; Yeshurun et al. 2007; Rabinovich et al. 2008; Thompson 2008, 2010; Thompson and Henshilwood 2011; Clark and Speth 2013).

Copious experimental and naturalistic studies of bone surface modifications conducted in East Africa have also shown that cut marks, percussion marks and tooth marks inflicted on long bone midshaft sections are the most informative to evaluate the order (sequence) of access to the carcasses by hominin and carnivore (Blumenschine 1986a, b, 1988, 1995; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Domínguez-Rodrigo 1997a-c; Domínguez-Rodrigo and Barba 2005, 2006, 2007a-c; Domínguez-Rodrigo et al. 2007a, 2014; Marean et al. 2002; Lupo and O'Connell 2002; Pante et al. 2012; Parkinson 2013; Gidna et al. 2014; Organista et al. 2016). Taphonomic studies of the Loiyangalani and Magubike MSA faunal assemblages indicate both hominin and carnivore were actively involved in the manipulation of bones while still in their nutritive state (see Tables 6.11-6.23 and 7.11-7.24 below). Consequently, the two faunal assemblages provide ideal case studies to evaluate the opposing hypotheses regarding the relative importance of hunting versus scavenging mode of meat acquisition during the MSA in Tanzania.

In order to discriminate with certainty the order (sequence) of access either to fully-fleshed or partially-fleshed carcasses by the MSA hominins and carnivores at Loiyangalani and Magubike, the percentages of cut marks, percussion marks, and tooth marks inflicted on long bone midshafts were also conjointly compared against several published datasets generated via experimental simulations and from the ethnoarchaeological studies of the Hadza in an uniformitarian manner (Gifford 1991; Lyman 1994; Blumenschine et al. 1994). The major strength of the experimental and ethnoarchaeological datasets compared lie in the fact that they robustly provide the inferential links between the observable present (known feeding sequence scenarios) and the inferred fossil faunal assemblage (unknown feeding sequence scenarios). Besides, they also permit to diagnose where the archaeological faunal assemblage (s) under study best fit (Marean et al. 2000; Lupo and O’Connell 2002; Domínguez-Rodrigo et al. 2014). Single-patterned models simulating hominin-only (HO) and carnivore-only (CO) foraging scenarios to fully-fleshed carcasses datasets were used in the comparisons (see Table 5.5). To get a finer resolution to the key question on “who was scavenging from whom” within the broader context of the manifestations of modern human behaviour debate, the results were also compared against the dual-patterned models simulating hominin-to-carnivore (H-C) and carnivore-to-hominin (C-H) foraging scenarios of the partially-fleshed carcasses i.e. defleshed and/or demarrowed bone fragments (Table 5.5).

Published experimental and ethnoarchaeological datasets have been applied on numerous Stone Age faunal assemblages among them the chief being the FLK 22

Zinjanthropus site (more commonly referred to as FLK 22 *Zinj* or just FLK *Zinj*) dated 1.75 mya at Olduvai Gorge, Tanzania (Blumenschine 1986a, b, 1995; Walker et al. 1991; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Oliver 1994; Monahan 1996; Domínguez-Rodrigo 1997a-c; Domínguez-Rodrigo and Barba 2005, 2006, 2007a-c; Domínguez-Rodrigo et al. 2007a, 2014; Egeland 2007; Ferraro 2007; Pobiner 2007; Pante et al. 2012; Parkinson 2013). The FLK 22 *Zinj* faunal assemblage is the well known largest and well-preserved early Stone Age faunal assemblage with both abundant hominin and carnivore bone surface modifications (Leakey 1971; Isaac 1978; Bunn 1981, 1982, 1983; Potts and Shipman 1991; Potts 1988). More than 60,000 bone fragments have been recovered from the site of which has produced nearly 4,000 specimens identified to skeletal parts. The site is also best known for the discovery of a nearly complete skull of the australopithecine (OH-05). The Loiyangalani and Magubike MSA faunal assemblages considered for this study, like FLK 22 *Zinj* also benefit from integrating the available published experimental and ethnoarchaeological datasets (see Tables 5.5, 6.13, 6.20, 7.13, 7.21, 8.4; Figures 6.14, 6.18, 7.10 and 7.13 below).

In order to expand the interpretive framework, the three classes of bone surface modifications in the Loiyangalani and Magubike faunal assemblages were also compared to the new estimates recently reported by Domínguez-Rodrigo and Barba (2006, 2007a-c), from the meticulous reanalysis of the FLK 22 *Zinj* faunal assemblage (Table 8.4). The new estimates of cut marks and percussion marks have reinstated the classical conclusion initially proposed by Mary D. Leakey (Leakey 1971) and later augmented by Henry T. Bunn and colleagues using stone tool cut marks and percussion marks evidence (Bunn 1981, 1982, 1996, 2001, 2007; Bunn and Kroll 1986, 1988; Bunn and Ezzo 1993), that the early hominins were aggressive hunters. On the other hand, new estimates of tooth marks have relegated the carnivores to the role of passive scavengers of the defleshed and/or demarrowed bone fragments at the site.

The use of the Stone Age faunal assemblage for a comparative purpose is based on a number of reasons. Many of the experimental and ethnoarchaeological datasets currently available and commonly used in the debate in support of either hunting or scavenging mode of meat acquisition were mostly developed to interpret the Oldowan hominin predatory behaviour and to attend the gaps in the early interpretations for the site. For more than five decades, the FLK 22 *Zinj* faunal assemblage also has been the subject of heated debates on its formation than any other site of comparable antiquity. Perhaps more important is the fact that compelling and robust evidence now exists for the faunal assemblage from the numerous meticulous re-analyses that have unequivocally implicated the early hominins as effective hunters (see Oliver 1994, 2015; Monahan 1996; Domínguez-Rodrigo 1997a-c; Domínguez-Rodrigo and Barba 2006, 2007a-c). Besides, many palaeontologists consider FLK 22 *Zinj* site in Tanzania along with Koobi Fora dated approximately 1.5 mya in Kenya as the standard archaeological sites and reference points to understand the remote page in the evolutional history of the *Homo* lineage and which every other Stone Age site at least should be compared (Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008). Both sites have been also interpreted as central places whereby a large number of carcass parts were repetitively transported to by the early hominins and shared by other members of the group (Leakey 1971; Isaac 1971, 1978; Bunn 1982, 1994; Pobiner 2007). Bone surface modification estimates from ST Site Complex also reported by Domínguez-Rodrigo and colleagues (2002, 2009) are also used for comparative purpose (see Table 8.4). The ST Site Complex from Peninj in northern Tanzania is another archaeological faunal assemblage with robust evidence that the hominin had primary (early) and carnivore secondary (late) access to the carcasses.

4.5. Interpretive Framework and Predictions

The following archaeologically testable analytical aspects and predictions will be used to test the two major hypotheses regarding the MSA hominins foraging economy that 1) MSA hominins were ineffective hunters until at least 50 kya and that 2) they were passive scavengers of the carnivore defleshed carcasses only to enjoy scraps of meat and bone marrow.

1. Diet breadth spectrum reflected through the following:
    a. Abundance indices (ratio of large versus small-sized animals) in the faunal assemblages;
    b. Prey diversity (richness and evenness) as reflected in the faunal assemblages;
    c. Diet breadth expansion including inclusions of the small-sized ungulates, aquatic and avian resources in the diet;
    d. The ratio of the high utility to low utility skeletal parts and processing intensity of the carcasses including routine cracking open of the high marrow-bearing long bones and those with small marrow stores in the faunal assemblages.
2. Mortality profile (ratio of prime-adults versus juveniles and old individuals) in the faunal assemblages;

3. The relative percentages of cut marks, percussion marks and tooth marks on long bone midshaft fragments in the archaeological faunal assemblages as compared to the published experimental and ethnoarchaeological datasets; and
4. Evidence of intentional burnt bones.

In an attempt to evaluate the hypotheses proposed by Klein and Binford regarding the Middle Stone Age hominin foraging ecology the following predictions were also made:

i. If the MSA hominins at Loiyangalani and Magubike were ineffective hunters and had no the ability to hunt the large-sized, dangerous animals and prime-adults, then taphonomical and zooarchaeological signatures corresponding to ineffective hunting-foraging niche should be prevalent in both archaeological faunal assemblages. Ideally, this would include a mortality profile dominated by the juveniles and old animals, low proportion of the large-sized/high-ranked prey and absence of dangerous animals; and

ii. If the MSA hominins at Loiyangalani and Magubike were passive scavengers who commonly had secondary (late) access to the carcasses defleshed by carnivores, then distinctive taphonomical and zooarchaeological signatures linked to the scavenging foraging niche should be prevalent in both archaeological faunal assemblages. Ideally, would include skeletal part representation dominated by the low-utility elements and relative higher percentages of tooth marks over cut marks on the axial bones and long bone midshafts as compared to the published experimental and ethnoarchaeological samples as well to the meticulously studied referential archaeological faunal assemblages; and

iii. Should the two assumptions above fail to match the patterns in the Loiyangalani and Magubike MSA faunal assemblages, the present study will have two implications. First, it will implicate MSA hominins were adept hunters and secondly were not passive scavengers of the nutritionally depleted carcasses abandoned by carnivores.

All other things being equal and in order to permit some direct comparability of the samples and subsamples, this study assumes roughly similar costs of prey acquisition, handling and post encounter return rates by aggregating the identified animals in the archaeological faunal assemblages into animal size groups following Brain (1981) and Bunn (1982) guidelines including the small (size 1-2) and large-sized (size 3-4) animals (Table 4.1). As predicted by the diet breadth model above, it is predicated, MSA hominins habitually foraged the prey and their carcass resources (meat, marrow and grease) optimally and always selected the high-yield/higher ranked resources first (large-sized animals, prime-adults and preferentially transported the high-utility skeletal parts), later sequentially in order of decreasing profitability selected the low-yield/low-ranked resources (small-sized animals, juveniles and the low-utility skeletal parts) to maximize the caloric returns of energy spent hunting them. Ideally, the large-sized (size 3-4) animals are also expected to preserve relatively higher percentages of cut marks and percussion marks on their long bone midshaft sections that also will suggest MSA hominins had primary (early) access to their fully-fleshed carcasses. The axial elements and the upper appendicular limb bones (ULB and ILB) midshaft sections that commonly retain no scraps of meat post-carnivore consumptions are also expected to bear high percentages of cut marks as opposed to the tooth marks. On the other hand, deviations of the findings and predictions set forth above (featuring an opposite pattern) in the Loiyangalani and Magubike faunal assemblages will suggest MSA hominins scavenged carnivore ravaged carcasses and will implicate them as ineffective hunters. The diet breadth and bone surface modification interpretative frameworks underscored above permitted to evaluate the degree to which the Loiyangalani and Magubike MSA faunal assemblages match or fail to match.

CHAPTER 5

RESEARCH METHODS AND ANALYTICAL PROCEDURES

5.1. Introduction

This chapter describes the research methods used in the recovery and analysis of the Loiyangalani and Magubike MSA faunal assemblages. Since the assemblages considered for this study come from sites of markedly different nature, deliberate efforts were made to ensure a uniformity of the selected analytical and recording protocols. This facilitated multivariate inter-site taphonomic and zooarchaeological analyses and comparisons. The chapter first outlines the excavation methods, followed by cleaning protocol used to prepare the faunal remains as well as descriptions of the analytical methods, recording, and quantifications of the taxonomic abundance.

5.2. Excavations and Data Collection Methods

The present study involved archaeological excavations with hand trowels and subsequent laboratory analysis of the faunal assemblages. Undergraduate archaeology students from the University of Dar es Salaam, Tanzania aided in the excavations at Loiyangalani between 2000 and 2005 and Magubike rockshelter in 2012 as part of their practical training (see Figure 5.1). The practice has a considerable antiquity and date back since the inception of pedagogical archaeology in the country in the mid-1980s (Schmitt 2005; Mehari et al. 2014). Students each year take part in the archaeological excavations directed by local archaeologists as well as those co-directed with foreigners conducted in different regions of the country (Figure 2.1). The Tanzanian government paid the students up-keeping allowances in the field and the number of students varied from season to season. As an undergraduate and postgraduate archaeology major student at the University of Dar es Salaam between 2001 and 2007, I participated fully in all the excavation seasons at the Loiyangalani site along with the project coordinators Professors John F.R. Bower and Audax Z.P. Mabulla.

As will be emphasized below, the test pits at each site were assigned identification numbers and some varied in size and maximum depth (Figures 5.2 and 5.3). Using 1 x 1 m squares excavations were mainly carried out. In order to maximize recovery of the specimens and to counter long bone midshaft fragments bias in favour of the large-sized and more diagnostic skeletal parts often reported from the old excavations, all excavated soil sediments were carefully dry-sieved through 5 mm meshes, then hand-picked for artefacts (Payne 1972; Turner 1989; Marean and Kim 1998; Marean et al. 2000, 2004). Regardless of size, potential identifiability, or state of preservation, all faunal specimens were collected including very small bones of < 1 cm in maximum length (Tables 8.1 and 8.2). This also permitted full recovery of different classes of archaeological materials including lithics, beads, and faunal remains (Figures 3.3 and 3.4).

As digging progressed, changes in soil texture and colors, as well as additional contextual information and stratigraphic data were recorded. Photographs and stratigraphic wall profiles were also drawn upon completion of levels (Figures 3.5 and 3.8). Recovered artefacts were sorted on-site and bagged in separate small finds-bags that were also labeled with the archaeological context information. Similarly, tags containing the same information were also kept inside each bag. Faunal remains were recovered throughout the archaeological sequences and mostly comprised of fragmentary skeletal parts. No skeletal parts articulated in their anatomical positions or with their epiphyseal portions still attached via matrices were recovered from either site.

Figure 5.1. University of Dar es Salaam Students at Magubike Rockshelter in 2012.

5.3. Excavations between 2003 and 2005 at Loiyangalani

The archaeological excavations between 2003 and 2005 at the Loiyangalani site were mainly focused on the recovery of additional artefacts (lithics, beads, ochre and faunal remains) and radiometrically dateable materials especially teeth for Electron Spin Resonance (ESR) dating. This was mainly intended to resolve the ambiguity in the chronology of Unit 1, which has yielded thousands of fossilized faunal remains in clear association with the MSA tools (Thompson et al. 2004:5; Bower and Mabulla 2013:17).

A total of 21 test pits were opened at the site, some were later joined into block excavations broadly envisioned to demonstrate evidence of hominin activities across the paleolandscape (Figure 5.2). The 2003 season test pits were numbered 13 through 18, which is a continuation from the previous seasons. The Serengeti Genesis Project introduced a new system of numbering the test pits starting in 2004. The new test pits were given alphabetic letters and numerals as N94E69, N94E70, N94E71, N94E72, N94E73, N94E74, and N95E70 for the 2004 season. For the 2005 field season the test pits were N64E72, N95E88, N95E94, N98E72, N96E115, N100E115, N130E72 and N160E72 (Figure 5.2). The alphabetic letters (N & E) stand for the North and East cardinal directions, and the numbers refer to a number of meters away from a permanently established datum point at the site designated as N100E100. The majority of the test pits were excavated to a depth of 2 m, and a few of them to 2.5 m below the modern surface where a sterile layer was hit. A total of 27.75 m^2 of sediments (including both LSA and MSA deposits) was excavated between 2003 and 2005. A total of 1,152 faunal remains were recovered in 2003 and 1,423 during the 2004 season. Of note, the 2005 season was less productive in comparison to the other seasons. Fewer than 700 faunal specimens were recovered from a total of the eight test pits opened for the season (see Table 5.1).

Excavations at the Loiyangalani site were mainly conducted in 1 x 1 m squares with each test pit excavated by arbitrary levels of 5 cm spits and sediments dry-sieved through 5 mm meshes that resulted in the recovery of additional small specimens including the ostrich eggshell beads (Figures 3.3 and 3.4). All finds were also individually piece-plotted in 3D and later integrated into a 3D GIS program in the field that permitted both an initial intra-site analysis of the artefacts recovered and their distribution (horizontal and vertical) and preliminary interpretation of the site formation process (Bower and Mabulla 2013). The overall stratigraphic and sedimentation contexts from the three seasons at the site is essentially similar (see Figure 3.5).

Faunal remains at Loiyangalani were retrieved throughout the archaeological sequence with the majority coming from the MSA deposits that may also suggest relatively prolonged hominin occupation at the site. However, some test pits yielded a relatively higher number of faunal remains than others (see Table 5.1 below for the details). Test pit 18, N94E71, N94E72, and N98E72 produced the highest number of specimens per unit volume of sediments unearthed. From the middle of the archaeological sequence, recovered specimens were generally high in frequency especially from the levels between 100 and 110 cm and notably relatively fewer from 140 cm down the archaeological sequence.

Archaeological excavations at Loiyangalani have exposed two discrete sedimentary deposits composed of the cultural materials mainly from the MSA deposits below and the LSA at the top (Figure 3.5). The LSA cultural stratum is about 0.9 m thick. Lithological properties of the sediments suggest it represents a poorly drained distal floodplain environment, probably a small ephemeral pond as indicated by both texture and color of the sediments (Thompson et al. 2004). Unfortunately, the LSA deposits have yielded relatively low proportions of microlithic stone chips and faunal remains per unit volume of sediments excavated (*n*=333, NISP=194 from the three seasons). Detailed results of the LSA faunal assemblage are not included in this work for the reason provided below. The age of the LSA deposits at the site is not precisely known, but LSA deposits in East Africa can be as old as 40 kya (Ambrose 1998).

The MSA stratum is about 1.6 m thick for some test pits. On the basis of sediment texture, particle size, and sorting, the MSA stratum at the site is interpreted as the product of a proximal overbank alluvium from an area next to a river channel (Thompson et al. 2004). According to Thompson (2004:4), 3D GIS analyses of the archaeological materials unearthed, exhibit a clear break of the MSA stratum suggesting Unit 1 may consist of two discrete occupations of MSA hominin groups (Figure 3.5). Faunal remains recovered from the MSA deposits consisted of 3,190 specimens mostly fragmentary are subject to this study (Tables 5.1 and 8.2). Overall mammal bones numerically dominate the faunal sample. The next most abundant are fish that are often rarely recovered from the MSA archaeological sites (Tables 6.8, 6.9; Figures 6.4 and 6.5). Other finds recovered but in limited number includes well-preserved tortoise carapace fragments as well as crocodile, rodent, and bird remains (Tables 5.1, 6.8 and 6.9). An Optically Stimulated Luminescence (OSL) date for the MSA deposits at the site is 65 kya which fall within the accepted chronological range of the MSA deposits in sub-Saharan Africa (Deino and McBrearty 2002; Feathers and Fusch 2005; Tryon and McBrearty 2006; Sahle et al. 2014).

For a decade, the Loiyangalani archaeological assemblage has been curated at the University of Dar es Salaam, Tanzania under the custody of Professor Audax Z.P. Mabulla. It remained unstudied and was never fully reported before being officially provided for this study in December 2012 by Professor John F.R. Bower, this was after his retirement from active archaeological research. It is important to emphasize that full detailed field notes and stratigraphic drawings were not made available at the official handover.

Upon reception of the Loiyangalani archaeological assemblage, all the large bags containing the faunal remains and lithics were thoroughly inspected, and conditions of the specimens were also evaluated. The artefacts were still well organized by separate excavation seasons, test pits, levels and by cultural layers (MSA or LSA). The individually piece-plotted finds were also still packed in small bags, which were also labeled on top with all relevant archaeological contextual information including the season of excavation, pit test number, and depth below the modern surface. Tags containing the same information were also still kept inside. The integrity of the Loiyangalani faunal assemblage was good, and no post-excavation loss of specimens was noted. In few cases, it was observed a few specimens were mixed in the lithic bags and vice versa, and these were later re-bagged into appropriate bags. A similar case of artefacts mixing also was noted for the Magubike faunal assemblage of which the preliminary artefacts sorting, washing and re-bagging was done in Iringa town with the help of students.

My initial personal goal was mainly to study the Loiyangalani faunal assemblage. My participation in archaeological excavations at Magubike rockshelter in 2012 along with my supervisor Professor Pamela R. Willoughby increased my familiarity with the site, and I later changed my mind to include the relatively large MSA faunal assemblage for my doctoral study (Tables 5.2 and 8.2).

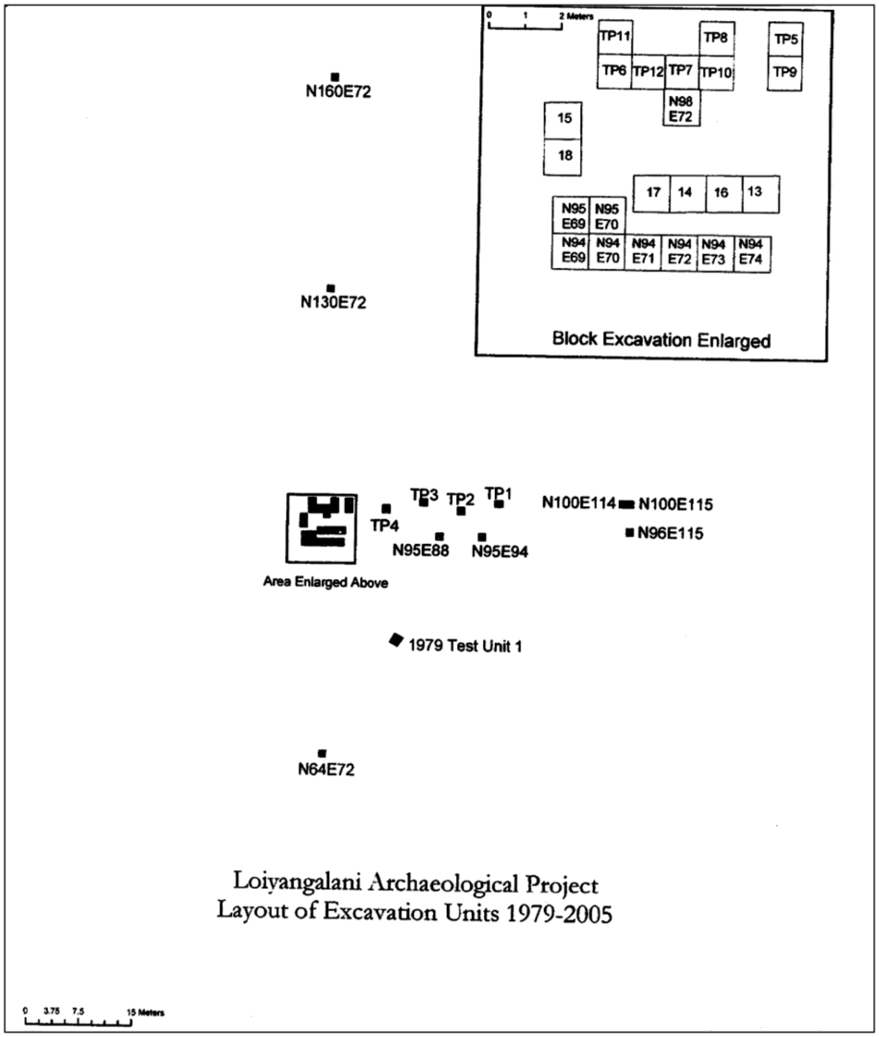


Figure 5.2. Test Pits Layout at the Loiyangalani Open-Air Site (Adapted from Bower et al. 2012).

Table 5.1. Faunal Remains from the MSA Deposits at Loiyangalani.

Season	Test Pit	Mammal	Fish	Tortoise	Crocodile	Bird	Total
2003	13	68	15	2	1	-	86
	14	96	22	3	-	-	121
	15	154	55	5	-	-	214
	16	152	25	6	-	-	183
	17	185	42	-	4	-	231
	18	214	90	12	1	-	317
2004	N94E69	100	18	2	18	-	138
	N94E70	139	14	1	-	-	154
	N94E71	207	45	-	2	-	254
	N94E72	259	59	-	3	-	322
	N94E73	132	15	-	-	-	150
	N94E74	204	24	3	2	-	233
	N95E70	163	5	2	2	-	172
2005	N95E88	36	4	-	-	1	41
	N95E94	12	2	-	-	-	14
	N98E72	215	98	11	2	-	326
	N64E72	46	4	5	-	-	55
	N96E115	67	9	3	-	-	80
	N100E115	42	4	1	-	-	47
	N130E72	15	7	-	-	-	22
	N160E72	20	10	-	-	-	30
	Total	2,526	567	60	36	1	3,190

5.4. Excavations in 2012 at Magubike Rockshelter

The immediate primary objective of the 2012 excavations at Magubike rockshelter were to collect more lithics, beads, animal bones, hominin remains and to retrieve samples for radiocarbon, Optically Stimulated Luminescence (OSL) and Electron Spin Resonance (ESR) dating. This was done to refine the chronology of the deposits under the overhang and to better understand the site formation processes (Willoughby 2012a; Miller and Willoughby 2014; Spiller et al. 2014; Feathers 2016; Werner and Willoughby 2017).

Excavations in 2012 mainly concentrated in the central part of the rockshelter where the MSA faunal remains and lithics were directly associated. A total of 7 test pits (6 through 12) were opened using 1 x 1 m squares and excavated using 10 cm arbitrary levels. The new test pits varied in size and depth with test pit 6, 7, 8 and 9 being 1 x 1 m squares whereas test pit 10 and 11 were comparatively smaller and measured 0.35 x 1 m (see Figure 5.3 below). This was because test pit 10 and 11 intersected the original test pits (test pit 2 and 3) from the 2006 test pits. Accordingly, test pit 12 measured 1 x 1.35 m as it was dug up to the edge of the 2006 units. Excavated sediments were dry-sieved through 5 mm meshes. A total of 9.63 m^2 of sediments (including both Iron Age and Middle Stone Age deposits) were excavated to a depth of 2 m below the modern surface. Except for test pit 6, which was suspended at 50 cm after being obstructed by a large boulder so exclusively yielded Iron Age materials, the rest were all excavated to the bedrock (Figure 3.8).

The majority of the test pits were rich in faunal remains, and test pit 9 and 12 yielded the highest numbers of specimens (see Table 5.2 for the details). Across the test pits opened for the season, the levels between 100 and 110 cm and between 140 and 150 cm were notably the most productive, which may suggest a high intensity of hominin occupation of the rockshelter. The levels that yielded relatively fewer specimens may apparently suggest low intensity of hominin occupation conceivably in different seasons. A cursory spatial distribution analysis of the specimens unearthed reveals the majority come from the western part of the rockshelter especially from test pit 12. It is possible this could have been a dumping area where the bone fragments consumed by hominin and other generated food wastes were tossed. The eastern part potentially was the main center of the anthropogenic activities (Figure 5.3).

On the basis of the artefacts composition, techno-typological attributes of the lithic assemblage as well as chronometric dates, two distinct archaeological strata are identified inside the rockshelter: the Iron Age (IA) at the top and the MSA below it (Figure 3.8). The Later Stone Age deposits appears to be missing in this part of the rockshelter conceivably reminiscent the site went deserted for some period for the reasons not yet precisely known. Werner and Willoughby (2017) have recently attributed the absence of the LSA materials inside the ain part of the rockshelter to two possible explanations: it is possible that the LSA materials are mixed with the Iron Age materials and/or conceivably they could have been washed out of the rockshelter by the water action. However, previous studies at the site have also suggested a possible mix of the LSA and MSA materials (see Biitner et al. 2007:64; Alexander 2010:60-61; Willoughby 2012b:113). A full sequence of the archaeological deposits ranging from the MSA below through the Iron Age/historical period at the top is recorded from test pit 4 and 5 just a few meters outside the rockshelter (Figure 5.3).

The uppermost levels (from 0-50 cm below the surface) mainly contain Iron Age (IA) deposits (Figure 3.8). Characteristic artefacts include a few iron implements, bits of tuyeres, iron slag, decorated and undecorated potsherd fragments, beads, charcoal, land snails, microlithic artefacts and a few faunal remains per unit volume of sediments unearthed (Willoughby 2012a). The faunal remains include both domesticated and wild animal species. Taphonomically, the faunal specimens from the IA deposits are less affected by concretions and numerous display traces of burning at different burning stages (*sensu* Stiner et al. 1995; Stiner 2005).

Half a dozen of isolated fossilized hominin deciduous teeth all without their roots were also recovered in 2012 from the IA deposits more precisely from test pit 12 near a furnace (probably an iron bloom refining furnace given its relative size and a place where constructed). The association of the hominin remains and the furnace is not immediately clear whether it is an intentional burial or it can be directly associated with the traditional iron smelting activities. Elsewhere in Tanzania, traditional iron smelters are reported to have intentionally tossed animal bones (not of humans) typically rich in calcium into furnaces during the iron smelting conceivably to act as a catalyst to speed up the process. New radiocarbon dates on ostrich eggshell fragment samples from the 2012 season have yielded a date of 4,477 ± 32 (uncalibrated BP) for the IA deposits (Miller and Willoughby 2014). Besides, Optically Stimulated Luminescence (OSL) results for the IA deposits also fall within the known Iron Age time range in East Africa (see Feathers 2016; Werner and Willoughby 2017 for the details).

MSA deposits extend from around 50 cm and go down up to 200 cm below the modern surface where the sediments eventually become sterile as the bedrock is approached (Figure 3.8). An absence of the iron slag, pottery fragments and remains of domesticated animals signal the beginning of the MSA deposits within the rockshelter. The MSA deposits include thousands of lithics, animal bones, land snail shells and a few ostrich eggshell beads (Willoughby 2012a; Miller and Willoughby 2014). A total of 6,567 faunal specimens were unearthed in 2012 from the MSA deposits are subject to this study (Tables 5.2 and 8.2). The new MSA faunal assemblage is the largest so far recovered from the southern highlands of Tanzania, and it is likely that further excavations at the site will yield more specimens. There are plans to expand the excavations inside and outside the rockshelter in future fieldworks (Willoughby per.com 2017).

Most importantly, MSA deposits at Magubike has also yielded new fossilized isolated remains of *Homo sapiens* (isolated incisors and molars) in association with stone tools and animal bones from test pit 9 and 10 at a depth of between 140 and 150 cm below the modern surface (Willoughby 2012a). Test pits number 9 and 10 are located very close to test pit 3, which also yielded 6 isolated hominin teeth in 2006. The proximity of the test pits and the relatively the same stratigraphic depth of their recovery connote might have come from the same individual. The new radiocarbon dates on two ostrich eggshell beads from the MSA deposits are close to or older than 50 kya (Miller and Willoughby 2014). Optimally Simulated Luminescence (OSL) dating has yielded age estimate of 64.8 ± 9.4 (Lab sample UW2857), which confirms a greater antiquity for the MSA deposits at the site (Feathers 2016). Besides, Electron Spin Resonance (ESR) dates on animal teeth, and *Achatina* shells suggest the MSA deposits could range between 250 and 50 kya (Grine 2016; Werner and Willoughby 2017) and in conjunction with the radiocarbon dating appear to work perfectly at the site. Nevertheless, the chronometric dates by different dating techniques at the site converge to indicate that the MSA deposits are older than 50 kya (see Werner and Willoughby 2017 for the details).

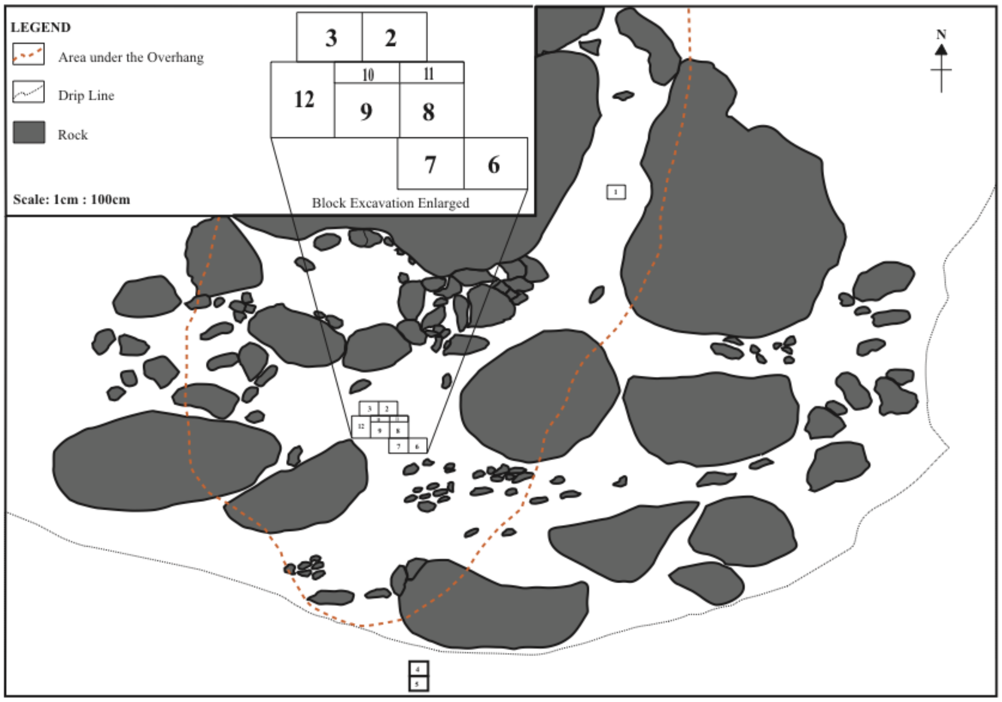


Figure 5.3. Test Pits Layout at Magubike Rockshelter.

Table 5.2. Faunal Remains from the MSA Deposits at Magubike.

Test Pit	Mammal	Bird	Total
7	364	4	368
8	773	4	777
9	1,765	6	1,771
10	866	12	878
11	345	4	349
12	2,417	7	2,424
Total	6,530	37	6,567

5.5. Middle Stone Age Faunal Assemblages Analyzed for this Study

New archaeological excavations at the Loiyangalani site and Magubike rockshelter have generated new large MSA faunal assemblages consisting of a wide diversity of taxa including ungulates, hominin, fish, rodents, carnivores, birds, and reptiles in clear association with the dense concentration of lithic assemblages (Tables

5.1, 5.2, 6.8, 6.9, 7.8, 7.9 and 8.2). Together, these permit to make a robust interpretation on a broad array of issues regarding the occupants of the sites. The MSA deposits appear between 90 and 250 cm and between 50 and 200 cm below the modern surface at Loiyangalani and Magubike respectively (Table 5.3). However, it is also important to emphasize, the archaeological deposits above the MSA deposits at both sites contrasted sharply and precluded potential diachronic study of the faunal assemblages into the LSA and IA respectively as a result were omitted for this study. However, the faunal assemblages were also subjected to detailed taphonomic and zooarchaeological analyses and are discussed in future publications. Large land snail shell debris (complete and fragments) that may have been collected as supplement food as they are easy to capture (Bird and Bliege-Bird 2000; Lubell 2004), also make the bulk of the faunal remains recovered in 2012 at Magubike rockshelter (Willoughby 2012a). These were also excluded, as I do not have the training necessary with which to analyze them. The eggshell beads and fragments from Magubike rockshelter are still under study by Jennifer M. Miller and those from the Loiyangalani site were also omitted. The isolated *Homo sapiens* remains from the IA, and MSA deposits at Magubike rockshelter are also currently under study by Professor Cris B. Stringer and Professor Pamela R. Willoughby. Therefore, could not be included in the analysis.

The faunal assemblage analyzed for this study derive exclusively from the MSA deposits for the reasons explained above and belonged to the multidisciplinary and large-scale archaeological projects namely the Serengeti Genesis (SEGEN) and the Iringa Archaeological Project (IRAP). This study is also part of the contributions of the two ongoing projects in Tanzania. The total sample from the MSA deposits analyzed for this study consisted of 9,757 specimens of which 5,506 (56.43%) mostly fragments were identified anatomically and taxonomically to skeletal parts from approximately 16 m^2 of MSA deposits. Earlier studies at both sites have studied comparatively smaller faunal assemblages (see Collins 2009; Collins and Willoughby 2010; Gifford-Gonzalez 1985; Marean 1996; Thompson et al. 2004; Thompson 2005), which provided an invaluable starting point for this study. Results for this study are presented in details in Chapter 6 and 7 for Loiyangalani and Magubike respectively, and subsequent discussions of the results are presented in Chapter 8.

Table 5.3. Archaeological Phases at Loiyangalani and Magubike.

Site	IA	LSA	MSA
Loiyangalani	NA	20-90 cm	90 -250 cm
Magubike	0-50 cm	50 – 70 (tp 1)*	60 – 200 cm
		0-90 cm**	90-250 cm**

*A possible mixed LSA/MSA level
** Test pit 4 and 5 are from outside the rockshelter

5.6. Cleaning of the Faunal Remains

The faunal specimens from Magubike rockshelter were initially gently washed in Iringa town, Tanzania with tap water to reduce the dust, and then were inventoried, re-bagged and later temporarily shipped to the University of Alberta, Canada on loan from the Tanzanian Antiquities Division. The faunal assemblages from Loiyangalani and Magubike were thoroughly cleaned between January and May 2013 (Figures 5.4 and 5.5).

The majority of specimens from Magubike had massive traces of concretions on their cortical surfaces of different degrees of coverage potentially resulting from the constant dampness of the sediments under the overhang (Figures 3.7, 5.4 and 5.5). To remove the adhering sediments necessitated an application of an effective cleaning procedure. Specimens were immersed in a dilute acetic acid (5%) for between 1 and 3 hours to remove the dirty and concretion matrices that obscured the cortical surfaces. This protocol has proved to be productive in many Stone Age faunal assemblages elsewhere (see Assefa 2002; Bar-Oz 2004; Prendergast 2008; Collins 2009; Rabinovich and Hovers 2004). The procedure usually limits damages as the dirty, and concretions often dissolve in the acid and consequently improve the detection of discrete taphonomic signatures on the bone cortical surfaces (e.g. cut marks, tooth marks, trample marks and burning).

All specimens were later washed in clean tap water to remove the salts and were then left to air-dry slowly (Figure 5.5). The only notable problems encountered with this approach were time and number of containers needed to clean the individually piece-plotted and separately bagged specimens from the Loiyangalani site. To get around the challenges, relatively cheaper acetic acid and containers of various smaller sizes were bought from dollar shops in Edmonton city. In general, the cleaning protocol was comparatively less fruitful for the Magubike specimens compared to those from Loiyangalani, which is an open-air site (see Figures 6.4, 6.5, 6.15, 6.16 and 6.19). Some specimens in the Magubike sample retained a thin coating of concretions after the cleaning process (see Figures 7.4 and 7.11). Mary E. Prendergast has also reported a similar problem at Sonai rockshelter from northern Tanzania (Prendergast 2008:238-239), as have Rivka Rabinovich and Erella Hovers for the Amud Cave faunal assemblage in Israel (Rabinovich and Hovers 2004:290).

Figure 5.4. Faunal Specimens from Magubike Rockshelter.

Figure 5.5. Cleaning Faunal Specimens at University of Alberta.

5.7. Analytical Methods and Recording Procedures

This study primarily involved taphonomic and zooarchaeological studies of the faunal assemblages. Both approaches are widely used tools in the reconstructions of prehistoric human subsistence and predatory behaviour (Klein and Cruz-Uribe 1984; Grayson 1984; Lyman 1994, 2008; Reitz and Wing 2008). Taphonomy is defined as the study of all the peri-and-post-mortem processes that modify the organic remains as they move from the biosphere (the living context) to the lithosphere (the geological context) (Efremov 1940). Taphonomic studies also deal with the reconstructions of the complex site formation processes that create faunal assemblages in paleontological and archaeological sites (Behrensmeyer and Hill 1980; Behrensmeyer 1991; Brain 1981; Shipman 1981). On the other hand, zooarchaeology is the study and interpretation of the faunal remains often recovered from these sites. Some researchers also refer to it as archaeozoology, ethnozoology, and osteoarchaeology (Reitz and Wing 2008). It is fundamentally an interdisciplinary discipline in nature and significantly overlaps with other disciplines such as anthropology, archaeology, ecology, biology, geology, ethnography, zoology, and palaeontology. Besides, zooarchaeology is a wide-open field and applicable across an unlimited range of the archaeological periods ranging from the Early Stone Age to historical times.

From the early 20th C, analyses of the faunal assemblages from paleontological and archaeological sites were frequently limited to the identification of species by zoologists who produced species lists that were mainly appended to sites reports and monographs (Reitz and Wing 2008). Later, archaeologists added descriptions on age, sex and relative abundance indices of species (White 1952, 1953; Binford 1979, 1981).

Advances in zooarchaeological studies also focus on how the animal prey became incorporated into the hominin diet spectrum (Klein and Cruz-Uribe 1984; Grayson 1984; Nitecki and Nitecki 1987; Lyman 1994; Stanford and Bunn 2001; Ungar 2007; Reitz and Wing 2008). New forms of analyses that include stable isotopes and ancient DNA are also currently one of the well-established domains of research in zooarchaeology (Hublin and Richards 2009).

5.7.1. Taxonomic Identification and Quantification

The Loiyangalani and Magubike MSA faunal assemblages were subjected to standard taphonomic and zooarchaeological analyses detailed below which took place at the University of Dar es Salaam, Tanzania. The analysis entailed identification of specimens to skeletal parts and quantification of the taxonomic abundances (see Tables 6.3-6.10 and 7.3-7.10). The analysis also involved evaluation of the state of preservation, weathering, surface modifications and mode of fragmentation of the bones (Tables 6.1, 6.2, 6.11-6.23 and 7.1, 7.2, 7.11-7.24)

Specimens were initially sorted into vertebrate classes: mammals, fish, birds, and reptiles (in this case tortoise and crocodile remains). Stone Age faunal assemblages frequently contain fragmented specimens (Brain 1981). Accordingly, specimens of different sizes characterize the studied samples as graphically shown in Figures 6.1, 6.2 and 7.1 and 7.2 below. Each specimen was recorded either as a complete or a fragment. Identified skeletal parts were also coded according to the fraction of completeness (i.e. remaining percentage of a whole specimen). A maximum length of each specimen (both identifiable and unidentifiable) was also measured to the nearest millimeter using a digital calliper to provide an estimate of the intensity of fragmentation of the studied samples. Maximum lengths of the specimens were later classified into designated metric bone size classes such as < 10 cm, 1-2 cm, 2-3 cm, 3-4 cm, 4-5 cm, 4-5 cm, 5-6 cm, 6-7 cm, 6-7 cm and so forth (see Figures 6.1, 6.2, 7.1 and 7.2). This exercise also permitted to determine whether MSA hominin employed methodological procedure during bone marrow extraction (Brain 1981; Bar-Oz 2004). According to Enloe (1993), mass processing of long bones for marrow extraction by hominin often results in almost the same average lengths.

Specimens were identified to the most discrete taxonomic level possible (e.g. a humerus, femur) and where possible, were identified to species level. Due to the highly comminuted nature of the faunal assemblages, only a few diagnostic specimens using Rikki Walker's (1985) guidebook and comparative skeletal reference collection permitted their identification to general taxa level e.g. bovid, equid, hare, rodent, fish, tortoise, bird, hyena and crocodile (Tables 6.8, 6.9, 7.8 and 7.9). Rigorous effort was also devoted to identify as many as possible long bone midshaft fragments mostly by using element specific morphological features including anatomical landmarks (e.g. foramina, muscle attachments), shaft cortical thickness, cross-sectional geometry and properties of the medullary cavity as outlined in Barba and Domínguez-Rodrigo (2005) and Pickering and Egeland (2006). The exercise permitted numerous long bone midshaft fragments that usually preserve bone surface modifications to be identified to skeletal parts (Marean and Kim 1998; Marean et al. 2000, 2004). Each identified long bone fragment was also assigned to one of the three portions i.e. proximal-end, midshaft, and distal-end. Paired skeletal parts were additionally coded for symmetry. Unfortunately, due to the overall comminuted nature of both faunal assemblages siding also was only achieved for a few specimens (Tables 6.3-6.5 and 7.3-7.5).

Finer taxonomic identification of the specimens to skeletal parts was mainly achieved through the use of comparative osteological reference collections of vertebrate skeletons held in the National Museum of Tanzania in Dar es Salaam and Sokoine University in Morogoro, Tanzania. Both have laboratories with comparative collections of some Tanzanian wildlife and modern domesticated species. Manuals by Schmid (1972), Hillson (1999, 2005), Cohen and Serjeantson (1996), and specifically for the East African mammals by Rikki Walker (1985) were also consulted. In this study, over 50% of the total specimens studied, mainly fragments were both anatomically and taxonomically identified to skeletal parts (Table 8.2).

Specimens that lacked diagnostic features to be identified to skeletal parts were categorized as unidentified (Table 8.2). These were later assigned to broader anatomical fragment groups including the cranial fragments, tooth fragments, vertebrate fragments, rib fragments, long bone fragments, bone flakes, and scraps. Metric analyses of the unidentifiable specimens exhibited a propensity of specimens measuring < 1 cm in maximum length. Of note, all unidentified specimens were entirely omitted from the quantification of the taxonomic abundance to avoid potential severe aggregation errors, which can lead to spurious comparisons and eventually eschewed interpretation on the prehistoric human behaviour. Nevertheless, to gauge an overall taphonomic profile of the faunal assemblages considered for this study, they were analyzed for the state of preservation, bone weathering, and surface modifications (see Tables 6.11, 6.18, 7.11, 7.19 and 8.1).

Quantification is central in zooarchaeological studies and provides the basis for interpretations of the prehistoric human behaviour and may provide a framework for future analyses (Grayson 1984; Klein and Cruz-Uribe 1984; Lyman 1994, 2008; Reitz and Wing 2008). The quantification units used in this study to quantify the taxonomic abundance include: Number of Identified Specimens (NISP), Minimum Number of Elements (MNE), Minimum Number of Individuals (MNI) and Minimum Animal Unit (MAU) and provide the essential characteristics of the studied faunal assemblages. The strengths and shortcomings of the units used are discussed in depth in different pieces of published literature and do not need to be repeated here. The NISP is a basic quantification unit used in this work to highlight the taxonomic abundance. The MNE, MNI, and MAU are all derived estimates from the basic NISP counts. Of note, NISP is highly mediated by the degree of fragmentation in the faunal assemblage (Klein and Cruz-Uribe 1984; Reitz and Wing 2008; Grayson 1984; Lyman 1994, 2008). In this exercise, specimens with recent fractures were excluded in the NISP counts.

Before the 1970s, zooarchaeologists often quantified long limb bones by counting diagnostic epiphyseal portions and systematically excluded the midshaft fragments. The omission has severe consequences in the computation of skeletal part profile always tend to generates an artificial “head-and-foot” dominated profile (i.e. reverse utility curve pattern), which consequently may be erroneously interpreted as a result of hominin scavenging mode of prey acquisition (Klein and Cruz-Uribe 1984; Binford 1984, 1985, 1988, 1991; Grayson 1989).

The MNE refers to a minimum number of elements required to account for all specimens attributed to a particular skeletal part. Long limb bones MNE estimates in zooarchaeological studies are better computed when the midshaft fragments are included in the counts (Bunn 1986; Bunn and Kroll 1986; Marean 1998; Marean and Spencer 1991; Marean and Bertino 1994; Marean and Frey 1997; Marean and Kim 1998; Marean and Assefa 1999; Marean et al. 2000, 2004; Bartram and Marean 1999; Pickering et al. 2003, 2006; Yravedra and Domínguez-Rodrigo 2009). To get precise estimates of the relative nutritional contribution of different skeletal parts, midshaft fragments were included in the MNE counts and their fracture morphologies were also examined to determine the timing of their fracturing i.e. green or dry breakage (Tables 6.4, 6.22, 6.23, 7.4, 7.23, 7.24; Figures 6.20-6.22, and 7.14-7.16 for the details). Taking into account the animal size class involved, symmetry, portion, and ontogenetic age an estimate of MNE value was generated for each identified skeletal part with the highest abundant side (left or right) then taken as the Minimum Number of Individual (MNI). For unpaired skeletal parts such as the vertebrae and phalanges, the MNE value was divided by the number times occur in a complete carcass to arrive at MNI count (Tables 6.5, 6.10, 7.5 and 7.10). The coefficient was then rounded up to the next whole number.

The MAU is derived by dividing the MNE values for each skeletal part of the number of times the relevant element occurs in a complete carcass of an animal size class involved following Binford’s (1981) guideline. The element with the highest MAU value in the sample was used to standardize the rest and then multiplied by 100 to get the standardized skeletal part representation (%MAU). For the cranial bones the MNE was divided into 2 to get the MAU. In this study, no attempts were made to calculate the MNE and MNI estimates for the isolated teeth, fish, and tortoise because these were heavily fragmented rendering such estimates unviable (Tables 6.3, 6.8, 7.3 and 7.8).

Besides, no rigorous attempts were made for mechanical refits of the specimens that can also give correct quantities of the skeletal parts and bone surface modification abundance in the archaeological faunal assemblage (Bunn 1986; Marean and Kim 1998; Bartram and Marean 1999; Abe et al. 2002; Domínguez-Rodrigo 2003).

In order to identify the MSA hominins hunting preferences of different prey and to maximize comparability of the results in meaningful statistical ways specimens were also assigned into animal size classes as defined by Brain (1981) and Bunn (1982) based on their body weights (Table 4.1). Given the taxonomic range of the mammals represented in the two MSA faunal assemblages considered for this study and to keep some straightforward comparisons, specimens were also further analytically grouped together as small (size 1-2) and large-sized (size 3-4) carcasses. Small-sized (size 1-2) carcasses also formed the low-yield/low-ranked prey group, and the large-sized (size 3-4) carcasses were categorized as high-yield/high-ranked prey in the available diet spectrum ranking scale. Of note, hare (*Lepus capensis*), warthog (*Phacochoerus africanus*) and zebra (*Equus burchellii*) were included into animal size classes 1, 2 and 4 respectively on the basis of their overlap in morphology, body weight and overall post-encounter return rates (Tables 4.1, 6.5, and 7.5). This approach provided the basis for rankings the ungulates hunted and to gauge their relative contribution to the diet at both sites. Besides, the approach also permitted explicit broad inter-site comparisons and evaluation of different taphonomic and zooarchaeological aspects related to the differential animal sizes (Table 4.1).

Each animal size class was further divided into five broad anatomical segments: cranial (horn, skull, mandible, and dentition), axial (vertebrae, ribs, pelves, and scapulae) and the appendicular limb bones. The appendicular limb bones were further sub-divided into the upper limb bones (humerus and femur), intermediate limb bones (radius and tibia) and the lower limb bones (metapodials) as suggested by Domínguez-Rodrigo (1997a-c, 1999a), Domínguez-Rodrigo and Barba (2007c), and Yravedra and Domínguez-Rodrigo (2009). Pelves and scapulae were included in the axial bone group based on their broad likeness in both texture and taphonomic properties. This approach is also commonly used in the documentation of cut marks, percussion marks, and tooth marks in experimental, naturalistic studies and in the studies of highly comminuted Stone Age faunal assemblages like the Loiyangalani and Magubike faunal assemblages (Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2007c; Domínguez-Rodrigo et al. 2014). Dividing the complete animal carcass into major five anatomical segments as defined above permitted to explicitly compare and evaluate the overall skeletal part representation, bone surface modifications patterning (i.e. cut marks and tooth marks) across a complete carcass and to diagnose hominin and carnivore processing intensity of the carcasses (see Tables 6.6, 7.6; Figures 6.13-6.18 and 7.9-7.13 below).

In order to determine the age at death of the hunted prey, the best indicator used in this study was the epiphyseal fusion of some ageable skeletal parts. Full fusion of the epiphyseal portions (proximal or distal) of some skeletal parts is frequently used as a marker of adulthood (Klein and Cruz-Uribe 1984; Stiner 1991b). Long bone articular ends indicative of ages were notably very few in both faunal assemblages, which is mainly attributed to the impact of post-discard carnivore ravaging, and density-mediated attrition in the deletion of the less-dense epiphyseal ends (see Tables 6.4 and 7.4). From both sites, only a total 169 specimens could be reliably coded for the state of fusion. Consequently, the epiphyseal fusion datasets for both MSA faunal assemblages at best serve to demonstrate very coarse trends in age estimates at the death of the prey hunted. Epiphyseal fusion counts for each skeletal part were later aggregated based on the following broad guideline: unfused epiphyseal as juvenile and full fused as prime-adult. According to Klein and Cruz-Uribe (1984), regardless of an animal sex, full maturity in bovids is achieved by 24 months for the alcelaphines (such as in wildebeest, topi, and hartebeest) and at 12 months for the antilopines (Thompson's gazelle, Grant's gazelle, and dik-dik). Of note, in modern East Africa grasslands between 15 and 30% of the living bovids are categorized as prime-adults (Estes 1991; Owen-Smith 2006).

Complete jaws and maxillae or their fragments with dentitions were also absent in both assemblages. Isolated teeth, which are very suitable for the reconstructions of the mortality profile, were highly fragmented, which consequently limited their age determination by both dental eruptions and wear methods. The evident absence of the old individuals which also could be potentially hunted and deposited at both sites as shown in Tables 6.10 and 7.10 below prevented plotting of the ternary and histogram diagrams showing the proportions of the three age classes: juveniles, prime-adults and old individuals (Klein and Cruz-Uribe 1984; Stiner 1990, 1991a, b, 1994, 2005; Steele 2005; Steele and Weaver 2002). Only two age categories were certainly determined as measured by both NISP and MNI counts. Nevertheless, the overall mortality profiles demonstrate the prime-age adults are prevalent at both sites.

5.7.2. Carcass Processing and Selective Transport

Skeletal part abundance (%MAU) values for the Loiyangalani and Magubike were plotted against their standardized food utility (SFUI) that measure the total mass of usable tissue (meat, marrow, and grease) to evaluate field processing and selective transport of the carcass parts made by Middle Stone Age hominins for different animal size carcasses (Tables 6.3, 7.3; Figures 6.11 and 7.7). Metcalfe and Jones (1988) whole element (SFUI) values were preferentially used as hunter-gatherers frequently transport the carcass parts as complete units rather than fragments of bones. Besides, complete bone values also helped to mitigate the impact of the high degree of fragmentation noted in both faunal assemblages (Table 8.2). Regardless of each skeletal part economic utility, a positive correlation coefficient between the two sets of data signifies the presence of hominin selective transport of the carcass parts from the kill sites (Binford 1978, 1981; Metcalfe and Jones 1988; Lyman 1994). On the other hand, a negative correlation coefficient often results in a reverse utility curve. Besides, bone surface modifications including cut marks, percussion marks, and burnt bones also provide essential information on the hominin manipulation of the animal bones while still in their nutritive state (Tables 6.13 and 7.13). However, density-mediated attrition often biases the original abundance of skeletal parts in archaeological faunal assemblages. Therefore, an evaluation of the impact of density-mediated attrition is also one of the necessary protocols that must be addressed in zooarchaeological research before making behavioural inferences regarding prehistoric human behaviour (Lyman 1994).

In order to further investigate the potential variability in prey encounters, differential field carcasses processing and the likely transport strategies of the small and large-sized animals made by the MSA hominins at Loiyangalani and Magubike; high-survival-elements including the cranium, mandible, humerus, radius, femur, tibia and metapodials standardized MAU values were used in the computation of the Shannon Evenness Index (*E*) on the basis of the proposal made by Marean and Cleghorn (2003), and following the protocol established by Faith and Gordon (2007). The high-survival-elements are typically dense and less sensitive to the destructive taphonomic processes even in the wake of both post-discard carnivore ravaging and density-mediated attrition. Accordingly, they are also the best quantitative measure of the carcasses field processing and transport strategies. As such, some scholars have recently argued that taphonomic and zooarchaeological analyses of the archaeological faunal assemblages should focus on the high-survival-elements set (see Marean et al. 2000, 2004; Marean and Cleghorn 2003; Cleghorn and Marean 2004, 2007; Faith and Gordon 2007; Faith et al. 2009). The Shannon Evenness Index was then calculated using the following formula:

$$E = -(\sum pi * \ln pi) / \ln S \ \ldots\ldots\ldots \ (4)$$

where *pi* represents the standardized proportion of specimens for the *i*-th element. *S* is the total number of elements present in the sample, and *E* is the evenness index value (Faith and Gordon 2007). The evenness values fall between 0 and 1.0 (Table 5.4). It is predicted there should be an entirely even distribution of the high-survival-elements set in the archaeological faunal assemblage. However, as the transport of the carcass parts from the kill sites back to the consumption site by hominin become selective, the evenness value always drops and when become less selective always increases. An evenness value of > 0.9 broadly reflects an even distribution and suggests short distance transportation and that of < 0.9 denotes an uneven distribution and implies long distance transport of the carcasses parts (Faith and Gordon 2007). An evenness value of 1.0 indicates all the carcass parts were transported equally. According to Faith and colleagues (2009:252), on the basis of the optimal foraging theory short distance transport of carcass parts is a common characteristic of the Early Stone Age sites; long distance transport appeared relatively later in hominin evolution starting during the MSA.

Faith and Gordon (2007: 875) have come up with four different transport strategies of the carcass parts based on the calculated evenness values (see Table 5.4 below). Three out of four are analogous to Binford's (1978) theoretical utility curves developed mainly by using the datasets collected from the Nunamiut to explain field butchery and transport strategies of the carcass parts from the kill site. Gourmet refers to situations whereby only the high utility skeletal parts are transported (quality maximized) with low and moderate utility parts discarded at the kill site. Bulk strategy denotes transport of large quantities of an assortment of high and moderate utility skeletal parts with the lower utility parts usually abandoned at the kill site. Unbiased is an intermediate category in Binford's (1978) utility curves, and signifies transport of the skeletal parts happened in direct correlation to their food economic utility. Recently added by Faith and Gordon (2007) to the list of the utility curves, is the "unconstrained" strategy that refers to the instances whereby regardless of the economic utility of skeletal parts differential transport have not occurred at all such would be the case for the transportation of an entire carcass (Table 5.4). The evenness index (*E*) values calculated for the small and large-sized carcasses in the faunal assemblages were compared to the values generated by Faith and Gordon (2007) and against the inferred transport strategies of the carcass parts from kill site to consumption site (see Tables 5.4, 6.7 and 7.7).

Table 5.4. Shannon Evenness Index Values vs. Inferred Carcass Transport Strategies.

Evenness Index Value	Transport Strategy
0.369	Gourmet
0.842	Unbiased
0.98	Bulk
1	Unconstrained

To explore MSA hominin economic choices and transport of the bones with high marrow contents for further processing, %MAU values were also correlated against Unsaturated Marrow Utility Index (UMI) values generated by Morin (2007:77). The UMI is broadly analogous to Binford's (1978) Marrow Index, but UMI takes into consideration of both the volume of the marrow cavity and the proportions of the unsaturated fatty acids present in the marrow-bearing bones that are a key source of fat in the ungulates (Binford 1978, 1981; Morin 2007). A positive correlation coefficient between the two sets of data denotes marrow contents was also a factor considered in the transportation of the carcass parts from kill to consumption site (Tables 6.15-6.17, 7.15-7.17; Figures 6.15, 6.16 and 7.11).

5.7.3. Density-Mediated Attrition

The survival of skeletal parts recovered from archaeological sites also significantly depends on their bone mineral density and combined properties tied to individual elements including age, size, morphology, and composition (Brain 1981; Lyman 1994; Lam et al. 1999; Munson and Garniewicz 2003; Munson and Marean 2003; Faith and Behrensmeyer 2006). Other factors that the can accelerate the bias in skeletal part abundance include the impact of the destructive diagenetic processes such as post-discard carnivore ravaging, weathering, trampling, soil acidity, and sediment compaction

(Lyman 1994). Plant roots may also damage and ultimately destroy skeletal parts especially those with low density during the site formation process (Andrews and Cook 1985).

Skeletal parts with high-density values often survive better postdepositional attrition. Cranial bones, mandibles, and limb bones, typically with higher structural mineral density commonly survive better and are collectively dubbed as the high-survival-elements (Lyman 1994; Lam et al. 1999; Marean and Cleghorn 2003; Cleghorn and Marean 2004, 2007). Teeth also tend to survive better postdepositional attrition in archaeological sites because of their general compactness, dense-enamel, and dentine composition (Hillson 1999, 2005). Low-density and grease rich skeletal parts including the vertebrae, ribs, scapulae, and pelves frequently survive quite poorly and are collectively labeled as the low-survival-elements (Lyman 1994; Lam et al. 1999; Marean and Cleghorn 2003; Cleghorn and Marean 2004, 2007). Low-survival-elements may also be completely ravaged by carnivore and density-mediated attrition (Sutcliffe 1970; Binford and Bartram 1977; Brain 1981; Blumenschine 1986a, b, 1987, 1988, 1991; Blumenschine and Marean 1993; Marean and Spencer 1991; Marean and Bertino 1994; Marean et al. 1992; Capaldo 1995, 1997, 1998).

Bone mineral density studies have also shown that the long bone midshaft portions are much denser and survive better both the impact of post-discard carnivore ravaging and density-mediated attrition (Binford 1978, 1981; Shipman 1981; Blumenschine 1986a, 1986b, 1988; Marean and Spencer 1991; Marean et al. 1992; Lyman 1994; Lam et al. 1999). The epiphyseal ends of the long bones are mainly cancellous and are often preferentially ravaged by carnivore while they consume grease

(Sutcliffe 1970; Binford 1978, 1981; Brain 1981; Blumenschine 1986a, b, 1988, 1995; Blumenschine and Marean 1993; Marean and Spencer 1991; Marean and Bertino 1994; Marean et al. 1992; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Faith and Behrensmeyer 2006) and also are consumed by hominin during grease rendering (Binford 1978, 1981; Lupo and Schmitt 1997; Martinez 2009).

Studies of bone mineral densities have also recognized strong positive and statistically significant correlations between skeletal part abundance (%MAU) against their bulk mineral density (hereafter BMD). The relationship between the two variables is typically labeled as density-mediated attrition, postdepositional attrition or *in situ* attrition (Lyman 1994). The positive and statistically significant correlation coefficient between the two sets of data indicates bone mineral density governed the survivorship of the skeletal parts in the archaeological assemblage.

To evaluate the degree of density-mediated attrition that the Loiyangalani and Magubike faunal assemblages have undergone, %MAU values were also plotted against their BMD values corresponding to different skeletal parts and portions (Tables 6.5, 6.6, 7.5 and 7.6). Density values that take into account the presence of empty internal cavities in the long bones (BMD_2) derived from Lam and colleagues (1999) of an adult wildebeest (*Connochates taurinus*) taking into consideration the values of each portion were preferentially used because of the comminuted nature of both faunal assemblages. Since little intertaxonomic variation in bone mineral density exists between species of comparable body sizes, weights and morphologies, wildebeest (BMD_2) values are considered appropriate for both small and large-sized animal subsamples (Lam et al. 1999).

The effect of density-mediation on skeletal part abundance in the archaeological faunal assemblages also statistically correlates positively with carnivore ravaging of the bones (Sutcliffe 1970; Binford and Bartram 1977; Binford 1978, 1981; Brain 1981; Marean and Spencer 1991; Blumenschine and Marean 1993; Marean et. 1992; Pickering et al. 2003; Munson and Marean 2003; Pickering and Domínguez-Rodrigo 2006; Domínguez-Rodrigo and Organista 2007). To ascertain the potential impact of the post-discard carnivore ravaging on skeletal part abundance in the Loiyangalani and Magubike faunal assemblages, %MAU values were also correlated against %survivorship values of a known hyena-ravaged faunal assemblage (Marean and Spencer 1991; Marean et al. 1992). The positive correlation coefficient between the two parameters signifies the presence of carnivore intervention on the animal bones. Carnivores are also known to completely ravage less dense and grease-laden elements such as ribs, scapulae, vertebrae, and pelves (Blumenschine 1986a, b; Blumenschine and Marean 1993; Marean and Spencer 1991; Marean et al. 1992; Capaldo 1995). Besides, carnivore ravaged faunal assemblages often exhibit a low ratio of the epiphyses to midshaft fragments as experimentally simulated by Marean and Spencer (1991) and Marean and colleagues (1992). An estimate of the degree of post-discard carnivore ravaging was also evaluated by considering their overall damage inflicted on the bones (Tables 6.11, 6.18, 7.19 and 7.11; Figures 6.17 and 7.9).

Taking into account the nature of the Loiyangalani site as described in details in Chapter 3, it was rational to assume the bone fragments were potentially exposed to fluvial action before finally buried. Consequently, this necessitated an assessment of the skeletal parts susceptibility to fluvial transport. Fluvial transport of skeletal parts mostly depends on their density, weight, size and shape. According to Voorhies (1969), fluvial transport can be recognized by an overall skeletal part representation whereby relatively smaller and less-dense elements are often moved easily by the water action and the large and heavier move last resulting in a lag deposit (Voorhies 1969; Behrensmeyer 1975a, b, 1982). The underrepresentation of the Voorhies Group I elements (ribs, vertebrae, sterna, sacra) and overrepresentation of Voorhies Group III elements (skull and mandibles) imply the lower density elements have been winnowed out while their presence in high proportions suggest fluvial action have not played a significant role in the configuration of the archaeological faunal assemblage (Voorhies 1969; Behrensmeyer 1975a, b, 1982). Identified skeletal parts in the Loiyangalani faunal assemblage were also assigned into different Voorhies Groups (see Figure 6.7 below).

Further analyses conducted to evaluate the possible role of fluvial action include the Fluvial Transport Index (FTI) that measures how readily the bones can be transported and the Saturated Weight Index (SWI) that measures the relationship between bone weight and potential for fluvial transport (Frison and Todd 1986; Behrensmeyer 1975a, b, 1982). Skeletal part abundance (%MAU values) in the Loiyangalani faunal assemblage were subsequently plotted against both FTI and SWI complete skeletal part values to determine the degrees to which the fluvial action may have configured the archaeological faunal assemblage (see Figures 6.8 and 6.9 below). The FTI values used are from Lyman (1994:175). Derived SWI whole bone values also provided in Lyman (1994:175, Table 6.7) for reedbuck (*Redunca* sp.) and zebra (*Equus* sp.) as closest rough estimates based on their body weights for the small and large-sized animal subsamples respectively were used in the pair-wise correlations. Besides, size distribution of specimens and the proportions of abrasion/polishing of the specimen edges were also considered in the evaluation of the integrity of the Loiyangalani MSA faunal assemblage (Shipman and Rose 1983; Pante and Blumenschine 2010).

5.7.4. Analysis of State of Preservation of the Faunal Assemblages

Various pre-and-post depositional destructive taphonomic processes often shape the faunal assemblages before their discovery by archaeologists (Behrensmeyer and Hill 1980; Binford 1978, 1981; Behrensmeyer 1991; Shipman 1981; Fernández-Jalvo and Andrews 2016). Pre-depositional processes include the actions of the hominin, carnivore, rodent, bone weathering, trampling and fluvial transport (Lyman 1994). Post-depositional processes include root-etching and sediment compaction (Fisher 1995; Villa and Mahieu 1991; Villa et al. 2004). In practice, the pre-and-postdepositional processes overlap, and high degree of their impact can significantly accelerate fragmentation of the bones, impede their identification, alter their cortical surfaces and may limit the ability to interpret prehistoric human-related behaviour (Klein and Cruz-Uribe 1984; Lyman 1987b, 1994; Marean 1995; Monahan 1996; Abe et al. 2002; Domínguez-Rodrigo 2003; Bar-Oz 2004; Thompson 2005).

One of the key objectives of the taphonomic studies is to understand the dynamics and the magnitude of the pre-and-post-depositional processes in the archaeological faunal assemblage under study. Rigorous taphonomic studies frequently help to unlock a considerable amount of zooarchaeological information, clarify preservation biases, and the limitations of the faunal assemblage under consideration to answer the research questions addressed. Consequently, taphonomic studies lay down a robust and sound foundation before drawing higher-level inferences regarding prehistoric human behaviour (Lyman 1987b, 1994; Behrensmeyer 1991; Behrensmeyer and Kidwell 1985; Gifford 1991; Marean 1991, 1995, 1998; Marean and Spencer 1991; Marean and Bertino 1994; Marean and Frey 1997; Marean and Kim 1998; Bertram and Marean 1999; Marean et al. 1992, 2000, 2004; Monahan 1996; Bar-Oz and Dayan 2003; Bar-Oz and Munro 2004; Thompson 2005; Fernández-Jalvo and Andrews 2016).

Being aware of the pre-and post-depositional processes potential effects on the archaeological faunal assemblages considered for this study of approximately 10,000 specimens, each specimen was assessed for various taphonomic signatures first with the naked eye followed by a thorough inspection under a binocular stereomicroscope to diagnose the discrete traces. Bone cortical surface preservation was subjectively scored as good (cortical surface well-preserved), moderate (cortical surface display some light cracking or peeling) and poor (little to no preservation of the original cortical surface). The percentage of the undamaged cortical surface area that also potentially could be studied for bone surface modifications was also recorded. Poor cortical preservation frequently leaves little prospect for the detection of bone surface modifications and can significantly depress their frequencies (Klein and Cruz-Uribe 1984; Monahan 1996; Thompson 2005; Pickering et al. 2008). For specimens that their cortical surfaces were visible (not encrusted by concretion matrices), weathering stages were scored according to Behrensmeyer's (1978) scheme, which also permitted to gauge an estimate of the exposure time before their final burial. The edges of each specimen were also scored as fresh, slightly abraded, abraded, and very abraded (Shipman and Rose 1983).

An evaluation of the relative degree to which the archaeological faunal assemblages under study may have been postdepositionally fragmented is also necessary and serves to strengthen the inferred prehistoric human behaviour. Fragmentation of the small compact bones typically with little nutritional values such as the astragali, carpals, tarsals, and sesamoids provide an estimate of the postdepositional fragmentation as hominin rarely break and carnivore ravaged them while still in their nutritive state (Binford 1978, 1981; Brain 1981; Marean 1991). The degree of postdepositional fragmentation is derived by estimation for each specimen the fraction of an original specimen that is present, summing the values and dividing that by a total number of the specimens (Marean 1991). Multiplication by 100 provides the mean percentage Completeness Index (CI). An easily achieved protocol following Villa and colleagues (2004:714-715), was used to generate the Completeness Indices (CIs). Small compact bones were coded as complete (CO), Almost Complete (ACO) and as Fragmented (FR). Then the proportion of the CO + ACO bones to the FR was calculated to get the relative Completeness Index of the archaeological faunal assemblages (Tables 6.2 and 7.2 below). The calcaneus was excluded in the exercise because has a small marrow cavity, which makes it more susceptible to differential fragmentation relative to other small compact bones. However, the third phalange was included in the calculation as it is characteristically sensitive to diagenetic breakage (Villa et al. 2004). All small compact bones bearing cut marks, percussion marks, tooth marks, and traces of burning were excluded in the analysis. Calculated Completeness Index values permitted inter-site comparison of the impact of postdepositional fragmentation (see Tables 6.2 and 7.2). Of note, high degree of postdepositional fragmentation in the archaeological faunal assemblage can considerably mediate skeletal part representation and bone surface modification tallies (Marean et al. 1992; Marean and Kim 1998; Villa and Mahieu 1991; Villa et al. 2004; Abe et al. 2002; Domínguez-Rodrigo 2003; Bar-Oz 2004).

5.7.5. Analysis of Bone Surface Modifications

A systematic study of bone surface modifications significantly helps to unravel a broad range of information including site formation, timing of access to the carcasses by hominin and carnivore and to reinforce the inferences drawn from the skeletal part profiles (Binford 1978, 1981; Bunn 1981, 1982, 1983, 1986; Bunn and Kroll 1986; Bunn and Ezzo 1993; Blumenschine 1986a, b, 1988, 1995; Blumenschine and Selvaggio 1988, 1991; Metcalfe and Jones 1988; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Marean et al. 2000; Lupo and O'Connell 2002; Domínguez-Rodrigo 1997a-c; 1999a, 2002, 2003; Domínguez-Rodrigo and Barba 2005, 2006, 2007a-c; Domínguez-Rodrigo and Pickering 2003; Domínguez-Rodrigo et al. 2007a, b, 2014). Bone surface modifications are mainly divided into two groups namely the human-induced and nonhuman-induced (Binford 1981; Fisher 1995). Human-induced surface modifications include cut marks, percussion marks, and burning. On the other hand, nonhuman-induced surface modifications include carnivore tooth marks, rodent gnaw marks, root-etching, biochemical marks, and trample marks.

Identification of bone surface modifications in archaeological faunal assemblages is a multifaceted process that involves detailed scrutiny to diagnose the distinctive type, orientation, frequency, and distribution. The search also includes identifying and attributing a particular damage to a potential modifying taphonomic agent including hominin, carnivore, natural processes, and the possible potential foraging contexts by either hominin or carnivore (see Table 5.5). Identification of bone surface modifications benefits much from the experimental and ethnoarchaeological studies to correctly diagnose the distinctive types (Binford 1978, 1981; Bonnichsen and Sorg 1989; Hudson 1993; Fernández-Jalvo and Andrews 2016). However, bone surface modifications in the archaeological faunal assemblages are hardly as clear as those generated via experimentally controlled samples and can be misidentified for another type of surface modification (see Behrensmeyer et al. 1986; Domínguez-Rodrigo and Barba 2006, 2007a, b). Besides, bone surface modifications on cortical surfaces can be significantly modified, obscured or obliterated by weathering, root-etching, soil leaching, action of water, and fragmentation (Behrensmeyer 1978; Andrews and Cook 1985; Lyman 1994; Monahan 1996; Abe et al. 2002; Domínguez-Rodrigo 2003; Thompson 2005).

Different bone surface modification classes were identified in the Loiyangalani and Magubike faunal assemblage following the criteria outlined by various scholars including cut marks (Binford 1981; Potts and Shipman 1981; Shipman and Rose 1983; Nilssen 2000), hammerstone percussion and percussion notches (Bunn 1981; Capaldo and Blumenschine 1994; Blumenschine and Selvaggio 1988, 1991; Blumenschine 1995; Pickering and Egeland 2006), percussion pits and striations (Blumenschine 1986a, b; Blumenschine and Selvaggio 1988, 1991; Pickering and Egeland 2006; Capaldo and Blumenschine 1994), carnivore punctures, scoring and digestion marks (Fisher 1995), rodent gnaw marks (Binford 1981; Brain 1981; Shipman and Rose 1983), root marks (Binford 1981; Andrews and Cook 1985) and biomechanical marks (Domínguez-Rodrigo and Barba 2006, 2007a, b), trampling (Behrensmeyer et al. 1986; Potts and Shipman

1981; Olsen and Shipman 1988), burning (Stiner et al. 1995; Stiner 2005), and abrasion of edges (Shipman and Rose 1983).

The identification of bone surface modifications in this study was mostly achieved by using a binocular stereomicroscope with a high-intensity oblique light source at magnification up to 45 (Blumenschine et al. 1996). The surfaces of each specimen were carefully examined from different angles. Type (s) of surface modification on each specimen was also noted. Other general features recorded included frequency, distribution (isolated, clustered or crossed), and orientation on the long axis (oblique, transverse, longitudinally). In recording the cut marks, functions were also identified based on the general attributes of their location and orientation along the long axis. Binford (1981:47) identifies three main butchery classes namely skinning, disarticulation/dismemberment, and filleting/deboning. The general high degree of fragmentation in the faunal assemblages, concretions, and root-etching made the inspection of surface modifications on some specimens a challenging task. In this study, only clear and unambiguous marks were recorded. Specimens with well-preserved surfaces and that had > 2 cm in maximum lengths were considered to permit a maximum comparability with the datasets generated via experimental simulations and ethnoarchaeological studies (Table 5.5). Specimens with extensive concretion matrices coverage, root-marking, and exfoliated surfaces at a rate of > 75% of their total cortical surface areas were eliminated.

Both human and nonhuman-induced surface modifications were recorded (see Tables 6.11, 6.18, 7.11 and 7.19 below). Approximately 1,900 specimens including identified and unidentified preserved at least a single type of surface modification. It is worth to emphasize bone surface modification frequencies in this work refer to the number of specimens bearing the discrete type i.e. NISP counts. Bone surface modification frequencies tallied by NISP counts are different from those tallied by MNE counts (Otárola-Castillo 2010). Bone surface modification tallies are also often very sensitive to bone fragmentation and always decrease in number with the intensity of fragmentation in the faunal assemblage (Bartram 1993; Abe et al. 2002; Lupo and O'Connell 2002; Domínguez-Rodrigo 2003; Domínguez-Rodrigo et al. 2007d; Gidna et al. 2014; Organista et al. 2016). Bone surface modification tallies in this study are also presented by skeletal element (e.g. on a humerus, femur), major anatomical sections of a complete carcass and size (Tables 6.11-6.23, 7.11-7.24, 8.4; Figures 6.13, 6.17, 7.9 and 7.12). For the case of the long bones, cut marks, percussion marks, and tooth marks are also reported by carcass size, element, and anatomical section on which they occur e.g. on the epiphyseal end or midshaft area (Tables 5.5, 6.13-6.15, 6.20, 7.13-7.15, 7.21 and 8.4).

Over the past five decades numerous controlled experimental studies simulating different scenarios of hominin and carnivore access to fully-fleshed and defleshed carcasses have been conducted in the Serengeti, Ngorongoro and Tarangire National Parks of Tanzania (Blumenschine 1986a, b, 1988, 1995; Blumenschine and Selvaggio 1988, 1991; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Capaldo and Blumenschine 1994; Domínguez-Rodrigo 1997a-c, 1999a; Gidna et al. 2014; Organista et al. 2016). Ethnoarchaeological datasets that link prey acquisition, field processing, and transport of the carcass parts from the butchery to consumption sites also have been collected on faunal assemblages generated by the Hadza, a modern hunter-gatherer group living near Lake Eyasi in Tanzania (Bunn and Kroll 1986; Bunn et al. 1988; O'Connell et al. 1988a, 1990, 1992; Oliver1993; Lupo 1994, 1995, 2001, 2006; Monahan 1998; Lupo and O'Connell 2002). Both experimental and ethnoarchaeological studies have shown that bone surface modifications inflicted on long bone midshaft areas typically covered by more meat can be reliably used to discriminate the order (sequence) of access to fully- and defleshed carcasses by hominin and carnivore (summarized in Marean et al. 2000; Lupo and O'Connell 2002; Domínguez-Rodrigo et al. 2014).

As remarked above, long bone midshafts are structural dense and also tend to survive better the rigor of both post-discard carnivore ravaging and density-mediated attrition and can also give a better estimate of the differential preservation bias prior to the introduction of different destructive diagenetic taphonomic processes (Lyman 1994; Lam et al. 1999; Marean et al. 2000, 2004). As a result, midshaft fragments frequently preserve in bulk in archaeological sites relative to other skeletal parts. Prospectively, long bone midshaft fragments also can give a relatively unbiased sample of the skeletal part abundance and bone surface modifications in the archaeological faunal assemblage under study (Marean and Cleghorn 2003; Cleghorn and Marean 2004, 2007). The analytical power of the long bone midshaft fragments in the reconstructions of the prehistoric human behaviour is collectively dubbed as the "shaft critique" and is well elaborated in different literature (see Bunn 1986; Bunn and Kroll 1986; Bunn et al. 1988; Marean 1998; Marean and Bertino 1994; Marean and Frey 1997; Marean and Kim 1998; Marean et al. 2000, 2004; Outram 2001; Pickering et al. 2003; Yravedra and Domínguez-Rodrigo 2009). The statistical foundation of bone surface modifications inflicted on long bone midshaft sections as a robust approach within a multivariate taphonomic and zooarchaeological studies is well detailed in Domínguez-Rodrigo and colleagues (2014) and in Pante and colleagues (2012) for the bootstrapped original data samples (Table 5.5). Besides, the experimental and ethnoarchaeological simulations developed and commonly used to differentiate the order of access to the carcass resources (meat and marrow) by both hominin and carnivore are mainly based on the surface modifications inflicted on long bone midshaft sections. For the same reasons, surface modifications inflicted on midshafts are considered in this study as the main analytical sample (Tables 5.5, 6.13, 6.15, 6.20, 7.13, 7.15, 7.21 and 8.4; Figures 6.14, 6.18, 7.10 and 7.13).

A total of 2,216 long bone fragments were identified to skeletal parts and assigned to animal size classes in the Loiyangalani and Magubike faunal assemblages (Tables 6.3, 6.4, 7.3 and 7.4). Long bone midshaft fragments also make up 94.67% (NISP=2,098) of the total long bones and the remaining were the epiphyseal ends. Of note, cut marks and tooth marks inflicted on the long bone epiphyseal ends were remarkably very few in both faunal assemblages (see Tables 6.13, 6.14, 6.20, 7.13, 7.14 and 7.21 for the details). Besides, percussion marks on the long bones were also mainly recorded on their midshaft sections (Tables 6.15 and 7.15).

Below single and dual-patterned experimental simulations that include the hominin-only (HO) and carnivore-only (CO) models as well as the dual-patterned models that the include hominin-to-carnivore (H-C) and carnivore-to-hominin (C-H) foraging scenarios are briefly reviewed (see Table 5.5). Of note, in experimental simulations primary or early access by either hominin or carnivore implies procurement of the fully-fleshed carcasses most likely through active hunting or confrontational scavenging. On the other hand, secondary or late access to the defleshed and/or demarrowed bone fragments by either hominin or carnivore denotes passive scavenging. The models summarized below were used in this study to evaluate the order of access primary (early) or secondary (late) access to fully or defleshed carcasses by the hominin or carnivore as reflected in the MSA faunal assemblages (see Figures 6.14, 6.18, 7.10 and 7.13).

Hominin-Only Model (HO)

The model simulates hominin primary access to fully-fleshed carcasses and as exclusive consumer of the resources (meat, marrow, and grease). Bones are defleshed with the aid of simple stone tools or metal knives and/or later cracked open their medullar cavities with a hammerstone often rested on anvil to extract bone marrow producing an assemblage with either cut marks only or percussion marks only or both but no tooth marks (Table 5.5).

Cut marks made during the butchery process frequently cluster between 10 and 30% depending on the animal size involved and intensity of carcass processing (Blumenschine 1986a, b, 1988, 1995; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Domínguez-Rodrigo 1997a-c; Marean et al. 2000; Lupo and O’Connell 2002). Experimental studies have also shown that in hominin first access to fully-fleshed carcasses to extract bone marrow also between 10 and 30% of the long bone midshaft fragments bear percussion marks (Marean et al. 2000; Domínguez-Rodrigo et al. 2014).

According to Domínguez-Rodrigo (1997a-c) and Domínguez-Rodrigo and Barba (2005), the ratios of cut marks on the appendicular limb bones (ULB and ILB) can also be used reliably to infer primary or secondary access by hominin to fully-fleshed carcasses. In actualistic studies simulating hominin primary access to fully-fleshed carcasses, the upper limb bones (ULB) often bear higher proportion of cut-marked specimens often by 60%, while on intermediate limb bones (ILB) by 30% and on the lower limb bones (LLB) by < 10% (Domínguez-Rodrigo 1997b:677-678). High proportions of cut marks on the upper appendicular limb bones (ULB and ILB) that are more directly linked to the defleshing/deboning of the large muscle mass relative to the lower limb bones (LLB) suggest hominin primary (early) access to fully-fleshed carcasses (Domínguez-Rodrigo 1997a-c; Domínguez-Rodrigo and Barba 2005; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008). An opposite pattern of cut marks incidences suggest hominin secondary (late) access or scavenging of the carcasses abandoned by carnivores (see also Domínguez-Rodrigo and Barba 2007c; Gidna et al. 2014).

Hominin-to-Carnivore Model (H-C)

The model simulates hominin primary access to fully-fleshed carcasses and as primary consumer of the resources (meat, marrow, and grease) followed by carnivore ravaging the defleshed and/or demarrowed bones (i.e. carnivore scavenging bone fragments discarded by hominin). This usually results in a faunal assemblage with three classes of feeding traces including cut marks resulting from butchery, percussion marks resulting from marrow extraction, and tooth marks resulting from carnivore scavenging the defleshed and demarrowed bone fragments (Table 5.5).

The mean percentages of cut marks and percussion marks on long bone midshaft fragments are also frequently high and range between 10 and 30% depending on the animal size involved and intensity of carcass processing (Blumenschine 1986a, b, 1988, 1995; Blumenschine and Selvaggio 1998, 1991; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Domínguez-Rodrigo 1997a-c; Domínguez-Rodrigo et al. 2014; Marean et al. 2000; Lupo and O'Connell 2002; Pickering and Egeland 2006). On the hand, tooth marks on long bone midshaft fragments are very low and frequently range between 5 and 15%, because the carnivore habitually tend to ignore the hominin defleshed and demarrowed bone fragments as they no longer retain much nutritional resources (Binford 1988; Blumenschine 1995; Blumenschine and Marean 1993; Bartram 1993; Bartram et al. 1991; Bunn 1993; Marean and Bertino 1994; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Lupo 1995; Lupo and O'Connell 2002; Domínguez-Rodrigo 1997a-c; Marean et al. 2000).

In scenarios whereby felids (lions) rather than hyenids (hyenas) are engaged as the key modifying taphonomic agent of the fully-fleshed carcasses, followed by hominin fracturing the long bones, the mean percentages of tooth marks can mimic those produced in hammerstone-to-carnivore (H-C) experimental simulations (Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo et al. 2007d; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014; Organista et al. 2016). However, the equifinality in the percentage of tooth marks in the archaeological faunal assemblage under study can be best solved by comparing the three classes of surface modifications conjointly to published datasets generated via experimental and ethnoarchaeological studies (Domínguez-Rodrigo et al. 2014; Pante et al. 2012). According to Domínguez-Rodrigo and Piqueras (2003) pits size (lengths and breadths) together with other lines of evidence also can be used reliably to discriminate among the diverse carnivore groups involved in modification of the faunal assemblage such as the hyenas, lions, leopards, cheetahs, jackals and domestic dogs (see also Selvaggio and Wilder 2001; Domínguez-Rodrigo et al. 2012).

The whole-bone-to-carnivore (WB-C) model simulates whole carcass defleshing by hominin using metal knives, but not fractured then followed by the carnivore ravaging of the complete bones. This usually results in a faunal assemblage with two classes of feeding traces including cut marks resulting from butchery and tooth marks resulting from carnivore scavenging the defleshed bones (Table 5.5). Cut marks and tooth marks on long bone midshaft fragments are high and frequently above 15% and 50% respectively (Capaldo 1995, 1997, 1998; Pante et al. 2012).

Carnivore-Only Model (CO)

The model simulates carnivore (mostly hyenas and lions) primary access to fully-fleshed carcasses and as exclusive consumer of the resources (meat, marrow and grease). The simulation produces an assemblage having only tooth marks as the feeding traces inflicted on the bones (Table 5.5). Of note, large carnivore also frequently abandons the lower limb bones (LLB) intact because they lack meat (Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2007b; Gidna et al. 2014).

Carnivore primary access to fully-fleshed carcass frequently results in higher percentages of long bone midshaft fragments bearing tooth marks often by > 75% (Blumenschine 1986a, b, 1995; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Domínguez-Rodrigo 1997a-c; 1999b; Marean et al. 2000; Gidna et al. 2014). Of note, when compared to the carcasses defleshed by the hyenas, the percentages of tooth marks made by leopards and lions on midshaft fragments are always substantially lower on the small and medium-sized carcasses by < 15% as well as on the large-sized carcasses by < 22% (Blumenschine 1988, 1995; Capaldo 1995, 1997; Domínguez-Rodrigo 2007d; Organista et al. 2016).

The proportions of tooth marks relative to cut marks on the axial elements (including ribs, vertebrae, scapulae and pelves) also can be used reliably to discriminate primary (early) from secondary (late) access to fully-fleshed carcasses by hominin and carnivore (Blumenschine 1986a, b; Domínguez-Rodrigo 1999a). In carnivore-first access to fully-fleshed carcasses scenarios, the axial bones are often completely defleshed post-carnivore consumption. They also frequently exhibit high proportions of specimens bearing tooth marks usually by above 40% (Blumenschine 1986a, b, 1988; Marean and Spencer 1991; Marean et al. 1992; Capaldo 1995, 1997, 1998; Domínguez-Rodrigo 1999a). Accordingly, the high proportion of the cut marks relative to tooth marks on the axial elements suggest hominin primary (early) and carnivore secondary (late) access to the carcasses (Domínguez-Rodrigo 1999a; Domínguez-Rodrigo and Barba 2007c).

Carnivore-to-Hominin-Model (C-H)

The model simulates carnivore primary access to fully-fleshed carcasses followed by hominin processing the defleshed bones with the aid of simple flaked stone tools (i.e. hominin scavenging carnivore killed and defleshed carcass parts). This results in three classes of bone surface modifications including tooth marks resulting from carnivore consumption, cut marks resulting from hominin removing the marginal scraps of meat and percussion marks resulting from bone marrow harvesting (Table 5.5).

When hominin butcher the carcasses hunted by large carnivore, cut marks on long bone midshaft fragments are markedly very low roughly by < 3% for the felids (lions) and > 15% for the hyenids (hyenas) defleshed carcasses (Gidna et al. 2014). Fracturing the marrow-bearing long bones also generates multiple fragments and percussion marks on the midshaft fragments that frequently range between 4 and 15% (Selvaggio 1994a, b, 1998; Domínguez-Rodrigo 1997a-c; 1999a; Marean et al. 2000; Gidna et al. 2014; Organista et al. 2016). Tooth marks on long bone midshaft fragments also drop drastically usually by < 8% (Gidna et al. 2014; Organista et al. 2016).

Of note, naturalistic studies have also shown that carcasses defleshed by large carnivores (felids and hyenids) frequently leave very little scraps of flesh to the next potential scavengers. According to Domínguez-Rodrigo (1999a) scraps refer to any bone that retained > 10% of its original flesh mass (see also Gidna et al. 2014:171). Much scraps of meat often occur along the neck areas. The proximal and distal ends of long bones also retain a substantial amount of scraps of meat (Domínguez-Rodrigo 1997a-c; 1999a; Domínguez-Rodrigo and Barba 2007c; Gidna et al. 2014). But, the midshaft sections of the upper limb bones (ULB) and intermediate limb bones (ILB) usually exhibit a complete lack of flesh scraps (Domínguez-Rodrigo 1999a; Domínguez-Rodrigo and Barba 2007c; Gidna et al. 2014). Besides, the patterning of butchery marks in hominin secondary (late) access to the carcass defleshed by large carnivore, the ILB also frequent bear relatively higher proportions of cut marks than the ULB (Gidna et al. 2014:177). The area on the long bones where scraps of meat never survive post-large carnivore consumption are referred by Domínguez-Rodrigo and Barba (2007c) as the "hot zones" and those preserve substantial flesh scraps as the "cold zones". Hereafter, unless otherwise specified, cut marks and tooth marks inflicted on the midshaft sections of the upper limb (ULB) and intermediate limb bones (ILB) are collectively referred to as the "hot zones" throughout the work. Accordingly, the high percentage of the cut marks relative to tooth marks on the areas that are regularly devoid of flesh scraps post-carnivore consumption suggest hominin primary access to fully fleshed (Domínguez-Rodrigo and Barba 2007b). Table 5.5 below provides summaries of the percentages of cut marks, percussion marks and tooth marks on long bone midshaft sections from the experimental and ethnoarchaeological studies.

Table 5.5. Percentages of Cut Marks, Percussion Marks and Tooth Marks on Long Bone Midshaft Sections from Experimental and Ethnoarchaeological Studies.

Modification Scenario	Researcher (s)	Size	CM	PM	TM
Hominin-Only	Blumenschine (1988, 1995)	(1-2)	10.3(3.1±17.6)	26.6(13.1±40.1)	-
		(3-4)	20.1(0±40)	33.3(-)	-
		(1-4)	11.7(4.5±19.3)	27.6(16.3±38.9)	-
	Pante et al. (2012)	(1-2)	10.3(3.1±17.6)	26.7(14±37.8)	-
		(3-4)	20.1(0±40)	33.5(13.3±60)	-
		(1-4)	11.7(4.5±19.3)	27.7(16.4±37.9)	-
	Capaldo (1995, 1997, 1998)	(1-3)	16.6(13.7±19.5)	-	-
	Domínguez-Rodrigo (1997a-c)	(1-4)	47.5(37±58)	-	-
	Marean et al. (2000)	(1-4)	-	49.2(42.2±55.8)	-
	Hadza	(1-4)	23.6(14.2±33)	-	-
Hominin-to Carnivore	Blumenschine (1995)	(1-2)	-	33.6(17.7±49.5)	15.9(2.6±29.2)
		(3-4)	-	20.6(6.4±34.5)	5.1(0.2±10)
		(1-4)	-	27.1(17.1±37.1)	10.5(3.5±17.5)
	Pante et al. (2012)	(1-2)	-	29.4(23.4±35.8)	14.9(10.5±18.9)
		(3-4)	-	14.6(8.1±22.4)	14.8(7.3±23.5)
		(1-4)	-	24.9(18.4±28.8)	14.5(11.4±18.1)
	Capaldo (1995, 1997, 1998)	(1-2)	14(10.1±17.9)	28.3(22.4±34.2)	14.9(11.2±18.6)
		(3)	12.3(7.7±16.9)	13.1(4.7±21.5)	16.2(10.4±22.8)
		(1-3)	13.5(10.5±16.4)	23.6(18.4±28.8)	15.4(12.3±18.5)
	Marean et al. (2000)	(1-4)	-	33.7(27.4±38.6)	7.1(4.1±9.8)
	Hadza	(1-4)	-	-	6.4(2.5±10.3)
Whole-Bone-to-Carnivore	Capaldo (1995, 1997, 1998)	(1-2)	15.3(0±32.1)	-	54.4(37±71.8)
		(3)	42.2(0±85.5)	-	66(59.8±72.2)
		(1-3)	22.4(6.9±37.9)	-	57.4(41.7±73.1)
	Pante et al. (2012)	(1-2)	16.4(2.5±36)	-	70.5(56.1±84.7)
		(3-4)	40(13±80.1)	-	57.3(18.1±89.8)
		(1-4)	25(9.1±44.6)	-	65.7(47±80.8)
Carnivore-Only	Blumenschine (1988, 1995)	(1-2)	-	-	69.1(47.5±90.7)
		(3-4)	-	-	86.5(75.7±97.3)
		(1-4)	-	-	82.6(72.9±92.3)
	Pante et al. (2012)	(1-2)	-	-	69.1(54.8±81)
		(3-4)	-	-	86.5(75.7±95.8)
		(1-4)	-	-	82.6(72.5±91.9)
	Capaldo (1995, 1997, 1998)	(1-3)	-	-	57.4(41.7±73.1)
	Marean et al. (2000)	(1-4)	-	-	75.8(66.4±82.4)
Carnivore-to-Hominin	Gidna et al. (2014)	(1-3)	1.11(0.5±1.73)	-	8(7.25±8.25)
		(4)	1.25(0±4.71)	-	6.1(5.53±6.67)
		(1-4)	1.14(0.06±1.2)	-	7.56(6.86±8.26)
	Domínguez-Rodrigo (1997a-c)	(1-4)	19.8(10.7±28.9)	-	-
	Selvaggio (1994a, b, 1998)	(1-4)	17.4(9.7±25.1)	12.2(7.3±17.1)	22(13±31)
	Capaldo (1995, 1997, 1998)	(1-3)	22.4(6.9±37.9)	-	-

Note: The values for the Hadza faunal assemblage are from Lupo and O'Connell 2002. All values by Pante and colleagues (2012) are from bootstrapped original samples from Blumenschine and Capaldo studies.

5.7.6. Analysis of Long Bone Fragmentation

Long limb bones are commonly fractured to extract bone marrow whereas, carpals, tarsals, and phalanges typically with little marrow contents are rarely fractured while still in their nutritive state (Binford 1978, 1981; Marean 1991). Hominin habitually favours bone marrow for its better-quality taste, softer texture and high contents of unsaturated fatty acids (Binford 1978; Morin 2007). Experimental studies have also demonstrated long bones breakage to extract the within-bone nutrients by hominin and carnivore often produce many long-bone cylinders and fragments that also some may be broken beyond identification (Brain 1981; Binford 1981; Binford and Bertram 1977; Bunn 1981, 1982, 1983; Blumenschine 1995; Blumenschine and Selvaggio 1988, 1991; Capaldo 1995, 1997, 1998). Besides, hominin generated faunal assemblages are also characterized by less representation of the complete long bones (Bunn 1982, 1983; Marean et al. 2000; Villa et al. 2004; Pickering et al. 2003, 2006; Pickering and Egeland 2006).

Mode of long bone fragmentation in the archaeological faunal assemblage under study serves to infer a wide variety of aspects at assemblage level such as the stage at which were broken (green or dry/nutritive or non-nutritive), the taphonomic agent involved (hominin, carnivore or natural process), force engaged in the fracture (hammerstone dynamic loading or teeth/sediment compaction static loading) and formation history of the faunal assemblage (predepositional or postdepositional fragmentation) (Bunn 1982, 1983; Johnson 1985; Blumenschine and Selvaggio 1988, 1991; Villa and Mahieu 1991; Capaldo and Blumenschine 1994; Pickering et al. 2003, 2005, 2006; Pickering and Egeland 2006).

Fragmentation analysis was conducted on a total of 2,142 long bone fragments (537 and 1,605 from Loiyangalani and Magubike respectively). Each long bone specimen was recorded as an estimate of the percentage of the remaining length by 25% intervals (Villa and Mahieu 1991; Villa et al. 2004). The degree of completeness of the long bone shaft circumference (i.e. cross-sectional completeness) was also recorded following Bunn's (1982, 1983) protocol: Type 1 shaft preserves <50% of the original completeness; Type 2 preserves between 50-100% of original completeness and Type 3 shaft as complete (100%). Excluded in the study are the complete long bones. Experimental studies have also shown that the ratio of the sum of the Type 2 and 3 shafts to the Type 1 shafts often ranges between 0.44 and 0.10. Type 1 shafts frequently dominate faunal assemblages created by hominin whereas Type 2 and 3 shafts characterize those generated by carnivore (Bunn 1982, 1983). To get finer resolution in the attribution of the key taphonomic agent involved in the fragmentation of the long bones, proportions of shaft types were also compared to several calibrated experimental samples simulating carnivore-only and hammerstone-to-carnivore interactions (see Tables 6.22, 7.23; Figures 6.20 and 7.14). Comparative datasets used are from Marean and colleagues (2000) and Pickering and Egeland (2006). According to Marean colleagues (2000, 2004), the proportions of shaft types can also provide a straightforward measure of bias in the faunal assemblage under study. Type 1 shafts frequently dominate complete collected archaeological faunal assemblages (Payne 1972; Turner 1989; Marean and Kim 1998).

Fracture and breaks on long bone fragments located on either side of the diaphysis were also analyzed and classified according to Villa and Mahieu (1991) to determine the stage at which were fractured. Fracture angles (as oblique, right and intermediate), fracture outlines (as curved, transverse and intermediate) and fracture edges (as smooth or jagged). Only explicit proximal and distal fractures were recorded. Specimens with recent fracture and all fragment ends that were indeterminate, unbroken, broken through the thick cancellous bones were excluded. Oblique angles, curved outlines, and smoothed edges denote fresh bone fractures and are commonly attributed to the hammerstone dynamic loading (Johnson 1985; Villa and Mahieu 1991; Blumenschine and Selvaggio 1988, 1991; Blumenschine 1995; Capaldo and Blumenschine 1994; Pickering and Egeland 2006). Dry breakages are often dominated by right angles, transverse outlines and jagged edges texture that mostly occur on mineralized archaeological bones and are usually attributed to the impact of sediment compaction static loading, animal trampling, rock falls, excavation and curation processes (Oliver 1989; Villa and Mahieu 1991; Outram 2001, 2002; Karr and Outram 2012).

The percentages of fracture angles and fracture outlines in the Loiyangalani and Magubike faunal assemblages were also compared to calibrated percentages in controlled experimental samples simulating hammerstone-only, hammerstone-to-carnivore and carnivore-only processing summarized in Marean and colleagues (2000:209, Table 2). The percentages were also compared to the archaeological faunal assemblages of known breakage histories of Sarrians and Fontbrégoua from southern France (Villa and Mahieu 1991). Sarrians is a late Neolithic site with a faunal assemblage broken *in situ* via sediment compaction, and Fontbrégoua represents a faunal assemblage broken while still fresh (see Figures 6.21, 6.22, 7.15, and 7.16). Regardless of the taphonomic agents involved (hominin or carnivore) in the fracture of the long bones while still in their nutritive state, experimental studies have demonstrated frequently yield similar proportions of green fractures usually in the region of around 85% (Marean et al. 2000:205).

Fragmentation patterns of the first and second phalanges were also evaluated. According to Jin and Mills (2011:1806), the overall breakage patterns of these elements can also yield robust evidence on prehistoric human behaviour, as their breakage usually do not produce percussion marks when fractured disarticulated. Splitting of the phalanges is also often considered as a measure of carcass exploitation intensity (see Bar-Oz 2004; Munro 2004; Munro and Bar-Oz 2005; Bar-Oz and Munro 2007; Adler and Bar-Oz 2009) and does not necessarily imply resource stress (Jin 2010; Jin and Mills 2011:1808).

To determine precisely the timeframe of breakage of the bones in the Loiyangalani and Magubike faunal assemblages, Fracture Freshness Index (FFI) was also evaluated following Outram (2001, 2002) protocol. To arrive at an overall FFI score, all long bone fragments including the first and second phalanges were studied for their fracture morphologies. The computation of the FFI score fundamentally relies on the analysis of each specimen attributes of the fracture angles, fracture outlines, and fracture edges (Villa and Mahieu 1991). Each specimen was given a score of between 0 and 2, for each of the three criteria above, and then the discrete scores later aggregated to get an overall FFI score for an individual specimen. A score of 0 was given to a specimen completely consistent with a "fresh fracture", 1 for a specimen with some "unfresh fracture" qualities present, and lastly a score of 2 for a specimen entirely dominated by "unfresh" characteristics. Excluded in the FFI study are the complete long bones and phalanges (Tables 6.17, 6.23, 7.17, 7.24; Figures 6.16 and 7.11). The total FFI score for each specimen often ranges between 0 and 6 (Outram 2001, 2002). Bones broken while fresh often yield a summation of individual scores of 0, 1, and 2. A score of 3 reflects an intermediate stage epitomizing fragments with both some evidence of "fresh" and "unfresh" fractures as the bone was progressively becoming dry. The FFI scores of 4 and 5 characterize the bones broken in a rather dry state more likely postdepositionally, and finally, a score of 6 signifies fragments with totally no evidence of fresh fracture. The average FFI score for each animal size class and for the entire faunal assemblages were also calculated (see Tables 6.23 and 7.24).

In order to achieve the primary goal of this study underlined in Chapter 1, the taphonomy of the faunal assemblages were initially evaluated followed by zooarchaeological analyses in the manner recently outlined and defended by Domínguez-Rodrigo and colleagues (2007c:27-32) in the studies of the Bed I archaeological faunal assemblages from Olduvai Gorge, Tanzania. Given the fact, the faunal assemblages studied originate from sites of markedly different nature (an open-air and a rockshelter) potentially each is a result of a unique depositional history. For convenience purpose and to provide an accurate picture of each faunal assemblage, results are presented in the next two chapters separately. The results are also routinely compared to published experimental and ethnoarchaeological datasets and on few occasions to meticulously studied archaeological faunal assemblages to facilitate interpretations of the results.

All data collected during the analysis of both faunal assemblages were entered into SPSS version 24 database, for further sorting and data analysis. Nonparametric statistical tests were preferably used in this study, as they are less prone to the effects of small sample sizes than the parametric tests. Spearman's rank order correlation coefficient (rho) was employed to test the quantitative validity of different pair-wise comparisons and to determine the statistical significance (*p*) thereof considered significant at ≤ 0.05. The Kolmogorov-sminorv test and Student's *t*-test were also used to examine the statistical differences between the datasets.

CHAPTER 6

LOIYANGALANI FAUNAL ASSEMBLAGE RESULTS

6.1. Introduction

This chapter presents detailed results for the Loiyangalani MSA faunal assemblage. Taphonomic aspects are initially underscored followed by the presentation of zooarchaeological results. Bone surface modifications are compared to several published datasets generated via experimental and ethnoarchaeological studies as well as to some meticulously studied archaeological faunal assemblages to fine-tune the reconstruction of the key taphonomic agent (hominin or carnivore) in the accumulation (Tables 5.5, 6.22, 6.23, 8.4; Figures 6.11-6.18 and 6.20-6.22).

6.2. State of Preservation of the Faunal Remains

The Loiyangalani MSA faunal assemblage is highly comminuted, much like in other Stone Age assemblages. Complete specimens are mainly comprised of a few isolated teeth and lower limb bones. These are typically more compact in nature, which makes them less prone to postdepositional destructive taphonomic processes (Tables 6.2, 6.17, 8.2; Figure 6.16). The calculated %whole that measures the extent of fragmentation in the archaeological faunal assemblage is 5.09 for the entire Loiyangalani mammalian sample designating skeletal parts have been subjected to heavy fragmentation (Lyman 1994; Wolverton 2002). The value for the small and large-sized animal subsamples is also very low (4.4 and 5.45 respectively) suggesting small-sized animal bones are relatively more intensively fragmented.

Specimens of different sizes also characterize the Loiyangalani faunal assemblage (Figures 6.1, 6.2, 6.4 and 6.5). Studied specimens had an average length of 1.74 cm, and approximately 18% of the total sample measured < 1 cm in maximum length. Specimens measuring > 5 cm only make up roughly by < 2% of the total sample. The majority of the specimens (about 80%) clusters between 1 and 4 cm in maximum length and suggest a consistent patterning in bone fracturing a practice that largely can be attributed to hominin bone marrow extraction practice (Voorhies 1969; Brain 1981; Gifford-Gonzalez 1989; Enloe 1993; Blumenschine 1995; Blumenschine and Selvaggio 1988, 1991; Pickering and Egeland 2006; Pickering et al. 2003, 2005, 2006). The overall, distribution of specimens by size in the faunal assemblage also clearly suggests an absence of the recovery, retention of large-sized specimens, and hydrodynamic sorting (Voorhies 1969; Payne 1972; Turner 1989; Marean 1998; Marean and Kim 1998; Marean et al. 2000, 2004). Faunal assemblages from archaeological sites located near or along rivers systems, as is a case for the Loiyangalani site are often characteristically biased towards the high proportion of large-sized specimens (Behrensmeyer 1975a, b, 1982; Pante and Blumenschine 2010).

Distributions of specimens by size broadly appear to be similar in the small and large-sized animal subsamples (see Figure 6.2). The overall distribution in the two subsamples is also normally distributed statistically (Kolmogorov-Sminorv two-sample test D=0.571, p=0.012). In the small and large-sized animal subsamples, specimens measuring < 1 cm in maximum length account for 11.11% and 2.22% respectively (Figure 6.2). There are notable differences recorded for the size classes of < 1 cm and 1-2 cm. Small-sized animal bones exhibit a high proportion of specimens in size class 1-2 cm, which decreases progressively in all the size classes above 2 cm. For the large-sized animals subsample, specimens are consistently more frequent in size class 3-4 cm and all the size classes above 4 cm (see Figure 6.2). Overall distribution of specimens by size suggests small-sized animal bones are more intensively fragmented.

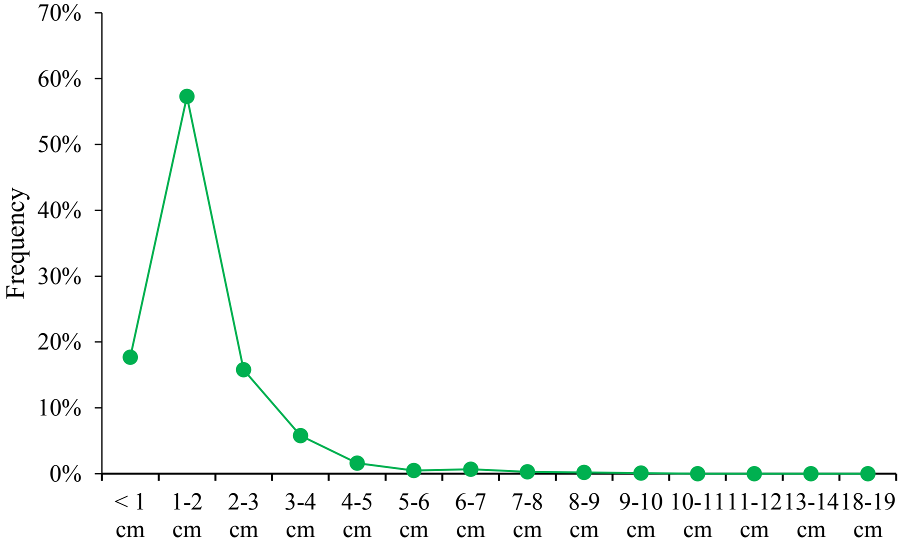


Figure 6.1. Distribution of Specimens in the Loiyangalani Faunal Assemblage.

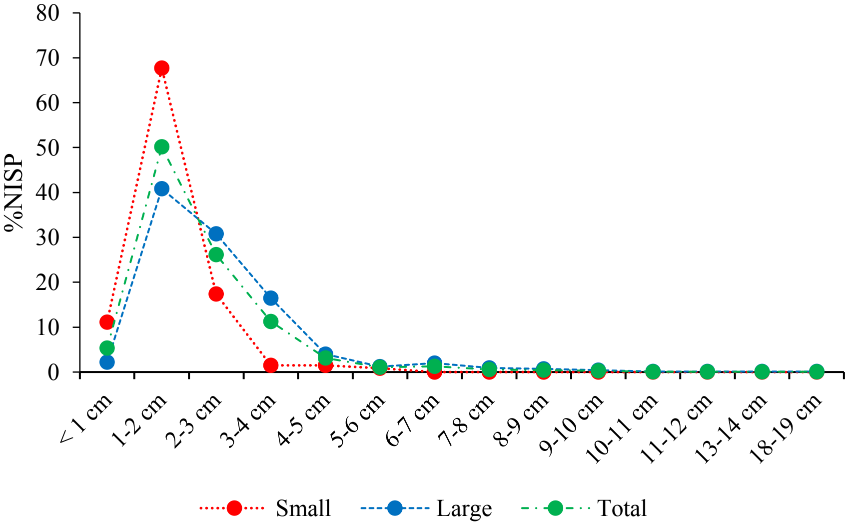


Figure 6.2. Distribution of Specimens by Animal Size.

The state of preservation of the faunal remains overall is excellent due to high soil pH (Figures 6.3-6.6). Of the 2,846 specimens for which state of preservation could be coded, 70.6% (*n*=2,010) displayed good preservation, 7.4% (*n*=212) moderate, and 21.9% *(n*=624) as poor. Bone cortical surface preservation also varied among specimens identified to skeletal parts (NISP=1,856 with teeth excluded). About 80.76% (NISP=1,499) were well-preserved, 6.47% (NISP=120) were moderately, and 12.77% (NISP=237) poorly preserved. The presence of numerous low-density skeletal parts including ribs, vertebrae, and pelves also attests the overall excellent state of preservation of the Loiyangalani faunal assemblage (Table 6.3; Figures 6.3, 6.5 and 6.6). Fish remains that are often fragile and weather more hurriedly because of their typical thin cortical thickness and tortoise carapace fragments were also noted well-preserved (see Figure 6.5 below). The moderately and poorly preserved specimens in the faunal assemblage mostly appear to mirror the effects of subaerial bone weathering, root-etching, and overall high degree of fragmentation. In this study, poorly preserved specimens were excluded in the study of bone surface modifications and tallies (Table 8.1). Among the mammalian specimens assigned to animal size classes, small-sized animals overall displayed relatively high excellent bone cortical surfaces preservation compared to the large-sized animals (74.03% versus 69.25% respectively). Figure 6.3 below presents the state of preservation of the skeletal parts identified and assigned to animal size classes.

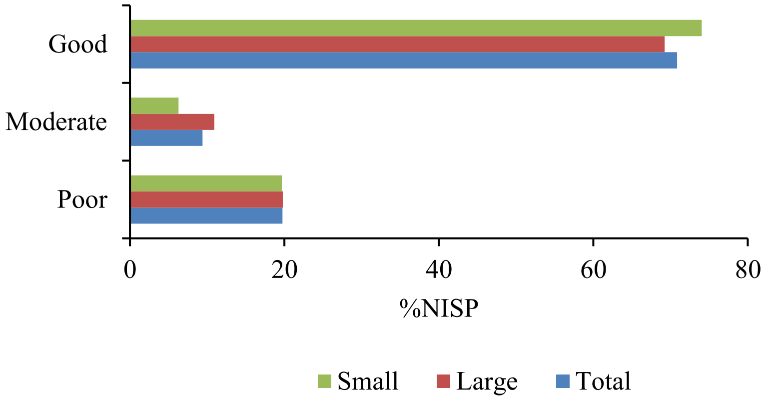


Figure 6.3. State of Preservation of the Loiyangalani Faunal Assemblage.

Figure 6.4. Some Faunal Remains from Loiyangalani Site.

Figure 6.5. Some Fish and Tortoise Carapace Fragments from Loiyangalani Site.

The Loiyangalani faunal assemblage exhibited different bone weathering stages with stage 2 being the most common type (Tables 6.1, 8.1; Figures 6.6 and 8.1). Some specimens exhibited stage 3, 4 and a very few were in stage 5, suggestive of different deposition moments of the faunal assemblage (Behrensmeyer 1978). Specimens weathered beyond stage 2 often exhibited exfoliated cortical surfaces and rough cortical texture. Of the total sample, only 13 specimens belonged to weathering stage 5, and no specimen was registered in stage 1.

The general trend of bone weathering in the Loiyangalani faunal assemblage is mostly biased towards the medium weathering profile (corresponding to Behrensmeyer's stages 2 and 3). This suggests the majority of the specimens remained on the ground for up to 4 years and were also exposed to the agents of alterations for a relatively short time (Behrensmeyer 1978; Andrews 1995). The proportion of specimens in high weathering profile is comparatively low which may also point to the possible rapid sediments accumulation and stratification at the site (Figure 6.6). Severe bone weathering and post-burial diagenetic processes usually weaken the bones, makes them more susceptible to breakage, and may hamper detection of bone surface modifications (Klein and Cruz-Uribe 1984; Thompson 2005, 2010; Monahan 1996). Table 6.1 below summarizes bone-weathering stages for the entire Loiyangalani faunal assemblage, and Figure 6.6 for specimens identified to skeletal parts (NISP) and assigned to animal size classes.

Table 6.1. Bone Weathering Stages in the Loiyangalani Faunal Assemblage.

Weathering Stages				Total
2	3	4	5	
1,464 (66.1%)	149 (6.7%)	590 (26.6%)	13 (0.6%)	2,216 (100%)

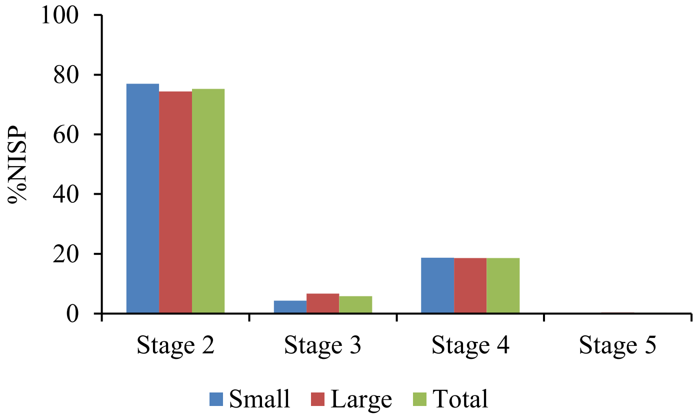


Figure 6.6. Bone Weathering Stages in the Loiyangalani Faunal Assemblage.

A total of 144 specimens in the Loiyangalani faunal assemblage had their cortical surfaces covered by concretions. However, the majority had < 5% of their total cortical surface area covered. Of the total sample examined, only 11 specimens exhibited traces of concretions at a rate of > 50% of their total surface area (Table 8.1). A single specimen was recorded as entirely covered. Concretions adhering on specimens appear to have little impact in the detection of bone surface modifications. On the other hand, root-etchings were also noted to affect a considerable number of specimens, which consequently made the detection of bone surface modifications challenging (Tables 6.18, 6.19 and 8.1).

As has been emphasized in Chapter 3, Loiyangalani is located along a river floodplain (Figures 3.1, 3.2 and 5.2). The proximity of the site to a river points to a possibility bone fragments discarded were potentially washed away and buried at some distance. An evaluation of the integrity of the Loiyangalani MSA faunal assemblage was indispensable. Identified skeletal parts were grouped according to Voorhies (1969) Groups of susceptibility to fluvial transport (see Figure 6.7 below). The results exhibited high proportions of the characteristically moderate transportable Group II skeletal parts including long bones (NISP=600, 49.5%) followed closely by the easily fluvial winnowed Group I skeletal parts including ribs and vertebrae (NISP=460, 37.95%). The next abundant are skeletal parts assigned to Group I&II including scapulae, ulnae, and phalanges (NISP=89, 7.34%) and Group III with skeletal parts including skulls and mandibles that are characteristically the lag deposit (NISP=58, 4.79%). Voorhies Group II&III takes the last position (NISP=5, 0.41%). Small and large-sized animal subsamples also share similar proportions trend of the Voorhies Groups (see Figure 6.7 below). Overall, skeletal part representation is mostly dominated by the elements belonging to Groups I, I&II and II, which suggest the Loiyangalani MSA faunal assemblage has not been significantly affected by hydrodynamic sorting and is also suggestive was rather rapidly entombed.

The Fluvial Transport Index (FTI) developed by Frison and Todd (1986), also permits to better determine the potential impact of the hydrodynamic process in the configuration of the archaeological faunal assemblage. Strong negative but statistically significant correlation coefficient is recorded between %MAU against their corresponding complete bone FTI values for the small-sized animals subsample (Spearman's rho: r_s= -0.591, p=0.016). The results of the pair-wise comparison for the large-sized animals subsample are also negative but not statistically significant (Spearman's rho: r_s= -0.307, p=0.248). Overall, the results also do not suggest significant fluvial disturbances of the Loiyangalani faunal assemblage (Figure 6.8).

Of note, the role of water in dispersing the Loiyangalani faunal assemblage is underscored by a strong positive and statistically significant correlation coefficient between %MAU and Saturated Weight Index (SWI) for the small-sized animals subsample (Spearman's rho: r_s=0.726, p=<0.010). The results demonstrate small-sized animal bone fragments were moved in an unsaturated (dry) state (Behrensmeyer 1975a, b, 1982; Lyman 1994). There is also a strong positive and significant correlation coefficient between %MAU and SWI values for the large-sized animals subsample (Spearman's rho: r_s= 0.686, p=<0.010), again denoting water has also played a significant role in the dispersal of the large-sized animal bones at the site in their dry state (Figure 6.9). Given the nature of the site, certainly water did not disperse the bone fragments to a great distance. The landscape at the site is predominantly flat and typical of the Serengeti National Park plains (Sinclair 1979b). Most elements in the small and large-sized animal subsamples also have SWI values of < 50 suggesting an average transportability of the Loiyangalani archaeological faunal assemblage.

The results underscored above are unexpected because the Loiyangalani site is located along a floodplain setting. The presence of skeletal parts belonging to all the Voorhies Groups despite their differences in density values mainly of Groups I and II, implies the Loiyangalani MSA faunal assemblage is not winnowed out, and significant bone fragments loss due to hydrodynamic sorting is more unlikely (Voorhies 1969; Behrensmeyer 1975a, b, 1982; Lyman 1994; Lam et al. 1999). This may also explain the relatively low incidences of edge rounding (abrasion) of the specimens in the faunal assemblage (see Table 8.1). About 18.05% and 10.99% of the total sample and total NISP respectively displayed smoothed fracture edges typical of the water-rolled specimens (Shipman and Rose 1983). The fact that, the Loiyangalani faunal assemblage also preserves numerous small-sized specimens also suggests low-energy fluvial deposition context (Figures 6.1 and 6.2). Accordingly, the overall autochthonous nature and integrity of the Loiyangalani MSA faunal assemblage are not questionable (Behrensmeyer 1975a, b, 1982; Pante and Blumenschine 2010). Further evidence for a minimal postdepositional disturbance of the Loiyangalani archaeological assemblage is drawn from the analysis of the lithic assemblage. As Thompson and colleagues (2004:7) classify it “the MSA artefact assemblage consists predominantly of stone tools, most of which are unabraded, but some have moderate to heavily abraded surfaces.”

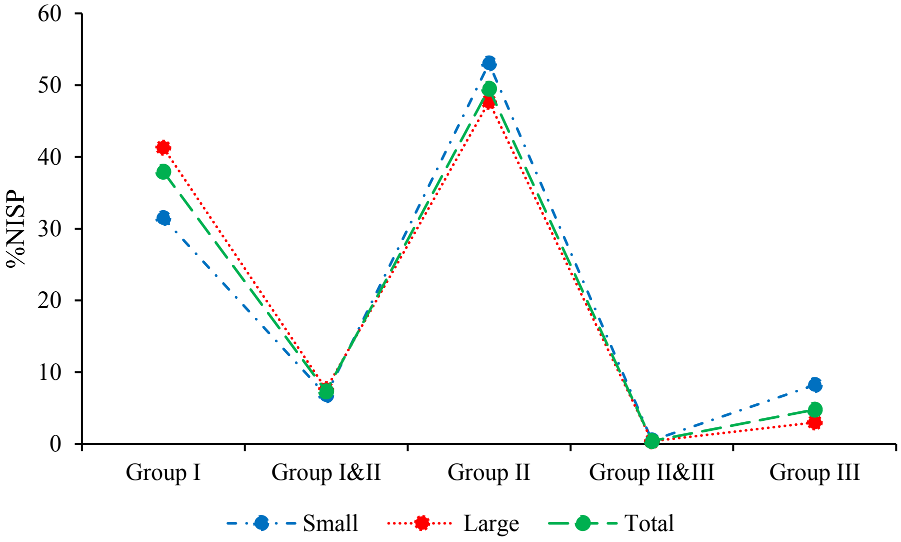


Figure 6.7. Voorhies Groups of Susceptibility to Fluvial Transport by Animal Size.

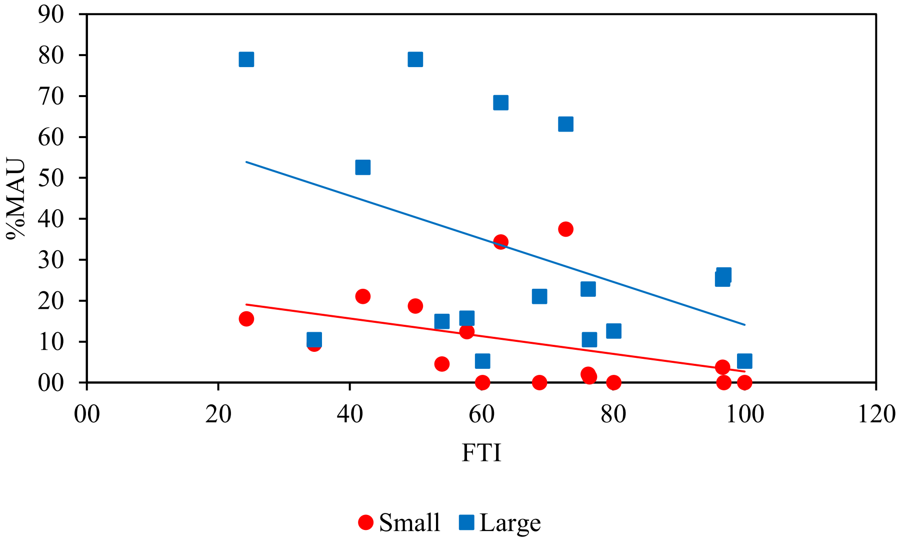


Figure 6.8. Bivariate Scatterplot between %MAU and FTI Values by Animal Size.

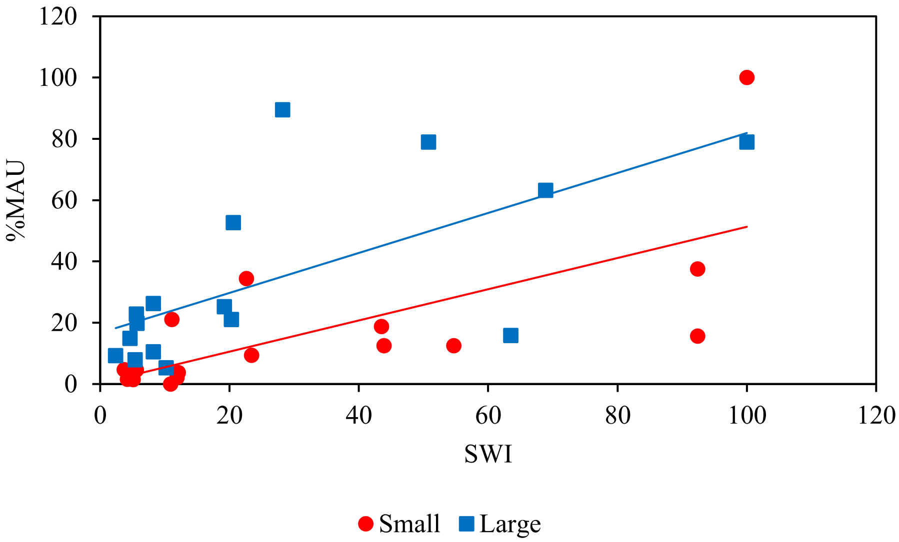


Figure 6.9. Bivariate Scatterplot between %MAU and SWI Values by Animal Size.

A total of 24 small compact bones were identified to skeletal part in the Loiyangalani faunal assemblage (Tables 6.2 and 6.3). The ratio of the complete (CO) and almost complete (ACO) to the fractured small compact bones (FR) is markedly high. The Completeness Index of the Loiyangalani faunal assemblage is 91.67%, which suggests has endured marginal postdepositional fragmentation (see Table 6.2 below for the details). Only two specimens of the total small compact bones sample were fractured which denotes some negligible diagenetic breakage occurred following deposition of the bones at the site (Marean 1991; Villa et al. 2004). The subsections below provide detailed taphonomic and zooarchaeological results for the Loiyangalani faunal assemblage.

Table 6.2. Completeness Index of the Loiyangalani Faunal Assemblage.

Size	Total Compact Bones	NISP CO+ACO	%CO+ACO	NISP FR	%FR
Small (1-2)	2	1	50	1	50
Large (3-4)	22	21	95.45	1	4.55
Total (1-4)	24	22	91.67	2	8.33

6.3. Skeletal Part Representation

The faunal remains analyzed from Loiyangalani consisted of 3,190 specimens. A total of 2,070 specimens were confidently identified to skeletal parts, and 1,120 were categorized as unidentified (Tables 6.3, 6.8 and 8.2). The majority of the skeletal parts belonged to terrestrial mammals, but others present included remains of fish, tortoise, crocodile, and bird (Tables 5.1, 6.3, 6.8, 6.9; Figures 6.4 and 6.5). Overall the identification frequency was relatively high at approximately 65% (Table 8.2). The average number of identified skeletal parts per m^3 of sediments is 218. The taxonomic representation is also high, and several skeletal parts represent the major five anatomical segments of the small and large-sized animal complete carcasses (Figure 6.10). Tables 6.3 and 6.6 below summarize skeletal part representation in the Loiyangalani faunal assemblage.

Mammal postcranial elements dominated the identified skeletal parts (Tables 6.3 and 6.6). The ratio of the cranial to postcranial elements is 0.18 for the entire faunal assemblage, which appears to be notably low. For the small-sized carcasses subsample, the ratio is 0.27, which matches the known value of 0.27 for a complete bovid carcass. The ratio also suggests small-sized carcasses were transported complete or almost complete as they often do not require exhaustive processing and defleshing at the kill sites before transporting them (Yellen 1977, 1991; Oliver 1993; Bunn and Kroll 1986; Bunn and Ezzo 1993; Bunn et al. 1988; O'Connell et al. 1988a, 1990, 1992; Lupo 1994, 2001, 2006; Stiner 1991a, 1994; Monahan 1998; Lupo and O'Connell 2002). For the case of the large-sized carcasses subsample, the ratio is 0.14, which is also very low. Numerous ethnoarchaeological studies have shown that skulls of the large-sized animals are typically heavy to carry, contain marginal food resources and are frequently discarded at the butchery sites (Binford 1978, 1981; Bunn et al. 1988; O'Connell et al. 1988a, 1990, 1992; Lupo 2001, 2006; Lupo and O'Connell 2002; Monahan 1998). Other taphonomic factors that may explain the low ratio for the large-sized animals subsample include the differential preservation of the individual skeletal parts as a function of their bone mineral density and the high degree of fragmentation in the faunal assemblage that potentially reduced the less dense skull elements to unidentifiable fragments (Lyman 1994; Stiner 1994; Lam et al. 1999).

All major five anatomical segments of a complete carcass are also represented in different proportions in the faunal assemblage (see Tables 6.3, 6.6; Figure 6.10). Mammalian skeletal part representation irrespective of the animal size class appear to be biased towards the axial bones (vertebrae, ribs, pelves, and scapulae) by 39.8% (NISP=548) followed by lower limb bones by 24.04% (NISP=331). The upper limb bones (humerus and femur) typically with the highest amount of meat attached are slightly represented by few elements 8.86% (NISP=122) compared to the intermediate limb bones (radius and tibia) by 11.84% (NISP=163). Overall, the axial and upper appendicular limb bones dominate the Loiyangalani MSA faunal assemblage by 60.49% (NISP=833) suggesting hominin selective transport of the carcass parts rich in nutrition values (Binford 1978; Bunn et al. 1988; Lupo 2006; O'Connell et al. 1988a, 1990; Monahan 1998). The same general picture is also evident in the small and large-sized animal subsamples (see Tables 6.3 and 6.6 for the details). The results are broadly in agreement with the documented ethnoarchaeologically carcass parts transport patterning (Lupo and O'Connell 2002:88, Table 1) for a Hadza campsite faunal assemblage. Here the axial and upper appendicular elements (upper and intermediate limb bones) accounted for approximately 72% of the total NISP.

One general pattern that also appears independent of the animal size class in the Loiyangalani faunal assemblage is a markedly lower representation of the cranial elements (skulls, maxillae, mandibles, and dentition) and lower limb bones (metapodials, carpals and tarsals). The cranial and lower limb bones are represented by a combined percentage of 39.51% (NISP=544) of the total mammalian NISP. A similar broad picture also prevails in the small and large-sized carcass subsamples (see Tables 6.3 and 6.6 for the details). The overall skeletal part representation in the Loiyangalani MSA faunal assemblage relative to their expected occurrences in a complete carcass do not seem to mirror the Klasies River MSA faunal assemblage pattern reported by Binford (1984) typically dominated by the head-and-foot elements. For that reason, an alternative explanation must be considered. As shown graphically in Figure 6.10 below, skeletal part abundance is quite complete for both animal size classes (small and large-sized) as measured by %MAU and can be mostly explained by hominin economic motives in the transport of the carcass parts from the butchery sites (Binford 1978, 1981; Metcalfe and Jones 1988; Bunn et al. 1988; O'Connell et al 1988, 1990; Stiner 1991a, 1994; Marean 1998; Marean and Frey 1997; Marean and Kim 1998; Marean and Assefa 1999; Marean et al. 2000, 2004; Bartram and Marean 1999). Details on skeletal part representation by animal size and per major anatomical segment of a complete carcass are summarized in Table 6.6 below.

Long limb bone fragments and rib shaft fragments constituted the majority of the anatomically and taxonomically identified mammal specimens making up about 46% of the total NISP. Isolated teeth that endure density-mediated attrition accounted for 7%. The mandibles are poorly represented (NISP=12). Other skeletal parts were also identified in varying low proportions ranging between 0.1 and 2.5% of the total NISP. The phalanges are notably scarce in the assemblage especially the medial and distal with a total NISP of eight each (Table 6.3). Carpals and tarsals are also less frequent represented. Identified skeletal parts by animal size as measured by NISP counts also appear to be more evenly distributed for the small-sized carcasses subsample (*E*=0.79 versus 0.70 in the large-sized carcasses subsample).

Long bone fragments remarkably dominated the postcranial subsample (NISP=559; 40.6% of the total postcranial bones sample) suggesting MSA hominins selectively transported them. Metacarpals and metatarsals are exceptionally abundant compared to the other long bones (Tables 6.3 and 6.4). The metapodial fragments are often easier to identify to skeletal parts based on their cortical thickness and general cross section (Barba and Domínguez-Rodrigo 2005; Pickering et al. 2003, 2005, 2006). The tibiae are also better represented as measured by both NISP and %MAU values. Tibia fragments are also simple to identify to skeletal parts based on marked landmarks on its shaft.

Long bone midshaft fragments are remarkably numerous in the Loiyangalani faunal assemblage and their less dense and grease-laden epiphyseal portions are scarce. The midshaft fragments are typically dense and frequently survive better both post-discard carnivore ravaging and density-mediated attrition at higher rates than their epiphyseal ends (Marean and Spencer 1991; Marean et al. 1992, 2000, 2004; Blumenschine and Marean 1993; Lyman 1994; Lam et al. 1999; Pickering et al. 2003).

Long bone midshaft fragments are also represented by higher NISP, MNE, MAU and %MAU estimates and their epiphyseal portions are evidently underrepresented (Table 6.4). The ratio of the epiphyses (*n*=35) to the midshaft fragments (*n*=518) for the entire faunal sample excluding the complete bones is 0.07. For the small and large-sized animal subsamples, the ratio is 0.03 and 0.09 respectively. Of note, the ratios do not match the range reported for the experimental hammerstone generated faunal samples which often range between 0.33 and 0.70, and that of 0.19 for a hyena den suggesting the presence of a strong taphonomic bias in the faunal assemblage (see Monahan 1996:101; Table 3).

An examination of the ratio of the proximal (low-density portion) to the distal (high-density portion) of the humerus and tibia, which also give an index of the degree of attrition an archaeological faunal assemblage has undergone following Binford (1981:219), is also too low and only at 0.11. Based on NISP values, the humerus and tibia distal portions are represented in relatively higher rates (6 and 3 respectively) than their corresponding proximal portions (0 and 1 respectively), again suggesting the Loiyangalani faunal assemblage has suffered significant postdepositional attrition (Table 6.4). The general poor representation of the long bone epiphyseal portions may suggest a combination of postdepositional destructive taphonomic processes that may include the impact of carnivore ravaging and density-mediated attrition.

To gauge the intensity of epiphyseal ends deletion in the Loiyangalani faunal assemblage, long bone portions representation were compared both against their corresponding bone portion-specific %survivorship values of a carnivore-ravaged faunal sample and against their BMD values (Lyman 1994; Lam et al. 1999; Marean and Spencer 1991; Marean et al. 1992). Results of the pair-wise comparisons yielded strong positive and very significant correlation coefficients for both animal size classes (Spearman's rho: small-sized, r_s=0.707, p=0.033; and for large-sized carcasses, r_s=0.940, p=<0.010). Spearman's rho also confirms the presence of a strong and statistically significant subsequent density-mediated attrition that also affected the bones of both animal size classes (small-sized, r_s=0.515, p=0.029; and large-sized carcasses, r_s=0.593, p=<0.010). The results above show significant post-discard carnivore intervention and later density-mediated attrition on long bone epiphyseal portions deletion to the extent as seen in the Loiyangalani faunal assemblage (see Table 6.4 below for the details).

Based on overall %MAU values, the element with the highest abundance of the epiphyseal portions is the distal radius followed by the proximal metatarsal by 36.84% and 31.59% respectively. The distal tibia also has a moderate abundance of 15.79%. The rest of the long bones have lower proportions of < 5.5%. Entirely missing in the faunal assemblage are the proximal parts of the humerus, radius, and metacarpal (Table 6.4). The distal parts of the humerus and metacarpal are also missing. When the overall abundance estimate is expressed by carcass size, long bone epiphyseal portions are totally missing in the small-sized animals subsample. In the large-sized animals subsample the element with the highest representation of epiphyseal portions again is the distal radius (%MAU=36.84) followed closely by the proximal metatarsal (%MAU=31.59).

To evaluate MSA hominins transport strategies of the carcass parts at the Loiyangalani site, %MAU considering all skeletal parts were correlated against their standardized food utility index (SFUI) values (Metcalfe and Jones 1988). Figure 6.11 below displays bivariate scatterplots for both small (size 1-2) and large-sized (size 3-4) carcass subsamples.

Plotting %MAU against SFUI values for the small-sized carcasses gave a very marginal positive but statistically insignificant correlation coefficient between the two variables (Spearman's rho: r_s=0.018; p=0.950). Nevertheless, a positive correlation coefficient albeit weak one suggests MSA hominins at the Loiyangalani site selectively transported the carcass parts with high nutritional values (Figure 6.11). However, plotting %MAU against their BMD values for the small-sized carcasses subsample provided a strong positive and statistically very significant correlation coefficient (Spearman's rho: r_s=0.727, p=<0.010), which indicates the two sets of data are strongly correlated each other (Figure 6.12). This implies density-mediated attrition has significantly dictated the abundance of the small-sized animal bones at the site.

For the large-sized carcasses, the plot of %MAU against SFUI values also yielded a relatively moderate positive but also statistically insignificant correlation coefficient (Spearman's rho: r_s=0.115, p=0.672). The results suggest a positive relationship between the two sets of data that also denotes MSA hominins selective transport of the high utility carcass parts. However, results of the test for a relationship between %MAU and BMD values for the large-sized carcasses subsample yielded a weak positive and statistically significant correlation coefficient (Spearman's rho: r_s=0.360, p=0.033). The results again show density-mediated attrition also governed the survival of the large-sized animal bones at the site.

To evaluate the potential impact of carnivore on skeletal part abundance in the Loiyangalani faunal assemblage, %MAU values involving all elements were also correlated against their corresponding %survivorship values derived from a hyena-ravaged faunal sample (Marean and Spencer 1991; Marean et al. 1992). The relationship between the two sets of data yielded a marginal negative but statistically insignificant correlation coefficient for the small-sized carcasses subsample (Spearman's rho: r_s= -0.013, p=0.954). The negative correlation coefficient alone cannot be robustly used to infer carnivore intervention of the small-sized animal bones at the site. In the case of the large-sized carcasses subsample, the correlation coefficient is weak positive but statistically significant (Spearman's rho: r_s=0.413, p=0.045). The results denote the carnivores ravaged the large-sized animal bones significantly at site post-discard. Carnivore damage and rodents gnaw marks were also registered on skeletal parts of the small and large-sized animals but overall less severe (see Tables 6.18-6.21; Figures 6.17 and 6.18). Of note, skeletal parts that are expected not to persist post-discard carnivore ravaging including ribs, scapulae, and pelves are also represented in relatively high abundance in the Loiyangalani faunal assemblage (Blumenschine 1986a, b; Marean and Spencer 1991; Marean et al. 1992; Blumenschine and Marean 1993; Capaldo 1995; Faith and Behrensmeyer 2006; Pickering and Domínguez-Rodrigo 2006; Domínguez-Rodrigo and Organista 2007).

To further probe MSA hominins potential variability in prey encounter, field processing, and selective transport of the carcass parts, the high-survival-elements set MAU values were used to calculate the Shannon Evenness Index (*E*). Small-sized animals yielded an evenness index (*E)* of approximately 0.8, which denotes an uneven distribution of the skeletal parts with the main focus on the high-survival-elements (Tables 5.4, 6.3, 6.6 and 6.7). The evenness index value is consistent with an unbiased transport strategy that involves long distance transport of the carcass parts in direct relationship to their economic utility (Binford 1978, 1981; Metcalfe and Jones 1988;

Faith and Gordon 2007: 875-877; Faith et al. 2009:250). An uneven index for the small-sized carcasses subsample may be attributable to the small sample size (MNE=62) and the possibility of some postdeposition attritional taphonomic bias associated with the small-sized animal bones including density-mediated attrition and ravaging by the carnivores (Klein and Cruz-Uribe 1984; Blumenschine 1986a, b, 1987; Blumenschine and Marean 1993; Marean and Spencer 1991; Marean et al. 1992; Lyman 1994; Lam et al. 1999; Faith and Gordon 2007; Faith et al. 2009).

The large-size animals yielded an evenness index (*E*) of 0.9, which is an even distribution with an abundance of the high-survival-elements (Tables 5.4 and 6.7). The value also falls in the middle between an unbiased and bulk transportation strategy that also involves short distance transport of the complete or nearly complete carcasses. The results by extension may suggest participation of a large group of people in hunting parties in the way the Hadza process in the field and transport the large-sized carcass parts from the butchery sites (O'Connell et al. 1988a, 1990, 1992; Oliver 1993; Lupo and O'Connell 2002). The evenness value also grants a tentative support to the idea that the Loiyangalani site might, in fact, represent a basecamp or a near kill location like those documented among the Hadza (O'Connell 1997; O'Connell et al. 1992; Lupo and O'Connell 2002; Lupo 1994). According to O'Connell and colleagues (1992) the kill sites at wildlife intercept locations (like the Loiyangalani site) may be scattered over the areas of up to several thousand square meters or depending on the characteristic of the site itself. Loiyangalani (HcJd-1) appear to be one of the localities that the MSA hominins in the Serengeti National Park purposely selected over the landscape for the activities certainly related to the carcasses butchery, processing, and delayed consumption (see also Gifford-Gonzalez 1985:48-52).

Table 6.7 below presents Shannon Evenness Index (*E*) values and Spearman's rho results between %MAU of the high-survival-elements set against their economic usefulness (SFUI values). Small-sized carcasses subsample provided a Spearman's rho of 0.286(p=0.535). The value denotes a moderate positive and statistically insignificant relationship. Strong positive but also statistically insignificant correlation coefficient is also recorded for the large-sized carcasses subsample (Spearman's rho: r_s=0.335, p=0.417). The coefficient of determination r^2 ranges between 0.082 and 0.112 (Table 6.7). Of note, bone surface modifications recorded in the faunal assemblage also demonstrate the MSA hominins also intensively processed the carcasses of both small and large-sized ungulates (see Tables 6.11-6.17, 6.22, 6.23; Figures 6.13-6.16). When considered in sum, skeletal part representation in the Loiyangalani faunal assemblage is consistent with the scenario in which the MSA hominins transported complete or relatively complete carcasses after some field butchery with the main focus on the elements with high nutritional values and deposited at the site after consumption. Later carnivore intervened, and density-mediated attrition further played role postdepositionally in biasing the original skeletal part abundance (Figure 6.12).

Large-sized animals (size 3-4 bovids) overall dominate skeletal part representation at the Loiyangalani site by NISP counts (Table 6.3). The result correlates well their abundance in the East African grassland ecosystems whereby the large-sized frequently numerically outnumber the small-sized ungulates (Estes 1991; Owen-Smith 2006). The MNI counts as shown in Table 6.5 below also display a prevalence of the large-sized animals (MNI=14, NISP=899). The predominance of the large-sized animals (size 3-4 bovids) signifies the MSA hominins mainly foraged on the high-yield prey which would also imply a participation of a group of people in the hunt and meat sharing by other members of the group (Isaac 1971, 1978; Driver 1990, 1995; Winterhalder 1997; Alvard 2001; Kelly 2007; Stiner 1994; Stiner et al. 2009). Small-sized animals are overall represented in relatively low proportions (NISP=477, MNI=11).

Other taxa identified in the Loiyangalani MSA faunal assemblage collectively accounted for 32% of the total site NISP (Tables 6.8 and 6.9). Fish remains mainly of the freshwater catfish (*Claris* sp.) and mostly represented by their diagnostic cranial fragments, vertebrae, and elements of the pectoral girdle accounted for 27.44% of the total site NISP (Figure 6.3). The majority of fish specimens (approximately 80%) measured > 1 cm in maximum length. A total of 60 tortoise carapace fragments were also identified and accounted for roughly 3% of the total NISP (Tables 6.8 and 6.9). Remains of crocodile mainly comprised of their dentition (NISP=36). A single medium-sized bird specimen (a right coracoid, MNI=1) was also identified.

Table 6.3. Skeletal Part Representation in the Loiyangalani Faunal Assemblage.

Element/Size	Small				Large			
	NISP	MNE	MAU	%MAU	NISP	MNE	MAU	%MAU
Cranium	32	32	16	100	19	19	9.5	100
Mandible	4	3	1.5	9.38	8	2	1	10.53
Tooth	65	-	-	-	85	-	-	-
Atlas	2	2	2	21.05	5	5	5	52.63
Cervical	3	3	0.6	3.75	12	12	2.4	25.26
Thoracic	3	3	0.23	1.44	13	13	1	10.53
Lumbar	2	2	0.33	2.06	13	13	2.17	22.84
Sacrum	-	-	-	-	6	6	1.2	12.63
Rib	120	19	0.73	4.56	282	37	1.42	14.95
Scapula	17	11	5.5	34.38	31	13	6.5	68.42
Humerus	6	4	2	12.5	9	3	1.5	15.79
Radius	26	5	2.5	15.63	24	13	6.5	68.42
Ulna	2	1	0.5	3.13	2	2	1	10.53
Lunate	1	1	0.5	3.13	-	-	-	-
Metacarpal	19	-	-	-	73	4	2	21.05
Magnum	-	-	-	-	1	1	0.5	5.26
Sesamoid	-	-	-	-	2	2	1	10.53
Pelvis	9	4	2	12.5	30	14	7	73.68
Femur	48	5	2.5	15.63	59	15	7.5	78.95
Tibia	78	12	6	37.5	30	12	6	63.16
Fibula	-	-	-	-	1	1	0.5	5.26
Astragalus	-	-	-	-	5	5	2.5	26.32
Nav. Cuboid	-	-	-	-	3	3	1.5	15.79
Calcaneum	-	-	-	-	1	1	0.5	5.26
Cuneiform	-	-	-	-	1	1	0.5	5.26
Uniciform	-	-	-	-	1	1	0.5	5.26
Metatarsal	31	-	-	-	156	17	8.5	89.47
Phalanx 1	6	6	0.75	4.69	15	15	1.88	19.79
Phalanx 2	2	2	0.25	1.56	6	6	0.75	7.89
Phalanx 3	1	1	0.125	0.78	7	7	0.88	9.26

Table 6.4. Long Bones NISP, MNE, MAU and %MAU by Animal Size.

Element/Size	Small				Large			
	NISP	MNE	MAU	%MAU	NISP	MNE	MAU	%MAU
Humerus, Proximal	-	-	-	-	-	-	-	-
Humerus, Shaft	5	4	2	12.5	4	3	1.5	15.79
Humerus, Distal	1	-	-	-	5	-	-	-
Radius, Proximal	-	-	-	-	-	-	-	-
Radius, Shaft	26	5	2.5	15.63	17	6	3	31.59
Radius, Distal	-	-	-	-	7	7	3.5	36.84
Metacarpal, Proximal	-	-	-	-	-	-	-	-
Metacarpal, Shaft	18	-	-	-	69	4	2	21.05
Metacarpal, Distal	1	-	-	-	4	-	-	-
Femur, Proximal	-	-	-	-	3	1	0.5	5.26
Femur, Shaft	46	5	2.5	15.63	54	13	6.5	68.42
Femur, Distal	2	-	-	-	2	1	0.5	5.26
Tibia, Proximal	-	-	-	-	1	1	0.5	5.26
Tibia, Shaft	78	12	6	37.5	26	8	4	42.10
Tibia, Distal	-	-	-	-	3	3	1.5	15.79
Metatarsal, Proximal	-	-	-	-	7	6	3	31.59
Metatarsal, Shaft	29	-	-	-	145	10	5	52.63
Metatarsal, Distal	2	-	-	-	4	1	0.5	5.26

Table 6.5. NISP and MNI Counts by Animal Size.

Count	Size 1	Size 2	Size 3	Size 4	Total
NISP	90	387	619	281	1,377
MNI	2	9	8	6	25

Table 6.6. NISP by Major Anatomical Sections and Animal Size.

Section	Size 1	Size 2	Size 3	Size 4	Total
CRA	1	100	104	8	213
AXL	35	121	273	119	548
ULB	17	37	58	10	122
ILB	30	76	44	13	163
LLB	7	53	140	131	331
Total	90	387	619	281	1,377

Table 6.7. Shannon Evenness Indices and Correlation Coefficients between %MAU of the High-Survival-Elements Set vs. SFUI Values.

Animal Size	MNE	Evenness	r_s
Small (1-2)	62	0.79	0.286(p=0.535)
Large (3-4)	87	0.9	0.335(p=0.417)

Table 6.8. Other Taxa Identified in the Loiyangalani Faunal Assemblage.

Taxa	Element	NISP
Fish	Neocranium	547
	Dentary	8
	Supracleithrum	3
	Vertebra	9
Rodent	Tooth	27
	Humerus	1
	Metacarpal	1
Tortoise	Carapace	60
Crocodile	Tooth	36
Bird	Coracoid	1

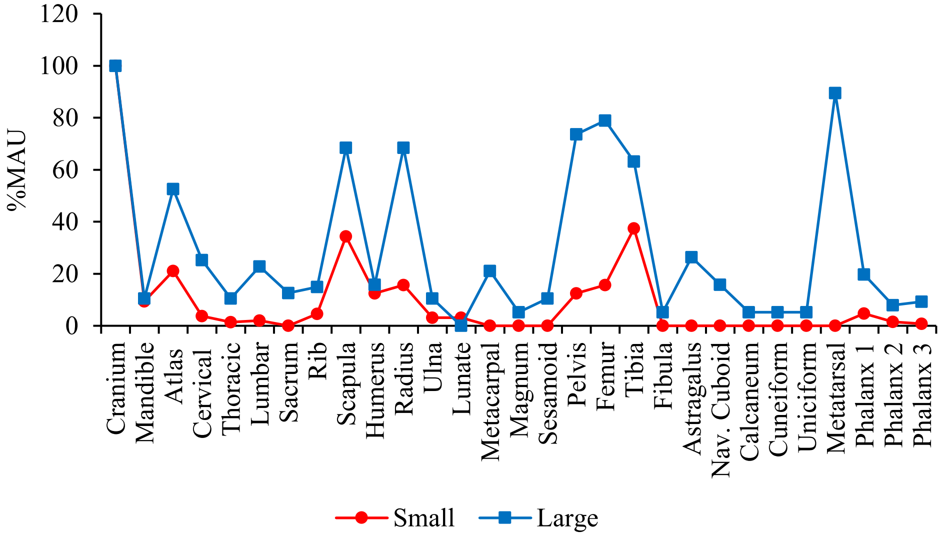


Figure 6.10. Skeletal Part Abundance by %MAU and Animal Size.

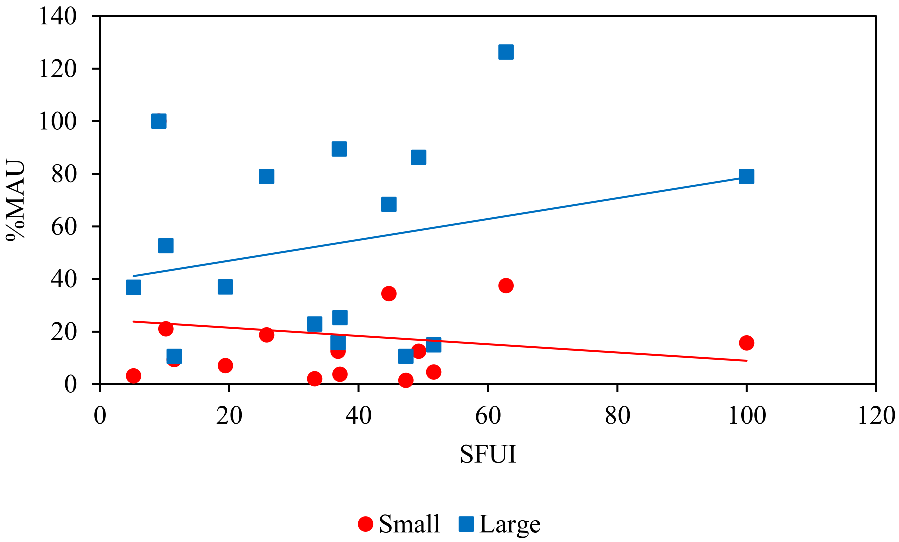


Figure 6.11. Bivariate Scatterplot between %MAU and SFUI for Small and Large-sized Animals.

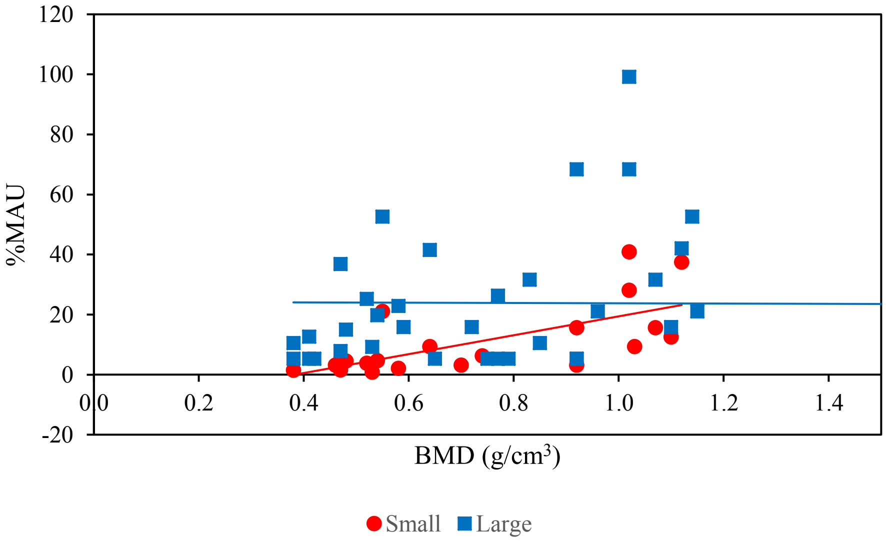


Figure 6.12. Bivariate Scatterplot between %MAU and BMD for Small and Large-Sized Animals.

6.4. Taxonomic Composition and Diversity

Table 6.9 below presents the major taxa identified in the Loiyangalani faunal assemblage. As is the case for the numerous African Plio-Pleistocene sites bovids dominate and accounted for approximately 66% of the total NISP (Tables 6.3 and 6.5). The ungulates are also strong evenly distributed between animal size classes 1 to 4 as measured by both NISP and MNI counts with the relatively higher contribution of the size 3 bovids (Tables 4.1 and 6.5). Previous studies of the faunal assemblages at the site have frequently reported bovids size 2 to dominate the NISP and MNI counts (Marean 1996:1; Thompson et al. 2004:5). Nonetheless, in this study medium-sized animals (size 3 bovids) that are typically the high-yield/high-ranked with an MNI of eight individuals are more abundant suggesting MSA hominins preferentially targeted them (Tables 6.3 and 6.5). Size 4 bovids are also represented in a relatively high proportion and provided an MNI estimate of six individuals (Table 6.5). Size 2 bovids are the second most abundant by NISP counts and yielded the highest MNI estimate of a total of nine individuals. Overall, the large-sized animals weighing up to 1,000 kilograms are the more plentiful in the Loiyangalani faunal assemblage, which correlates well their abundance in the Serengeti National Park today (Packer et al. 2005; Holdo et al. 2011).

Remains of a broad range of the small and large-sized animal species were identified by a very few diagnostic isolated teeth and skeletal parts mostly using Rikki Walker's (1985) guidebook and comparative skeleton collections. They include wildebeest (*Connochaetes taurinus*), hartebeest (*Alcelaphus buselaphus*), Thompson's gazelle and Grant's gazelle (*Gazella granti*). Other mammals also identified in relatively small proportions included eland (*Taurotragus oryx*), buffalo (*Syncerus caffer*), zebra

(*Equus grevyi*) and warthog (*Phacochoerus africanus*). The taxonomic spectrum of the identified taxa mirrors the diversity of known animal species that are commonly associated with the Serengeti National Park grassland setting today.

Microfaunal remains were exclusively composed of rodents (*Thryonomys swinderianus*) mostly represented by their isolated dentition and a few long bones representing a total of ten individuals (Tables 6.8 and 6.9). Rodents often reside in a wide variety of habitats including open grasslands and bush; and these most likely entered the Loiyangalani faunal assemblage on their own, given the fact that they often live in burrows (Aluko et al. 2015). A medium-size bird coracoid along with the ostrich eggshell fragments (*n*=120) constitutes the remains of birds at the site from the MSA deposits. However, exploitation of birds at the site is not immediately clear given the relatively small sample size of the skeletal parts identified. In addition, it is also unclear whether MSA hominins at the site consumed the contents of the large ostrich eggs. A fuller understanding of the bird contribution to the diet at the site certainly awaits recovery and identification of more bird bone fragments.

Other taxa identified in the Loiyangalani faunal assemblage included the aquatic and semi-aquatic species such as fish, tortoise, and crocodiles and jointly make up 32% of the total NISP (Tables 6.3, 6.8 and 6.9). Of note, fish are the second most abundant taxa making up approximately 27% of the total NISP and were distributed evenly down the MSA deposits. Leopard tortoises (*Geochelone pardalis babcocki*), which are slow-moving game, accounted for approximately 3% of the total NISP. Isolated crocodile (*Crocodylus niloticus)* teeth represent the second common reptile taxon making up roughly 2% of the total NISP. In open-air contexts like at the Loiyangalani site, crocodiles might be attracted by the smell of animal flesh killed by hominin or carnivore and/or may have died out there naturally. Land snails shells were also recovered but less frequent. Land snails shells were typically small in size compared to those recovered at Magubike rockshelter.

Table 6.9. Major Faunal Groups Documented at Loiyangalani Site.

Taxa	NISP	%NISP
Bovid	1,361	65.75
Suid	9	0.43
Equid	6	0.29
Crocodile	36	1.74
Tortoise	60	2.9
Rodent	29	1.41
Fish	568	27.44
Bird	1	0.05
Total	2,070	100

6.5. Mortality Profile

A mortality profile was generated from the analysis of the epiphyseal fusion stages and provides very coarse information on the age at death of the prey hunted at the Loiyangalani site. Complete long bones were virtually missing, due to the high degree of fragmentation in the faunal assemblage (Tables 6.4, 6.22, 6.23 and 8.2). Only 70 specimens, mainly long bone fragments, had at least one of their epiphyseal ends (proximal or distal) present to record for the state of fusion.

From the total sample of 70 specimens, 56 had fused and 14 unfused epiphyseal ends either proximal or distal with the majority belonging to the large-sized animals. Using full fusion as a measure of maturity as defined above, about 18.18% in the small-sized animals subsample are juveniles, and 81.82% are prime-adults by NISP counts. For the case of the large-sized animals subsample that are typically the high-yields/high ranked prey, prime-adults are represented in slightly lower proportion of 79.17%, and juveniles accounted for the remaining 20.83% of the total NISP counts. Epiphyseal fusion based on MNI counts for each animal size and age class also demonstrates a similar broad pattern widely biased towards the prime-adult individuals (Tables 6.5 and 6.10). The abundance of prime-adults in the archaeological faunal assemblages is commonly cited as one of the evidence of hominin selective and effective hunting of prey (Klein 1982; Klein and Cruz-Uribe 1983, 1984; Stiner 1990, 1991a, b, 1994; Gaudzniski and Roebroeks 2000). This observation is also fully supported by the overall skeletal part representation and abundance of anthropogenic bone surface modifications in the faunal assemblage (Tables 6.3, 6.6, 6.11-6.17; Figures 6.13-6.16 and 6.20-6.22).

Of note, the percentage of the prime-adults in the Loiyangalani faunal assemblage as recorded by both NISP and MNI counts fall well above the rate expected in a living population. In the Serengeti National Park, the percentage of the prime-adult ungulates in a living population often ranges between 15 and 18% (Estes 1991; Owen-Smith 2006). Consequently, mortality profile datasets in the Loiyangalani MSA faunal assemblage should be treated with caution (Klein and Cruz-Uribe 1984). However, the observed pattern may be an artefact of the small sample size, given that only 70 specimens were available for the analysis, and likely may be explained by the high degree of fragmentation in the faunal assemblage (Table 8.2). The underrepresentation of the juveniles may be attributed to the impact of both carnivore ravaging and density-mediated attrition on their skeletal parts (Klein and Cruz-Uribe 1984; Blumenschine 1986a, b, 1987, 1991; Lyman 1994; Marean 1995; Munson 2000; Munson and Marean

2003). Nonetheless, mortality profile datasets for the Loiyangalani MSA faunal assemblage at least serve to provide a general quantitative picture of the age at death of the hunted mammalian prey with the prime-adults being the most prevalent. In addition, mortality profile datasets also suggest more than 75% of the hunted prey at the Loiyangalani site at least had an age of above one and two years for the antilopini (such as Thompson's gazelle, Grant's gazelle, and dik-dik) and alcelaphini (such as in wildebeest, topi, and hartebeest) respectively (Klein and Cruz-Uribe 1984).

Table 6.10. Epiphyseal Fusion Data for the Loiyangalani Faunal Assemblage.

Animal Size	Juvenile		Prime-Adult	
	NISP	MNI	NISP	MNI
Size 1	-	-	4	1
Size 2	4	1	14	5
Size 3	6	1	25	3
Size 4	4	1	13	4
Total	14	3	56	13

6.6. Bone Surface Modifications

The overall excellent preservation of the Loiyangalani faunal assemblage made it possible to diagnose various human and nonhuman surface modifications on different skeletal parts and animal size classes (Tables 6.1, 6.2, 8.1; Figures 6.3-6.6, 6.15 and 6.16). A total of 746 specimens exhibited at least a single type of bone surface modification that also offers an opportunity to investigate hominin and carnivore interactions with the faunal remains at the site while still in their nutritive state. Tables 6.11 and 6.18 below summarize the types and frequencies of the human and nonhuman-induced surface modifications recorded in the faunal assemblage.

6.6.1. Human-Induced Modifications

Evidence of human-induced surface modifications attributable to different stages of carcass reduction and processing into consumable parts including cut marks, percussion marks, and burning were recorded in the Loiyangalani faunal assemblage. The most common were cut marks followed by percussion marks. Burning, however, is far less common (Table 6.11). The cut marks and percussion marks inflicted on the bone fragments forge the behavioural links between the lithic and faunal assemblages at the site.

A total of 144 specimens preserved cut marks resulting from the MSA hominins manipulation of the meat-bearing bones of the small and large-sized animals (Tables 6.11-6.17). These were recorded on 134 identified skeletal parts and only ten on unidentified specimens. The overall percentage of cut-marked mammalian skeletal parts for the entire assemblage is 10.43% (teeth which are unlikely to be modified during butchery process excluded). For the small and large-sized animal subsamples, the percentage is 8.25% and 11.53% respectively (Tables 6.11 and 6.12). The relatively high proportion of cut-marked elements in the large-sized animals subsample conceivably implies were subjected to intensive field processing at the kill site before transport (Yellen 1977, 1991; Binford 1978, 1981; Bunn and Kroll 1986; Bunn et al. 1988; Lyman 1987a; O'Connell et al. 1988a, 1990, 1992; Oliver 1993; Lupo 1994, 2001, 2006; Lupo and O'Connell 2002; Monahan 1998; Nilssen 2000).

Cut marks are preserved on different skeletal parts in the faunal assemblage from the skull to the feet (see Table 6.11; Figure 6.13). Cut marks were more frequent on the ribs that also have significant amount of meat attached to them (Binford 1978, 1981;

Metcalfe and Jones 1988; Domínguez-Rodrigo 1997a-c, 1999a). The majority of the cut marks preserved on the ribs are linked to the filleting/deboning, and those recorded on the ventral sides of some ribs (relatively few) are ascribed to the evisceration process (Binford 1978, 1981; Nilssen 2000; Lyman 1987a, 1994). A few vertebrae, including atlas, cervical, and lumbar were also cut-marked preferentially on their caudal and cranial articular facets, which may be related to the disarticulation from the body and filleting of the carcasses. Slicing marks recorded on the lateral process of the lumbar vertebra of a size 4 bovid denote retrieval of the abundant meat package located on the hump area. Cut marks on the pelves (neck of the acetabulum) and scapulae are also attributable to the filleting episode. A mandible ramus fragment belonging to a medium-sized animal (size 3 bovid) preserved a single cut mark on the outer face is also attributed to the skinning episode (Nilssen 2000). A total of 4, proximal and medial phalanges also exhibited transversely orientated cut marks near their proximal joints possibly resulting from skinning operations (Binford 1978, 1981; Nilssen 2000). Cut marks on the metapodials are mostly attributed to the skinning (Tables 6.11 and 6.13). Notably, very few cut marks were recorded on the cranial bones, and these may be also related to the skinning operations (Figure 6.13). The majority of cut marks in the Loiyangalani faunal assemblage were inflicted on long bone fragments accounting for 56.25% of the total cut marks bearing specimens.

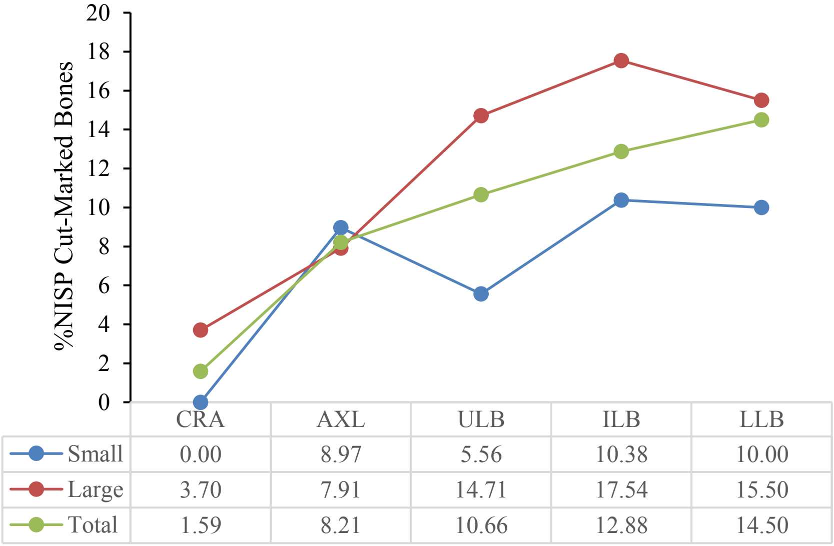
Skeletal parts bearing cut marks (NISP cut-marked) in the Loiyangalani faunal assemblage are very strongly and positively correlated with the total NISP of each skeletal part in both animal size classes (Spearman's rho: small-sized, r_s= 0.728, p=<0.010 and for large-sized carcasses, r_s=0.844, p=<0.010). The results also suggest the incidences of cut marks in the faunal assemblage are related to the sample size and can be reliably used to infer prehistoric human subsistence behaviour (Lyman 1987b, 1994:301-303). Besides, moderate positive correlation coefficients are also recorded between the numbers of cut marks-bearing bones (NISP cut-marked) against the economic utility (SFUI values) of skeletal parts (Spearman's rho: small-sized, $r_s=0.357$, $p=0.311$; and for large-sized carcasses, $r_s=0.362$, $p=0.203$). The results also suggest the large-sized carcasses were relatively intensively butchered than those of the small-sized (Lyman 1987b, 1994).

Cut marks were recorded on all major five anatomical segments of a complete carcass and animal size classes, which suggests that MSA hominins at the Loiyangalani site were well-skilled butchers and intensively processed their carcasses. Figure 6.13 below shows the proportions of cut-marks bearing bones (NISP cut-marked/NISP) by major anatomical segments and animal size. Overall, cut marks are more plentiful on the lower limb bones (LLB) accounting for 14.5% (teeth excluded). This can be explained by the fact that skinning is always a necessary butchering practice in carcass processing (Binford 1978, 1981; Lyman 1987a, 1994; Nilssen 2000; Galán and Domínguez-Rodrigo 2013). The upper appendicular limb bones (ULB and LLB) also have numerous specimens bearing cut marks (Figure 6.13). Comparing the proportions of cut marks on the upper limb bones (ULB) to the intermediate limb bones (ILB), a slight difference is noted (10.66% vs. 12.88% respectively). The axial bones also bear cut marks by 8.21% of the total cut-marked specimens in the assemblage. Notably, low proportion of cut-marked cranial bones was recorded only by < 2% (Figure 6.13).

The proportions of cut marks across a complete carcass also exhibit some notable differences between the small and large-sized carcass subsamples. The difference is also statistically significant (two sample *t*-test: *t*=2.8118, *p*=0.0482). The intermediate limb bones (ILB) are highly cut-marked in the small-sized carcasses subsample at the rate of 10.38%, followed closely by lower limb bones (LLB) by 10%. The axial and upper limb bones (ULB) preserve lower proportions of specimens bearing cut marks at the rate of 5 and 9% respectively. Of note, no cut-marked specimen in the small-sized carcasses subsample was registered on the cranial bones (see Table 6.11; Figure 6.13).

For the case of the large-sized carcasses subsample, cut marks are recorded all over the entire carcass, which suggests the MSA hominins at the Loiyangalani site intensively processed their relatively complete or complete carcasses (see Table 6.11; Figure 6.13). The intermediate limb bones (ILB) also typically with a significant amount of meat attached to them are heavily cut-marked by 17.54% followed closely by the lower limb bones (LLB) by 15.5% of the total cut-marked specimens. The upper limb bones (ULB) typically with the highest amount of meat attached to them are cut-marked by 14.71%. The axial and cranial bones are also cut-marked by 8.97% and 3.7% respectively.

As shown in Figure 6.13 below, the proportions of cut-marked specimens on the major six long limb bones in the Loiyangalani faunal assemblage occurs preferentially on the upper appendicular limb bones (ULB and ILB) that are typically the high meaty-bearing elements with a combined percentage of 23.54% (10.66% and 12.88% for the ULB and ILB respectively). The proportion of cut marks on the lower limb bones (LLB) that are the none-meaty bearing bones is 14.5%. The pattern is also similar in the small and large-sized carcass subsamples. The overall cut marks incidences in the Loiyangalani faunal assemblage is consistent with hominin primary (early) access to the complete carcasses (Binford 1981; Potts and Shipman 1981; Bunn 1982, 1996, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Oliver 1994; Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2007c; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014).



	CRA	AXL	ULB	ILB	LLB
Small	0.00	8.97	5.56	10.38	10.00
Large	3.70	7.91	14.71	17.54	15.50
Total	1.59	8.21	10.66	12.88	14.50

Figure 6.13. Proportions of Cut-Marked Bones by Major Anatomical Segments and Animal Size in the Loiyangalani Faunal Assemblage.

As has been highlighted above, long limb bones make the bulk of the cut-marked specimens in the Loiyangalani faunal assemblage (Tables 6.11 and 6.14). Of the total of 77 cut-marked long bone fragments, 63 were preferentially inflicted on their midshaft sections that typically tend to be covered by more meat and these are linked to the filleting/deboning of the carcasses. Only 14 specimens were cut-marked on the epiphyseal (proximal or distal) ends. The overall proportion of cut-marked midshaft fragments ranges between 7 and 14%. The radius has the highest proportion (14%)

followed closely by the metatarsal (13.9%) and metacarpal (13.04%) of the total cut-marked midshaft fragments. The humerus preserves no cut marks in both animal size classes (see Table 6.13 for the details). However, the difference in the proportions of cut-marks on the major six long bone midshaft fragments between the small and large-sized animal subsamples is statistically not significant (two sample *t*-test: *t*=0.6814, *p*=0.5259).

As detailed in Table 6.13 below, overall the lower limb bones (LLB) midshaft fragments in the Loiyangalani faunal assemblage are cut-marked more frequently than both the intermediate limb bones (ILB) and the upper limb bones (ULB) combined. Besides, the intermediate limb bones (ILB) are also more cut-marked than the upper limb bones (ULB), suggesting MSA hominins scavenged defleshed carcasses at the site (Binford et al. 1988; Domínguez-Rodrigo 1997a-c, Domínguez-Rodrigo and Barba 2005, 2007c; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014). The same quantitative trend is also evident for the small and large-sized animal subsamples. Nonetheless, the relatively high proportion of cut marks on the midshaft sections of the lower limb bones (LLB) presumably reflects localized preparation for marrow extraction and those on their epiphyseal are certainly ascribed to the skinning operations (Binford 1978, 1981; Lyman 1987a, 1994; Nilssen 2000; Pobiner 2007; Galán and Domínguez-Rodrigo 2013). According to Bunn and Kroll (1986), all cut marks inflicted on the metapodials mostly reflect the skinning operations. Of note, the lower limb bones (LLB) in the Loiyangalani faunal assemblage are identified almost three and two times more than the upper limb bones (ULB) and intermediate limb bones (ILB) respectively. Besides, the intermediate limb bones (ILB) are also identified more than the upper limb bones (ULB), which also can explain the observed pattern (Tables 6.3 and

6.6). However, when the proportions of cut-marked long bone midshaft fragments are expressed into high-meaty bearing versus none-meaty bearing long bones, the proportions are consistently higher on the upper appendicular limb bones (ULB and ILB) than on the lower limb bones (LLB).

The mean percentage of cut marks on long bone midshaft fragments on all animal size classes (size 1-4) in the Loiyangalani faunal assemblage is 11.27%. However, when divided into subsamples, the percentage on the small-sized (size 1-2) and large-sized (size 3-4) carcasses is only 7.7% and 13.39% respectively. Table 6.13 below provide details of cut marks on long bones by element, anatomical section on which they occur, and animal size.

Comparing the percentage of cut marks on midshaft fragments on all animal size classes (size 1-4) of 11.27% to published experimental and ethnoarchaeological datasets, the value falls within the range of variation exhibited when hominin had primary (early) access to fully-fleshed carcasses (Tables 5.5 and 6.13; Figure 6.14). Such faunal assemblages frequently exhibit percentage of cut-marked midshafts ranging between 10 and 30% depending on the size of the animal involved and intensity of carcass processing (Marean et al. 2000; Lupo and O'Connell 2002; Pante et al. 2012; Domínguez-Rodrigo et al. 2014). Of note, the value is also very close to that of 11.7% reported by Blumenschine (1988, 1995) and Pante and colleagues (2012) in their hominin-only foraging scenario experimental simulations (Tables 5.5 and 6.13). But, the value is slightly low to that of 16.6% and 47.5% and their corresponding 95% confidence limits provided by Capaldo (1995, 1997, 1998) and Domínguez-Rodrigo (1997a-c) respectively in their hominin-only experimental simulations. Besides, the value is also low to that of 23.6% and falls outside the 95% confidence limits of the faunal assemblage butchered by the Hadza (Lupo and O'Connell 2002). The value is also slightly below to that of 13.5% but within the corresponding 95% confidence limits provided in Capaldo's hominin-to-carnivore foraging scenario experimental simulations (Capaldo 1995, 1997, 1998). The value also falls within the 95% confidence limits range of the small and large-sized animal subsamples in the hominin-only experimental simulations (see Table 5.5 for the details). However, the value is also slightly lower to that of 15.5% in the FLK 22 *Zinj* archaeological faunal assemblage (Tables 6.13, 8.4; Figure 6.14). The slight difference in the percentages of the cut-marked midshaft fragments between the two archaeological faunal assemblages mainly may reflect the nature of the sites (Leakey 1971; Bunn 1982; Potts 1988; Domínguez-Rodrigo et al. 2007a).

For the small-sized (size 1-2) carcasses subsample, the percentage of cut-marked midshafts of 7.7% falls slightly outside the reported threshold in the experimental studies simulating hominin primary (early) access to fully-fleshed carcasses (Tables 5.5 and 6.13; Figure 6.14). The value is also lower to that of 10.3% for a comparable animal size class (size 1-2) reported by Blumenschine (1988, 1995) and Pante and colleagues (2012) in their hominin-only experimental simulations. But, the value falls in the middle of a comparable animal size group 95% confidence limits of 3.1 ± 17.6, and that of 4.5 ± 19.3 involving all animal size groups (size 1-4) in the hominin-only simulations and therefore may suggest primary (early) access to their intact carcasses (Tables 5.5 and 6.13). However, the value is below to that of 14% of a comparable animal size class in the hominin-to-carnivore experimental simulations reported by Capaldo (1995, 1997, 1998). Besides, the value is also low to that of 11.9% for a comparable animal size class (size 1-

2) subsample in the FLK 22 *Zinj* archaeological faunal assemblage (Tables 6.13, 8.4; Figure 6.14).

For the case of the large-sized (size 3-4) carcasses subsample, the percentage of cut-marked midshaft fragments of 13.39% also falls perfectly within the range of variation of between 10 and 30% reported in experimental and ethnoarchaeological studies that replicate hominin primary (early) access to fully-fleshed carcasses feeding scenarios (Tables 5.5 and 6.13; Figure 6.14). The value also falls at the lower end of the corresponding 95% confidence limits of 0 ± 40 of a comparable animal size group (size 3-4) in the hominin-only and that of 7.7 ± 16.9 provided by Capaldo (1995, 1997, 1998) in the hominin-to-carnivore experimental simulations (Tables 5.5 and 6.13). Of note, the value also falls slightly above the assemblage mean percentage of 11.7% involving all animal size groups (size1-4) reported by Blumenschine (1988, 1995) and Pante and colleagues (2012) for their hominin-only experimental simulations (Table 5.5 and 6.13). Moreover, the value is also very close to the new cut marks estimate for a comparable animal size class (size 3-4) subsample of 17.2% in the FLK 22 *Zinj* archaeological faunal assemblage (Tables 6.13, 8.4; Figure 6.14). Therefore, the value is broadly consistent with hominin early access to their fully-fleshed carcasses (Domínguez-Rodrigo and Barba 2005, 2007c).

As remarked above, in experimental studies modeling large carnivore primary access to fully-fleshed carcasses the midshafts of the upper appendicular limb bones (ULB and ILB) frequently retain no flesh scraps post-consumption i.e. yield marginal foraging returns to the next potential scavengers (Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2007c; Pickering and Domínguez-Rodrigo 2006;

Pickering et al. 2008; Gidna et al. 2014). In the prospective MSA hominins passive scavenging scenarios of the carcasses initially defleshed by the large carnivores at the Loiyangalani site, it is improbable cut marks can be imparted in high proportions on the areas that are regularly devoid of the edible nutritional resources i.e. the "hot zones". When the proportions of cut marks are compared against tooth marks on the upper limb bones (ULB) and intermediate limb bones (ILB) in the Loiyangalani faunal assemblage, a clear picture emerges. Overall, their "hot zones" are more cut-marked than tooth-marked. Distribution of the proportions of cut marks versus tooth marks on all animal-size classes (size 1-4) in the Loiyangalani faunal assemblage is as follows: on the ULB 6.56% vs. 2.46% and ILB 10.76% vs.4.43% respectively. The same quantitative picture also prevails in the small and large-sized carcass subsamples. For the small-sized carcasses: on the ULB 3.7% vs. 0.0%, and ILB 8.65% vs. 4.81%; and for the large-sized carcasses: on the ULB 8.82% vs. 4.41%, and on ILB 14.81% vs. 3.7% respectively (see also Tables 6.13 and 6.20 for the details). The relatively high percentages of cut marks on these elements consistently suggest MSA hominins defleshed substantial large quantity of meat rather than removed scraps of flesh from them (Binford 1981; Potts and Shipman 1981; Bunn 1982, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Oliver 1994; Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2007c; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014). Consequently, the hypothesis that MSA hominins regularly scavenged marginal scraps of meat from the carnivore hunted and defleshed carcasses is not supported at the Loiyangalani site.

The proportions of cut marks in the Loiyangalani MSA faunal assemblage fit well within the range of variation reported in numerous experimental and ethnoarchaeological studies that simulate hominin primary (early) access to fully-fleshed carcasses (Tables 5.5, 6.13 and 8.4). Besides, the relatively high percentage of cut marks on long bone midshafts of the large-sized (size 3-4) animals subsample signifies MSA hominins at the site also enjoyed primary (early) access to the most of their high-meat bearing bones (Tables 6.11-6.14 and 8.4). The implications of the new findings point to the conclusion that the MSA hominins in the Serengeti National Park of Tanzania effectively hunted and exploited the large-sized ungulates. Figure 6.14 below shows the percentages of cut marks on long bone midshaft fragments in the Loiyangalani faunal assemblage matched to several published experimental and ethnoarchaeological datasets that replicate feeding scenarios both involving hominin primary (early) access to fully-fleshed carcasses (HO) and secondary (late) access to the carcasses defleshed by the large carnivores (C-H) as well as to the FLK 22 *Zinj* archaeological faunal assemblage (see also Tables 5.5, 6.13 and 8.4 for the details).

Four fish specimens and two tortoise carapace fragments in the Loiyangalani faunal assemblage also exhibited cut marks that constitute a direct evidence of MSA hominin processing and consumption of the aquatic and semi-aquatic resources in the Serengeti National Park in Tanzania (Table 6.11). This should not come as a surprise, previous studies of the Loiyangalani MSA faunal assemblages have also reported cut-marked fish and tortoise remains (Thompson et al. 2004:6-7).

Table 6.11. Human-Induced Modifications in the Loiyangalani Faunal Assemblage.

Element/Size	Cut Marks		Percussion Marks	Burning
	Small	Large		
Mandible	-	1	-	-
Atlas	-	1	-	-
Cervical	1	3	-	-
Lumbar	-	1	-	-
Rib	9	22	-	1
Scapula	4	2	-	-
Humerus	1	1	4	-
Radius	5	2	6	1
Ulna	-	1	-	-
Metacarpal	3	11	15	-
Pelvis	-	2	-	-
Femur	2	9	10	-
Tibia	6	7	16	-
Metatarsal	2	28	37	-
Phalanx 1	-	2	-	-
Phalanx 2	1	1	-	-
Fish	4	-	-	-
Carapace	2	-	-	-
Indeterminate	10	-	5	-
Total	50	94	93	2

Table 6.12. Human-Induced Modifications by Animal Size.

Animal Size	Cut Marks	Percussion Marks	Burning	Total
Size 1	3	1	-	4
Size 2	31	22	1	55
Size 3	47	34	1	82
Size 4	47	31	-	78
Total	128	88	2	219

Table 6.13. Proportions of Cut Marks on Long Bones by Element, Anatomical Sections and Animal Size.

Element/Size	Epiphyseal		Midshaft		
	Small	Large	Small	Large	Total
Humerus	1/6(16.67)	1/9(1.11)	0/6(0.00)	0/9(0.00)	0/15(0.00)
Radius	0/26(0.00)	0/24(0.00)	5/26(19.23)	2/24(8.33)	7/50(14.00)
Metacarpal	0/19(0.00)	2/73(2.74)	3/19(15.79)	9/73(12.33)	12/92(13.04)
Femur	0/48(0.00)	3/59(5.08)	2/48(4.17)	6/59(10.17)	8/107(7.48)
Tibia	2/78(2.56)	1/30(3.33)	4/78(5.13)	6/30(20.00)	10/108(9.26)
Metatarsal	0/31(0.00)	4/156(2.56)	2/31(6.45)	24/156(15.38)	26/187(13.9)
ULB	1/54(1.85)	4/68(5.88)	2/54(3.70)	6/68(8.82)	8/122(6.56)
ILB	2/104(1.92)	1/54(1.85)	9/104(8.65)	8/54(14.81)	17/158(10.76)
LLB	0/50(0.00)	6/229(2.62)	5/50(10.00)	33/229(14.41)	38/279(13.62)
Total	3/208(1.44)	11/351(3.13)	16/208(7.69)	47/351(13.39)	63/559(11.27)

Numerator is the total of cut-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

Table 6.14. Cut Marks, Percussion Marks and Tooth Marks on Long Bones by Animal Size and Anatomical Sections.

Animal Size	Total Long Bones	Epiphyseal		Midshaft		
		CM	TM*	CM	PM**	TM*
Small (1-2)	208	3	1	16	23	7
Large (3-4)	351	11	2	47	65	25
Total (1-4)	559	14	3	63	88	32

*Tooth marks include pits and scores
**Percussion marks include notches, striae and pits

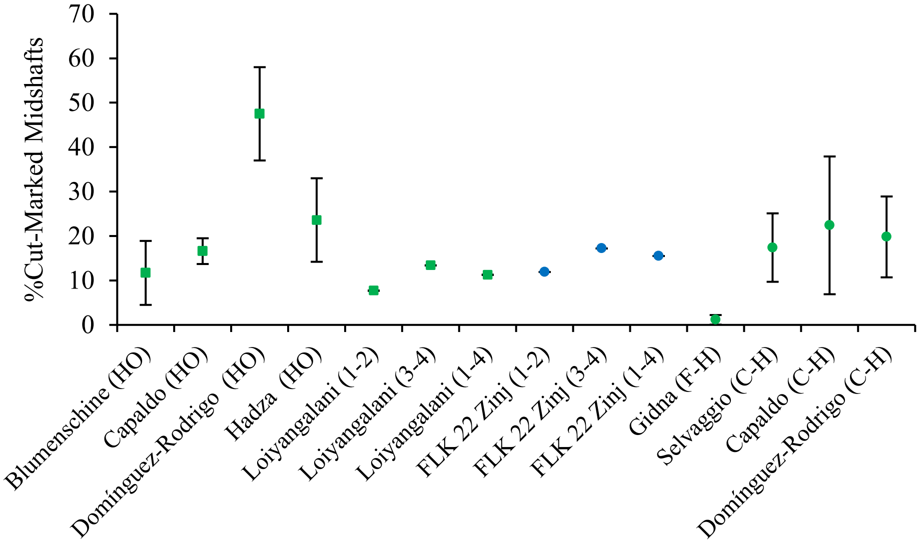


Figure 6.14. Cut-Marked Long Bone Midshafts in the Loiyangalani Faunal Assemblage Compared to Several Experimental, Ethnoarchaeological, and Archaeological Samples.

A total of 88 skeletal parts in the Loiyangalani faunal assemblage preserved percussion marks resulting from bone marrow extraction (Tables 6.11, 6.12, 6.14 and 6.15). Among the hammerstone percussion mark types, notches were more frequent (*n*=65), followed by the striae marks (*n*=21). Only two specimens exhibited clear percussion pits. No notch typical of the carnivore-created with semicircular shape and a none-jagged edge was recorded in the faunal assemblage (Blumenschine and Selvaggio 1988, 1991; Capaldo and Blumenschine 1994; Galán et al. 2009).

Percussion marks were recorded consistently on long bone midshaft sections. Percussion notch morphology and their orderly anatomical placements are consistent with bone marrow extraction practice. Figure 6.15 below shows an example of a typical hammerstone percussion notch in the Loiyangalani faunal assemblage. The proportion of percussion marks on midshaft fragments ranges between 12 and 27%. The humerus exhibited slightly high proportion of percussion-marked specimens (26.67%) followed by the metatarsal (19.79%) and metacarpal (16.3%). The element with highest proportion in the small-sized animals subsample is the humerus (33.33%) followed by tibia (16.67%). Femur (2.08%) is an element with the lowest proportion and no percussion marks were recorded on midshaft section of the metacarpal (Table 6.15). For the case of the large-sized animals subsample again the humerus has the highest proportion (22.22%) but it is followed by the metatarsal (21.15%) and metacarpal (20.55%). The rest have proportions of <16% (see Table 6.15 for the details). However, the difference in the proportions of percussion marks on the major six limb bones in the small and large-sized animal subsamples is not statistically significant (two sample *t*-test: t=0.8514, p= 0.4334). Tables 6.11, 6.14 and 6.15 below provide details on the incidences of percussion marks by element and animal size.

Overall, the midshaft sections of the lower limb bones (LLB) that typically have restricted bone marrow cavities appear to bear the majority of the percussion marks in the Loiyangalani faunal assemblage accounting for 18.64%, which may suggests MSA hominins at the site preferentially fractured them. Regardless of this observation, the combined percentage of percussion marks on the upper appendicular limb bones (ULB and ILB) that contain more marrow including humerus, femur, tibia, and radius is high by 25.39% than on the lower limb bones (Table 6.15).

Percussion marks on midshaft fragments on all animal size classes (size 1-4) yielded an assemblage mean percentage of 15.74%. Splitting the value into the small (size 1-2) and large-sized (size 3-4) carcass subsamples, the percentage is 11.06% and 18.52% respectively, which also suggests the large-sized animal bones were subjected to massive fragmentation during marrow harvesting (Tables 6.15 and 8.4). The relatively high amount of marrow available in the bones of the large-sized animals might offer a good explanation for the observed pattern (Binford 1978, 1981; Jones and Metcalfe 1988; Gifford-Gonzalez 1989; Blumenschine and Madrigal 1993; Bartram and Marean 1999; Morin 2007).

The percentage of percussion marks on long bone midshafts of 15.74% on all animal sizes (size 1-4), when compared to experimental datasets falls within the known range of variation documented in foraging scenarios hominin having had the primary (early) access to long bones to extract marrow (Tables 5.5 and 6.15). Percussion marks often range between 10 and 30% on the total long bone midshaft fragments also depending on the size of the animal involved (Marean et al. 2000; Pante et al. 2012; Domínguez-Rodrigo et al. 2014). However, the value is low when compared to assemblage mean percentages and just outside the corresponding 95 % confidence limits provided by Blumenschine (1995), Pante and colleagues (2012), and Capaldo (1995, 1997, 1998) in their experimental simulations that include both hammerstone-only and hammerstone-to-carnivore foraging scenarios (see Table 5.5 for the details). The value is also well below to that of 49.2% and 33.7% in the hammerstone-only and hammerstone-to-carnivore experimental simulations respectively both provided by Marean and colleagues (2000). However, the value falls within the 95% confidence limits range of the small and large-sized animal subsamples in both hammerstone-only and hammerstone-to-carnivore experimental simulations (Table 5.5). When the value is compared to that of 24.5% in the FLK 22 *Zinj* is also lower, but it is very close to that of 19.7% in the ST Site Complex archaeological faunal assemblage (Tables 6.15 and 8.4).

For the small-sized (size 1-2) carcasses, the percentage of percussion marks on midshaft fragments of 11.06% also falls within the known range for the hammerstone fractured long bone samples (Tables 5.5 and 6.15). However, the value is lower to that of nearly 27% for a comparable animal size class (size 1-2) reported by Blumenschine (1995) and Pante and colleagues (2012) in their hammerstone-only experiments. Of note, the value falls within the 95% confidence limits range provided by Blumenschine (1995), Pante and colleagues (2012), and Capaldo (1995, 1997, 1998) in their hammerstone-to-carnivore experimental simulations (Tables 5.5 and 6.15). But, the value is very low when compared to that of 37.3% for a comparable animal size class subsample in the FLK 22 *Zinj,* but again very close to that of 19.2% in the ST Site Complex archaeological faunal assemblages (Tables 6.15 and 8.4).

For the large-sized (size 3-4) carcasses, the percentage of midshaft fragments bearing percussion marks of 18.52% also falls within the known range of the hammerstone fractured long bone samples (Tables 5.5 and 6.15). But, the value is below to all the values for the comparable animal size subsamples in the hammerstone-only experimental simulations but within their corresponding 95% confidence limits (Table 5.5). Of note, the value is slightly above to that of 14.6% and 13.1% for comparative animal size subsamples in the hammerstone-to-carnivore experimental simulations reported by Pante and colleagues (2012) and Capaldo (1995, 1997, 1998) respectively (Tables 5.5 and 6.15). The value is also within the 95% confidence limits range involving all animal size groups (size 1-4) and subsamples (small and large-sized) in the hammerstone-only and hammerstone-to-carnivore simulations. When compared to that of 20.4% and 22.2% for comparable animal size subsamples in the FLK 22 *Zinj* and ST Site Complex archaeological faunal assemblages respectively, the value is also very close (Tables 6.15 and 8.4).

The percentage of percussion-marked long bone fragments in the Loiyangalani faunal assemblage suggests MSA hominins rather than the carnivore smashed open the medullary cavities to extract marrow. Statistical correlations also support the inference. Strong positive and statistically significant correlation coefficients between the marrow bearing bones %MAU values against Morin's (2007:77) Unsaturated Marrow Index (UMI) are registered for both animal size classes (see Table 6.16 below). The inference is also further supported by other lines of evidence of bone marrow harvesting including the prevalence of long bone fragments with green fractures, Type 1 shafts, and an average Fracture Freshness Index (FFI) of ≤ 2 (see Tables 6.22, 6.23; Figures 6.20-6.22 below).

Table 6.15. Proportions of Percussion Marks on Long Bone Midshafts by Element and Animal Size.

Element/ Size	Midshaft		
	Small	Large	Total
Humerus	2/6(33.33)	2/9(22.22)	4/15(26.67)
Radius	3/26(11.54)	3/24(12.50)	6/50(12.00)
Metacarpal	0/19(0.00)	15/73(20.55)	15/92(16.30)
Femur	1/48(2.08)	9/59(15.25)	10/107(9.34)
Tibia	13/78(16.67)	3/30(10.00)	16/108(14.81)
Metatarsal	4/31(12.90)	33/156(21.15)	37/187(19.79)
ULB	3/54(5.55)	11/68(16.18)	14/122(11.47)
ILB	16/104(15.38)	6/54(11.11)	22/158(13.92)
LLB	4/50(8.00)	48/229(20.29)	52/279(18.64)
Total	23/208(11.06)	65/351(18.52)	88/559(15.74)

Numerator is the total of percussion-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

Table 6.16. Spearman's rho between %MAU against UMI Values.

Animal Size	*n*	r_s	*p*-value
Small (1-2)	8	0.952	<0.01
Large (3-4)	13	0.922	<0.01

n= number of skeletal parts considered in the correlation.

Figure 6.15. Hammerstone Percussion Notch.

Fragmentation of the phalanges furnishes additional evidence of hominin involvement with the faunal remains at the Loiyangalani site. Phalanges typically with marginal amount of bone marrow are rarely cracked opened by hominin and carnivore while still in their nutritive state (Binford 1978, 1981; Marean 1991; Marean and Spencer 1991; Marean et al. 1992; Morin 2007). A total of 29, first and second phalanges were identified in the faunal assemblage. The first phalanges are quite well represented (NISP= 21), but there are also a total of 8 medial phalanges identified in the faunal sample (Table 6.3). The majority of the phalanges are fractured, and those survived intact are relatively few (Table 6.17).

Longitudinally split phalanges typically with green fracture morphologies and smooth fracture edges are numerous (NISP=16, 55.17% of the total phalanges sample) suggesting MSA hominins at the site cracked them open in a systematic way probably to extract bone marrow. Only three phalanges (10.34%) exhibited transverse fracture morphology that may reflects diagenetic breakage resulting from sediment compaction and/or animal trampling; and these are certainly not related to marrow extraction practice at the site (see Tables 6.17; Figure 6.16).

Table 6.17. Fragmentation of the First and Second Phalanges.

Animal Size	Element	Complete	Mode of Fragmentation	
			Longitudinally Split	Transversely Split
Small (1-2)	1st Phalange	4	-	2
	2nd Phalange	1	1	-
Large (3-4)	1st Phalange	2	13	-
	2nd Phalange	3	2	1
Total (1-4)	-	10	16	3

Figure 6.16. Longitudinally and Transversely Fractured Phalanges.

Burnt bones are usually considered as direct evidence of hominin activity (*sensu* Stiner et al. 1995; Stiner 2005). However, burnt bones can also result from accidents or natural fire. Burnt bones in the Loiyangalani faunal assemblage comprised of only two specimens (a size 2 bovid radius and size 3 rib shaft fragment) both are < 50% calcined suggestive of deliberate burning (Tables 6.11 and 6.12). Recovery of more burnt bone fragments at the site may strengthen this interim suggestion. It is also tempting to suggest the two bone fragments may have been burnt by natural wildfires, which is a standard feature of the eastern Africa savannah ecology (Vesey-Fitzgerald 1973).

6.6.2. Nonhuman-Induced Modifications

Nonhuman modifications in the form of tooth marks, rodent gnaw marks, trample marks, root marks, and biochemical marks were also recorded in the Loiyangalani faunal assemblage. Table 6.18 below provides summaries of the types and incidences of the nonhuman surface modifications documented on both identified and unidentified specimens.

A total of 70 specimens preserved carnivore damage mainly tooth scores and tooth pits. Score marks are the most abundant identified types of the carnivore damage (*n*=41) and tooth pits (*n*=29). These allegedly resulted from carnivore scavenging of the bone fragments discarded at the site (Tables 6.18-6.21; Figures 6.17 and 6.18). Large-sized carnivores (hyena) are mainly implicated, as suggested by the dimensions of the damage (Selvaggio and Wilder 2001; Domínguez-Rodrigo and Piqueras 2003; Domínguez-Rodrigo et al. 2012).

Despite meticulous microscopic analysis of all specimens, there are relatively few tooth marks bearing specimens recorded in the Loiyangalani faunal assemblage, which also may suggest the carnivore played a rather marginal role in modification. The overall percentage of tooth marks bearing mammalian skeletal parts is 5.7% (teeth excluded). Splitting the percentage into the small and large-sized carcass subsamples also show no marked difference and are only at 3.4% and 6.87% respectively (Tables 6.18 and 6.19).

The results are astonishing given the open nature of the Loiyangalani site and its location along the wildlife migration route (Kruuk 1972; Schaller 1972; Maddock 1979; Blumenschine 1986, b, 1987, 1988; McNaughton 1988, 1990; Hoffer et al. 1993; Hanby et al. 1995; Holdo et al. 2011). Hyenas and lions should have initially processed the bones deposited at the site as emphasized in Chapter 3. The Serengeti National Park has approximately 3,000 lions and 10,000 hyenas today roaming the Serengeti National Park plains (Caro and Durant 1995). The low proportion of tooth marks bearing skeletal parts in the assemblage might be attributed to some other factors, including the carnivore-feeding behaviour. According to Kruuk (1972), spotted hyenas habitually hoard meat or bones in still muddy water so that other predators and scavengers cannot steal them. As a result, they may get lost. Another consideration is the potential threats from the other predators at the site including the MSA hominins, which may have dictated the carnivore-processing time of the bones bearing meat (Bunn 1982, 1996, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Blumenschine 1986a, b, 1987, 1988, 1995; Blumenschine and Marean 1993; O’Connell et al. 2002; Ferraro 2007). The low proportion of tooth-marked fragments may also mirror the high degree of fragmentation and root marking in the faunal assemblage. Besides, crocodile also identified in the Loiyangalani faunal sample frequently consume whole or leave the entire bones behind that may or may not have tooth marks while feeding (Njau and Blumenschine 2006). They also rarely break ungulate bones while feeding.

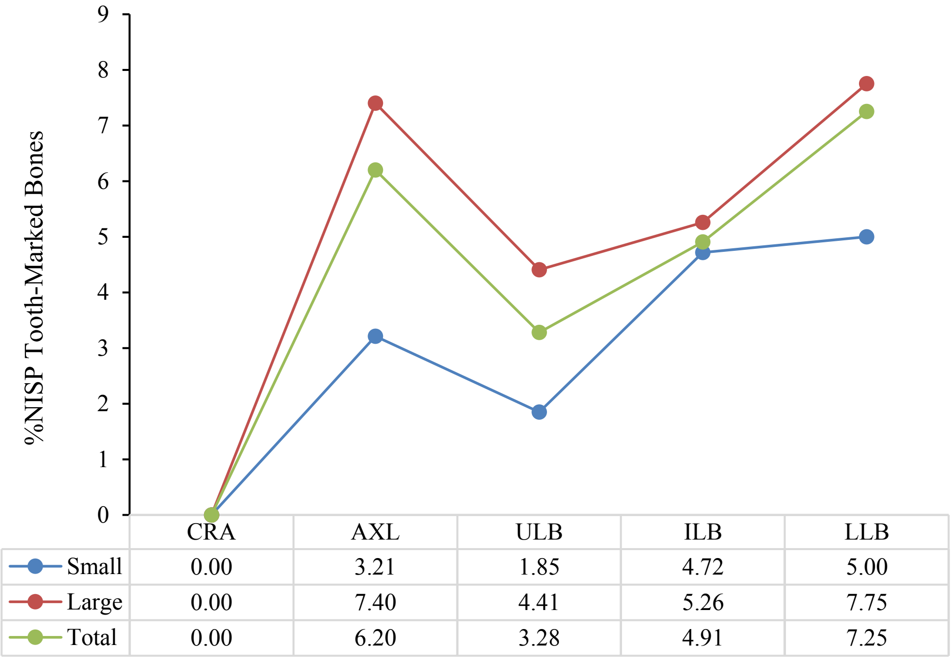
Rib shaft fragments exhibited the majority of the carnivore damage in the faunal assemblage followed by metatarsal. Figure 6.17 below shows the proportions of tooth-marks bearing specimens (NISP tooth-marked/NISP) by major anatomical segments and animal size. Overall, the majority of the tooth-marked specimens are the lower limb bones (LLB) by 7.25% followed closely by axial bones by 6.2%. Tooth marks are relatively fewer on both the upper limb bones (ULB) and intermediate limb bones (ILB) by 3.28% and 4.91% respectively. Of note, no tooth marks were recorded on the cranial bones for either animal size class (see Figure 6.17). The overall proportion of tooth marks in the Loiyangalani faunal assemblage suggests marginal carnivore intervention on the bones.

Tooth marks bearing elements across a complete carcass also appear to exhibit some notable differences between the small and large-sized animal subsamples. However, the difference between the two animal size groups is not quite statistically significant (two sample *t*-test: t=2.6138, p=0.0592). Tooth marks are more prevalent on the lower limb bones (LLB) by 5% followed closely by intermediate limb bones (ILB) by 4.72% in the small-sized animals subsample. The upper limb bones (ULB) notably bear fewer tooth marks by < 2%. The axial bones constitute 3.21% of the total tooth-marked specimens in the faunal assemblage (Figure 6.17).

For the case of the large-sized carcasses subsample, again there are relatively more tooth marks on the lower limb bones (LLB) by 7.75% but followed closely by axial elements by 7.4% of the total tooth marks bearing specimens. The upper limb bones (ULB) and intermediate limb bones (ILB) preserve slightly lower proportions of the tooth-marked elements only by 4.41% and 5.26% respectively (Figure 6.17).

Focusing the discussion on the major six long limb bones, the upper appendicular limb bones (ULB and ILB), which are the high meat-bearing bones, are tooth-marked by a combined percentage of 8.19% (3.28% and 4.91% for the ULB and ILB respectively).

On the other hand, the lower limb bones (LLB) typically the none-meat bearing elements have a proportion of 7.25% (Table 6.11; Figure 6.17).



	CRA	AXL	ULB	ILB	LLB
Small	0.00	3.21	1.85	4.72	5.00
Large	0.00	7.40	4.41	5.26	7.75
Total	0.00	6.20	3.28	4.91	7.25

Figure 6.17. Proportions of Tooth-Marked Bones by Major Anatomical Segments and Animal Size in the Loiyangalani Faunal Assemblage.

A total of 35 long limb bone fragments were tooth-marked in the Loiyangalani faunal assemblage. The midshaft fragments preserved the majority of the tooth marks (*n*=32). The element with the highest proportion of tooth marks on midshaft sections is the metatarsal (8.56%) followed by metacarpal (6.52%). subsample, Radius (7.7%) is the element with the highest proportion followed by metacarpal (5.26%) in the small-sized animals. The femur preserves no tooth marks on its midshaft sections. In the large-sized animals subsample, the metatarsal (9.61%) has the highest proportion followed by the metacarpal (6.85%) and tibia (6.67%). No tooth marks were also recorded on the midshaft of the humerus in both animal size subsamples (Table 6.20). The difference in proportions of tooth marks on the major six long limb bone midshaft fragments is not significant statistically (two sample *t*-test: *t*=0.6672, *p*=0.5342).

The mean percentage of tooth marks on long bone midshaft fragments on all animal size classes (size 1-4) in the Loiyangalani faunal sample is 5.72%. The percentage is 3.37% and 7.12% for the small (size 1-2) and large-sized (size 3-4) carcass subsamples respectively. Details of the tooth marks on midshaft fragments by element, anatomical section where they occur, and animal size is provided in Table 6.20 below.

Comparing the mean percentage of tooth marks on midshaft fragments on all animal size classes (size 1-4) as well as those on the small (size 1-2) and large-sized (size 3-4) carcass subsamples, the values fall well below all those reported in experimental studies simulating carnivore-first access to fully-fleshed carcasses and those involving whole-bone-to-carnivore (WB-C). Besides, the values also fall outside their corresponding 95% confidence limits range (see Table 5.5 for the details). In carnivore-first access scenarios, tooth marks on midshaft fragments are often above 75%, and those in the whole-bone-carnivore are frequently above 50% (Capaldo 1995, 1997, 1998; Marean et al. 2000; Lupo and O'Connell 2002; Pante et al. 2012; Domínguez-Rodrigo et al. 2014).

The mean percentages of tooth marks on midshafts in the Loiyangalani faunal assemblage are more consistent with the results reported in experimental studies replicating foraging scenarios whereby the carnivores scavenged defleshed and demarrowed bone fragments (Tables 5.5 and 6.20; Figure 6.18). In carnivore secondary (late) access to the carcasses the percentage of tooth marks on midshafts frequently ranges between 5 and 15% (Marean et al. 2000; Lupo and O'Connell 2002; Pante et al.

2012; Domínguez-Rodrigo et al. 2014). This is due to the fact that, carnivore habitually tend to ignore the nutritionally depleted bone fragments (Blumenschine 1986a, b, 1988, 1995; Blumenschine and Marean 1993; Bartram 1993; Bartram et al. 1991; Bunn 1993; Marean and Bertino 1994; Selvaggio 1994a, b, 1998; Capaldo 1995, 1997, 1998; Lupo 1995; Lupo and O'Connell 2002; Domínguez-Rodrigo 1997a-c; Marean et al. 2000).

A comparison of the mean percentage of 5.72% on all animal size classes (size 1-4) to published datasets falls within the range of variation documented in the experimental studies modeling hominin-to-carnivore (H-C) foraging scenarios (Tables 5.5 and 6.20; Figure 6.18). The value is also very close to that of 6.4% for a Hadza basecamp faunal assemblage and that of 7.1%, but also within their corresponding 95% confidence limits provided by Lupo and O'Connell (2002) and Marean and colleagues (2000) respectively both replicating carnivore scavenging defleshed and demarrowed bone fragments foraging scenarios (Tables 5.5 and 6.20). In addition, the value also falls within the 95% confidence limits provided by Blumenschine (1995) in his hammerstone-to-carnivore experiments involving all animal size groups (size 1-4) and subsamples (Tables 5.5 and 6.20).

As shown in Table 6.20, the percentage of tooth-marked midshaft fragments in the small-sized (size 1-2) carcasses subsample of 3.37% falls slightly below the range of variation documented in experimental studies modeling hominin-to-carnivore (H-C) foraging scenarios (Tables 5.5, 6.20; Figure 6.18). But, the value also falls at the lower end of the 95% confidence limits of 2.6 ± 29.2 for a comparable animal size class (size 1-2) reported by Blumenschine (1995) in his hammerstone-to-carnivore experimental simulations. The value is also slightly below to that of 6.4% but within the corresponding

95% confidence limits of a Hadza basecamp faunal assemblage post-discard scavenged by carnivore (Lupo and O'Connell 2002). Of note, the value also falls within the 95% confidence limits in Blumenschine (1995) hammerstone-to-carnivore experiments for the large-sized (size 3-4) animals subsample (Tables 5.5 and 6.20). However, the value is also well below the new tooth marks estimate of 13.8% for a comparable animal size class in the FLK *Zinj* 22 archaeological faunal assemblage (Tables 6.20, 8.4; Figure 6.18).

The percentage of tooth marks on midshafts on the large-sized (size 3-4) carcasses subsample of 7.12% also falls within the range of variation reported in experimental studies modeling hominin-to-carnivore (H-C) foraging scenarios (Tables 5.5, 6.20; Figure 6.18). The value is also slightly above to that of 5.1% for a comparable animal size class provided by Blumenschine (1995) in his hammerstone-to-carnivore experiments. However, the value is also nearly identical to that of 7.1% provided by Marean and colleagues (2000) in their hammerstone-to-carnivore experimental simulations. When the value is compared to a Hadza faunal assemblage post-discard scavenged by carnivore, the value is also slightly above (see Tables 5.5 and 6.20; Figure 6.18). Of note, the value is also very close to the new estimate of 9.95% for a comparable animal size class in the FLK 22 *Zinj* archaeological faunal assemblage (Tables 6.20 and 8.4; Figure 6.18).

The proportions of tooth marks against cut marks on the "hot zones" of the upper appendicular limb bones (ULB and ILB), which are often completely defleshed post-carnivore consumption are notably very low and only in the region of between 2.4 and 4.5%. The same quantitative pattern also prevails in the small and large-sized carcass subsamples (see Tables 6.13 and 6.20 for the details). There are also more cut-marked than tooth-marked axial bones documented in the Loiyangalani faunal assemblage, which also suggest MSA hominins active defleshing of the axial skeleton perhaps in scenarios of first access to the complete or almost complete carcasses (see Table 6.21 for the details).

Tooth marking in the Loiyangalani faunal assemblage certainly demonstrate secondary (late) access by carnivore to the high meat-bearing limb bones and axial bones (Figures 6.17 and 6.18). Overall, the percentages of tooth marks on long bone midshafts nearly match those documented in the ST Site Complex archaeological faunal assemblage summarized as follows: for the small-sized carcasses (3.37% vs. 4%), large-sized (7.12% vs. 7.4%) and on all sizes (5.72% vs. 4.6%) respectively (see Table 8.4 for the details).

Table 6.18. Nonhuman-Induced Modifications in the Loiyangalani Faunal Assemblage.

Element/Size	Tooth Marks		Rodent Gnaw Marks	Biochemical Marks	Root Marks	Trample Marks	Pathology
	Small	Large					
Cranium	-	-	-	2	2	-	-
Mandible	-	-	-	-	2	-	-
Cervical	-	-	-	-	1	-	-
Thoracic	-	1	-	-	-	-	-
Rib	5	26	-	24	108	18	-
Scapula	-	1	-	-	14	2	-
Humerus	-	-	-	-	3	-	-
Radius	2	1	1	1	16	-	-
Ulna	-	-	-	-	2	-	-
Metacarpal	1	6	-	6	41	5	-
Pelvis	-	1	-	2	12	15	-
Femur	1	3	-	2	29	5	1
Tibia	3	2	-	4	26	4	-
Astragalus	-	-	-	-	1	-	-
Calcaneum	-	-	-	-	1	-	-
Uniciform	-	-	-	-	1	-	-
Metatarsal	1	15	1	8	82	11	-
Phalanx 1	-	-	-	-	4	-	-
Phalanx 2	1	-	-	-	1	-	-
Fish	-	-	-	-	31	-	-
Carapace	-	-	-	-	4	-	-
Indeterminate	-	-	1	12	151	7	-
Total	14	56	3	61	532	67	1

Table 6.19. Nonhuman-Induced Modifications by Animal Size.

Animal Size	Tooth Marks	Rodent Marks	Biochemical Marks	Root Marks	Trample Marks	Pathology
Size 1	1	-	1	17	1	-
Size 2	13	1	9	78	9	-
Size 3	35	1	21	166	22	1
Size 4	21	-	18	85	13	-
Total	70	2	49	346	45	1

Table 6.20. Proportions of Tooth Marks on Long Bones by Element, Anatomical Sections and Animal Size.

Element/Size	Epiphyseal		Midshaft		
	Small	Large	Small	Large	Total
Humerus	0/6(0.00)	0/9(0.00)	0/6(0.00)	0/9(0.00)	0/15(0.00)
Radius	0/26(0.00)	1/24(4.17)	2/26(7.70)	0/24(0.00)	2/50(4.00)
Metacarpal	0/19(0.00)	1/73(1.37)	1/19(5.26)	5/73(6.85)	6/92(6.52)
Femur	1/48(2.08)	0/59(0.00)	0/48(0.00)	3/59(5.08)	3/107(2.80)
Tibia	0/78(0.00)	0/30(0.00)	3/78(3.85)	2/30(6.67)	5/108(4.63)
Metatarsal	0/31(0.00)	0/156(0.00)	1/31(3.22)	15/156(9.61)	16/187(8.56)
ULB	1/54(1.85)	0/68(0.00)	0/54(0.00)	3/68(4.41)	3/122(2.46)
ILB	0/104(0.00)	1/54(1.85)	5/104(4.81)	2/54(3.70)	7/158(4.43)
LLB	0/50(0.00)	1/229(0.44)	2/50(4.00)	20/229(8.73)	22/279(7.88)
Total	1/208(0.48)	2/351(0.57)	7/208(3.37)	25/351(7.12)	32/559(5.72)

Numerator is the total of tooth-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

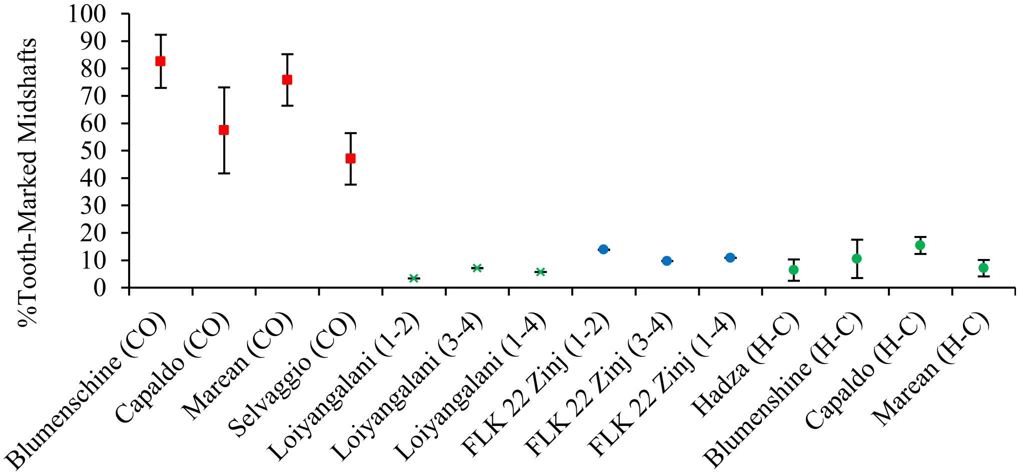


Figure 6.18. Tooth-Marked Long Bone Midshafts in the Loiyangalani Faunal Assemblage Compared to Several Experimental, Ethnoarchaeological, and Archaeological Samples.

Table 6.21. Proportions of Tooth-Marks vs. Cut-Marks on the Axial Elements.

Element/ Size	Small		Large		Total	
	TM	CM	TM	CM	TM	CM
Ribs	5/120(4.17)	9/120(7.5)	26/282(9.22)	22/282(7.80)	31/402(7.71)	31/402(7.71)
Vertebrae	0/10(0.00)	1/10(10.00)	1/49(2.04)	5/49(10.20)	1/59(1.69)	6/59(10.17)
Scapulae	0/17(0.00)	4/17(23.53)	1/31(3.22)	2/31(6.45)	1/48(2.08)	6/48(12.50)
Pelves	0/9(0.00)	0/9(0.00)	1/30(3.33)	2/30(6.67)	1/39(2.56)	2/39(5.13)
Total	5/156(3.20)	14/156(8.97)	29/392(7.40)	31/392(7.91)	34/548(6.20)	45/548(8.21)

Numerator is the total of tooth and cut-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

Rodent gnaw marks represent typically closely spaced, and flat-bottomed parallel grooves. Rodents habitually gnaw bones to wear down their teeth. These were also recorded in the Loiyangalani faunal assemblage but notably less frequent in comparison to the large carnivore damage. Only three specimens displayed evidence of rodents gnawing denoting they played, at most, a minor role in the modification of the bones at the site (Tables 6.18 and 6.19).

A total of 67 specimens also exhibited traces of trampling, in the form of randomly oriented and distributed scratches and grooves (Behrensmeyer et al. 1986). This also indicates the Loiyangalani site for a long time has been a locus of heavy foot traffic by large herds of animals probably during the wildlife migration within the Serengeti National Park and/or when they visited the river for its fresh water and fresh grass grazing during the heightened dry seasons. Trample marks typically closely mimic cut marks, but they can be differentiated by their general random orientations (Shipman and Rose 1983; Behrensmeyer et al. 1986; Olsen and Shipman 1988).

Numerous specimens in the Loiyangalani faunal sample are also root-etched (Table 6.18). Some specimens displayed traces of dense dendritic branches on their cortical surfaces that also extend to inner cavities and on fractured edges, suggesting a presence of a relatively heavy vegetated ground cover at the site during the deposition of the faunal remains (Figure 6.19). Root marks were recorded on a total of 346 mammal specimens identified to skeletal parts and commonly on the medium-sized animal bones (Table 6.19). A few root marks were also observed on fish bones (*n*=31) and tortoise carapace fragments (*n*=4). No etched specimen typical of the carnivore digestion was identified in the faunal assemblage.

Figure 6.19. Root Marks.

Considering other forms of nonhuman bone surface modifications, biomechanical marks typically resulting from fungi and bacteria colonies that also may significantly alter the bone underlying cortical layer, were documented on a total of 64 specimens (see Domínguez-Rodrigo and Barba 2006, 2007a, b, on the details on how they are formed and on how may lead to erroneous interpretation of prehistoric human behaviour). None of the biomechanical marks in the Loiyangalani faunal assemblage could be mistaken for tooth marks. A single specimen was recorded with the possible pathological damage that may be resulting from infection or an injury inflicted by hominin stone tool (Table 6.18).

6.7. Patterns of Long Bone Fragmentation

Virtually all long bones in the Loiyangalani faunal assemblage were fractured, and the majority preserved less 25% of their original length. Of note, only six of the total long bones sample was found complete, and only five retained > 50% of their original total length (Tables 6.4 and 6.22). The phalanges, which are typically small amount marrow-bearing elements, were also intentionally cracked open (Table 6.17; Figure 6.16).

Bunn's (1982, 1983), Type 1 shafts are the most abundant recorded type in the faunal assemblage, which also denotes being an unbiased sample (Marean et al. 2000, 2004). Type 2 and 3 shafts, which are the distinguishing feature of the carnivore-generated faunal assemblage, are notably rare (Table 6.22; Figure 6.20). The ratio of Type 2 and 3 shafts, to the Type 1 shafts yielded a value of 0.12, which falls at the lowermost end of the reported range of between 0.44 and 0.10. The ratio suggests MSA hominins played a key role in fracturing the long bones at the site as opposed to the carnivore, sediment compaction, and/or animal trampling. Figure 6.20 below shows the percentages of Bunn's (1982, 1983) shaft types in the Loiyangalani faunal assemblage compared to several experimentally calibrated faunal samples.

Long bone fragments fracture morphologies in the Loiyangalani faunal assemblage demonstrate the prevalence of oblique angles (72.63%), V-shaped outlines (72.63%) and smooth fracture edges (72.81%) normally associated with the fresh state fracturing mostly as a result of marrow harvesting (Tables 6.22 and 6.23). Overall, the faunal assemblage has relatively low proportions of specimens bearing right angles, transverse outlines, and jagged edges only at around 25% indicative of minimal diagenetic (dry) breakage (Bunn 1982, 1983; Villa and Mahieu 1991; Villa et al. 2004;

Marean et al. 2000). Trampling and sediments compaction are the potential causes of the postdepositional fragmentation. Analysis of the fracture morphologies also demonstrates roughly 2% of the total sample bears both green and dry characteristics (Tables 6.22 and 6.23). The proportions of the breakage types do not diverge much in the small and large-sized animal subsamples. Figures 6.21 and 6.22 below show the proportions of fracture angles and fracture outlines documented in the Loiyangalani faunal assemblage compared to several calibrated experimental faunal samples and archaeologically known fragmented faunal assemblages (Marean et al. 2000; Villa and Mahieu 1991; Villa et al. 2004; Pickering and Egeland 2006). The proportions of the fracture angles and fracture outlines fall perfectly within the spectrum of green fractured faunal assemblages. The proportions are also notably higher to those in the Sarrians faunal assemblage reported to undergone its fragmentation while dry via sediment compaction (Villa and Mahieu 1991; Villa et al. 2004).

Fracture Freshness Index (FFI) scores also permit to explore further the time frame of bones breakage in the Loiyangalani faunal assemblage (Outram 2001, 2002). Only a total of 16 specimens including long bones as well as the first and second phalanges survived complete (Tables 6.17, 6.22; Figures 6.15 and 6.16). Table 6.23 below presents the total FFI scores and averages for the entire Loiyangalani faunal assemblage and by animal size class. The majority of the specimens had total FFI scores of ≤ 2 with a cumulative proportion of roughly 71%. Splitting the FFI score for the entire faunal assemblage into the small and large-sized animal subsamples, the respective cumulative proportion is 72.047% and 71.11%, which implies the bulk of the specimens were broken while still in relatively fresh (green) state certainly during bone marrow extraction (Outram 2001, 2002). The relatively high proportions of percussion marks on the high marrow-bearing long limb bones documented in the faunal assemblage support the inference (Tables 6.11, 6.12, 6.14 and 6.15). Very few specimens displayed mixed fractures (green and dry), which also suggests some, were fractured while the bones were gradually becoming dry. Specimens with unfresh fractures account for around 21%, which likely reflects the impact of animal trampling and/or sediment compaction remarked above. The average FFI score for the Loiyangalani MSA faunal assemblage is 1.48, and for the small and large-sized animal subsamples is 1.43 and 1.49 respectively (see Table 6.23 below for the details). The overall mode of bone fragmentation in the faunal assemblage is consistent with green breakage and fits within hominin marrow extraction practice as opposed to the carnivore and diagenetic (dry) breakage (Tables 6.11, 6.12, 6.13-6.15; Figures 6.20-6.22).

Table 6.22. Long Bones Fracture Morphologies by Animal Size in the Loiyangalani Faunal Assemblage.

Fracture Morphologies		Small	Large	Total
Fracture Angle	Oblique	152(74.51%)	238(71.47%)	390(72.63%)
	Right Angle	45(22.06%)	81(24.32%)	126(23.46%)
	Intermediate	7(3.43%)	14(4.20%)	21(3.91%)
Fracture Outline	V-Shaped	152(74.51%)	238(71.47%)	390(72.63%)
	Transverse	45(22.06%)	80(24.02%)	125(23.28%)
	Intermediate	7(3.43%)	15(4.50%)	22(4.10%)
Fracture Edge	Smooth	152(74.51%)	239(71.77%)	391(72.81%)
	Jagged	52(25.49%)	94 (28.23%)	146(27.19%)
Shaft Length Proportion	< 0.25	206(99.04%)	337(96.01%)	543(97.14%)
	< 0.5	2(0.96%)	3(0.85%)	5(0.89%)
	< 0.75	-	3(0.85%)	3(0.54%)
	> 0.75	-	2(0.57%)	2(0.36%)
	Complete	-	6(1.71%)	6(1.07%)
Shaft Circumference	< 0.5	190(91.35%)	311(88.60%)	501(89.62%)
	> 0.5	5(2.40%)	6(1.71%)	11(1.97%)
	Complete	13(6.25%)	34(9.69%)	47(8.41%)

Table 6.23. FFI Scores Cumulative Frequencies and Averages by Animal Size.

FFI Score	Small		Large		Total	
	NISP	%NISP	NISP	%NISP	NISP	%NISP
0	152	72.04	256	71.11	408	71.45
1	1	0.47	4	1.11	5	0.88
2	6	2.84	9	2.5	15	2.63
3	2	0.95	4	1.11	6	2.63
4	4	1.9	6	1.67	10	1.75
5	3	1.42	6	1.67	9	1.58
6	43	20.38	75	20.83	118	20.67
Total	211	100.00	360	100.00	571	100.00
Average FFI Score	1.43		1.49		1.48	

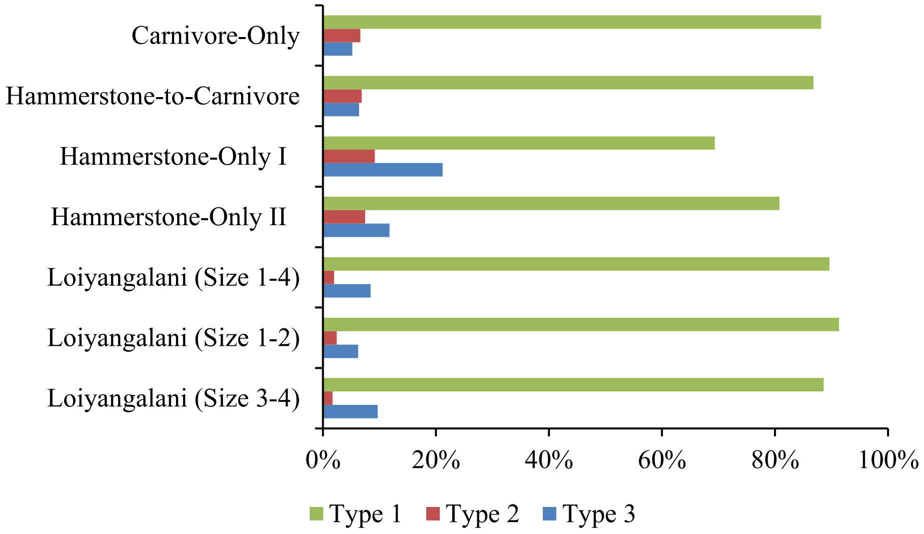


Figure 6.20. Long Bone Shaft Types in the Loiyangalani Faunal Assemblage Compared to Several Experimental Samples.

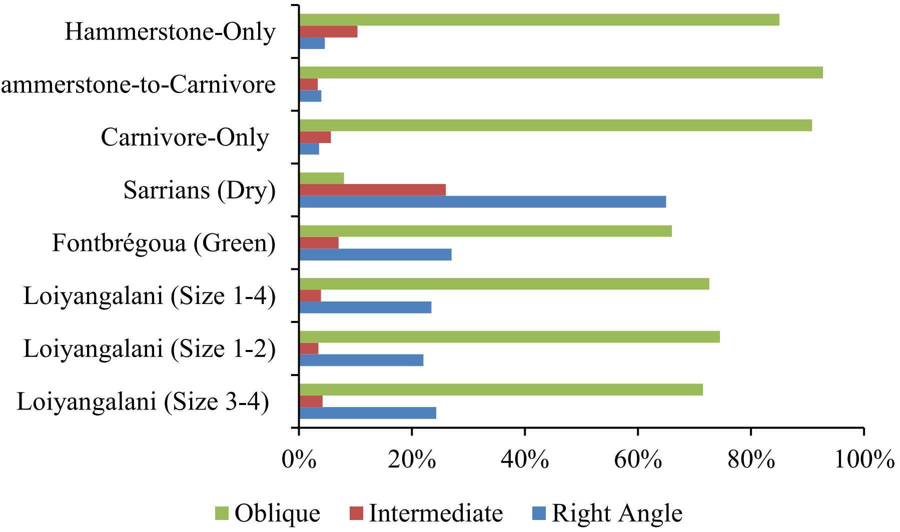


Figure 6.21. Long Bone Fracture Angles in the Loiyangalani Faunal Assemblage Compared to Several Experimental and Archaeological Samples.

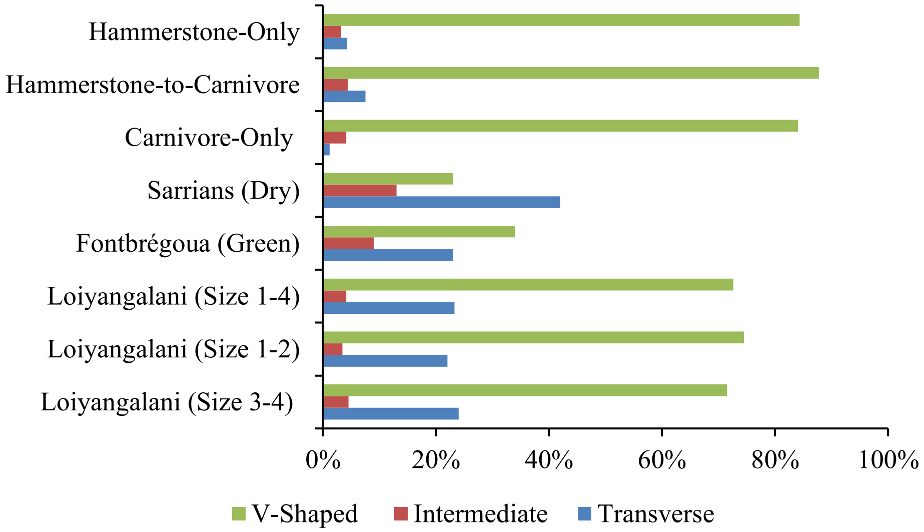


Figure 6.22. Fracture Outlines in the Loiyangalani Faunal Assemblage Compared to Several Experimental and Archaeological Samples.

6.8. Analysis of the Loiyangalani MSA Lithic Assemblage

Maíllo-Fernández and colleagues (2016) have analyzed the MSA lithic assemblage recovered from the 2003 to 2005 seasons, and the preliminary results are summarized below. Quartz and quartzite are the most common raw materials used in stone tool manufacture at the Loiyangalani site. Chert and sandstone were also infrequently used. Quartz was commonly used in bipolar knapping and quartzite for the Levalloisian and discoid-type lithic operative schemes. Overall, Levalloisian and discoid-type lithic operative schemes are the most common core reduction strategies used at the Loiyangalani site.

The most abundant types of the retouched tools in the MSA lithic assemblage are those broadly categorized as "domestic tools" including side-scrapers, notches, and denticulates. End-scrapers are notably scarce. Cores and burins are virtually absent. The proportions of the pieces that likely served as weapon tips and used in prey carcass processing mostly consist of a handful Levallois points, bifacial points and backed pieces.

Recent typo-technological analysis of the MSA lithic assemblage suggests Loiyangalani was a specialized residential basecamp as typified by a highly specialized toolkit (Maíllo-Fernández et al. 2016 for the details).

CHAPTER 7

MAGUBIKE ROCKSHELTER FAUNAL ASSEMBLAGE RESULTS

7.1. Introduction

This chapter presents the Magubike MSA faunal assemblage results. A taphonomic profile of the sample is highlighted below followed by the presentation of various zooarchaeological datasets. As was the case for the Loiyangalani results are also compared to published experimental and ethnoarchaeological datasets and to some of the best studied archaeological faunal assemblages in an attempt to better reconstruct the contribution of hominin and carnivore in the faunal assemblage formation (Tables 5.5, 8.4; Figures 7.9, 7.10, 7.12, 7.13 and 7.14-7.16).

7.2. State of Preservation of the Faunal Remains

The majority of the specimens studied from Magubike rockshelter were fragmented (Table 8.2). Remarkably, very few specimens were complete and mainly included isolated teeth, tarsals, and carpals, which regularly survive well in archaeological sites (Tables 7.2, 7.17, 7.23, 7.24, 8.2; Figures 7.4 and 7.11). The %whole, which provides an estimate of the extent of fragmentation calculated is 1.19 for the entire faunal assemblage and suggests the skeletal parts have suffered massive fragmentation (Lyman 1994; Wolverton 2002). The %whole for the small and large-sized animal subsamples is 2.55 and 1.8 respectively, which also suggest the large-sized animal bones are relatively more intensively fragmented.

Distribution of specimens by size shows different size classes are represented in the faunal assemblage (see Figures 7.1 and 7.2). Studied specimens had an average length of

2.4 cm. About 42% of the total sample consisted of fragments measuring ≤ 2 cm in maximum length, which also denotes the assemblage is an unbiased sample (Payne 1972; Turner 1989; Marean 1998; Marean and Kim 1998; Marean et al. 2000, 2004). Bone specimens measuring > 5 cm are numerically less represented and only accounted for roughly < 3% of the total sample (Figures 7.1 and 7.2).

Small and large-sized animal subsamples appear to display broadly similar distribution of specimens by size (see Figure 7.2). Despite this conservative observation, the distributions are not normally distributed statistically (Kolmogorov-Smirnov two-sample test D=0.500, p=0.066). In the small and large-sized animal subsamples, specimens measuring < 1 cm in maximum length accounts for 1.44% and 0.26% respectively. Size class 1-2 cm specimens are prevalent in the small-sized animal bones subsample. But, no specimen measuring 5 cm in maximum length was registered in the small-sized animals subsample. On the other hand, there are slightly more specimens in size class 2-3 cm and all the size classes above 3 cm in the large-sized animals subsample (Figure 7.2). To the contrary observed above, maximum lengths of specimens suggest the small-sized animal bones are more intensively fragmented.

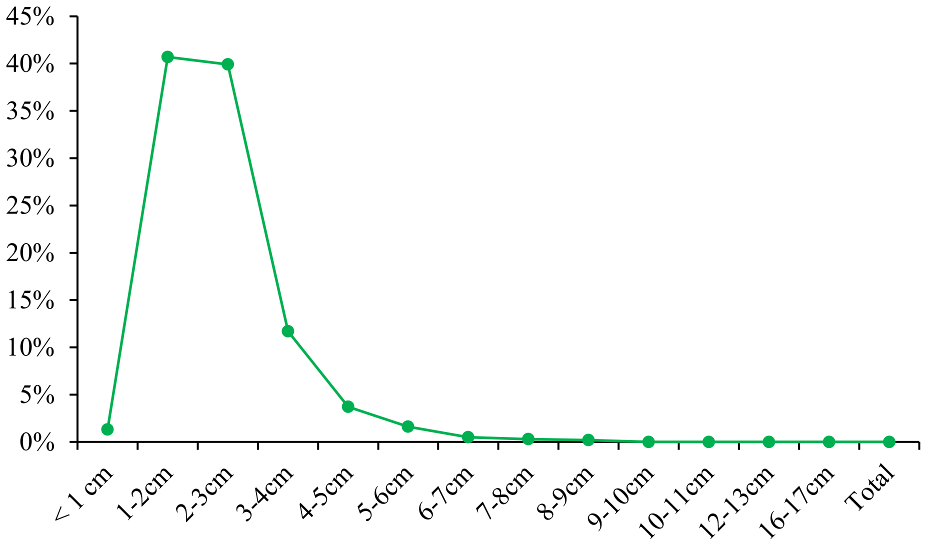


Figure 7.1. Distribution of Specimens in the Magubike Faunal Assemblage.

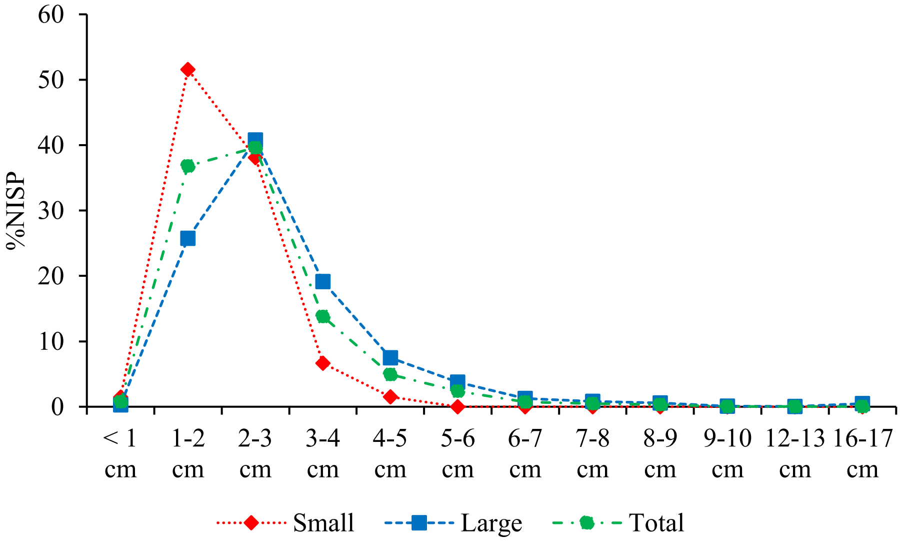


Figure 7.2. Distribution of Specimens by Animal Size.

About 67.5% (*n*=4,227) of the total sample scored for bone cortical surface preservation displayed excellently preserved surfaces, and 6.2% (*n*=387) were moderate. The remaining 26.31% (*n*=1,650) exhibited poorly preserved cortical surfaces. As for the specimens identified to skeletal parts, bone surface preservation is also broadly excellent

(Figure 7.3). Of the total identified skeletal parts (NISP=3,188 teeth excluded), about 82.12% (NISP=2,618) had well-preserved cortical surfaces. The rest were moderately (4.74%, NISP=151) or poorly preserved (13.14%, NISP=419). The poorly preserved specimens in the faunal assemblage are mostly attributed to the effect of concretions adhering on the cortical surfaces, and these typically had limited values for the study of bone surface modifications (Table 8.1).

The number of well-preserved specimens is broadly similar in the small and large-sized animal subsamples (see Figure 7.3). The site being a rockshelter with a cap covering an area approximately 540 m^2 protected the bones including ribs, pelvis, and vertebrae that are typically low-density and fragile elements from the destructive postdepositional taphonomic processes (Table 7.3; Figures 3.7 and 5.3). Caves and rockshelters habitually provide excellent conditions for the burial and preservation of the organic (Goldberg and Mandel 2008).

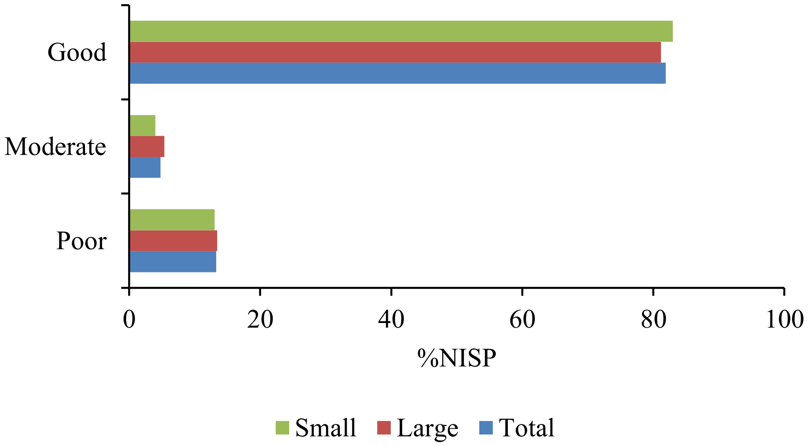


Figure 7.3. Bone Cortical Preservation in the Magubike Faunal Assemblage.

Figure 7.4. Some Faunal Remains from Magubike Rockshelter.

The Magubike faunal assemblage displayed different bone weathering stages when classified using Behrensmeyer (1978) scheme and reflect different episodes of depositional histories. About 69% of the total sample was recorded in weathering stage 2 and lacked the cracking and flaking typical of the subaerial bone weathering. The remaining about 31% belonged to stages 3, 4 and 5 with roughly 25% being in stage 4 and remarkably very few specimens belonged to stage 5 (Table 7.1). No specimen was registered in weathering stage 1.

The majority of the skeletal parts identified and assigned to animal size classes displayed a middle weathering profile mostly corresponding to the Behrensmeyer (1978) stages 2 and 3 suggestive the assemblage was rather deposited rapidly and exposed to a fewer destructive taphonomic processes post-discard (Andrews 1995). Weathering stages 2 and 4 constituted the bulk of the bone weathering profile representing about 82.56% and 13.25% respectively as graphically seen in Figure 7.5 below. Specimens in weathering stage 3 accounted for about 4%, and those exhibiting stage 5 for roughly < 1%. Heavily weathered specimens were excluded in the study of bone surface modifications (Table 8.1). Table 7.1 below summarizes bone weathering stages for the entire Magubike faunal assemblage studied and Figure 7.5 for the identified skeletal parts (NISP) and assigned to animal size classes.

Table 7.1. Bone Weathering Stages in the Magubike Faunal Assemblage.

Weathering Stages				Total
2	3	4	5	
4,320 (69%)	302 (4.8%)	1,556 (24.8%)	86 (1.4%)	6,264 (100%)

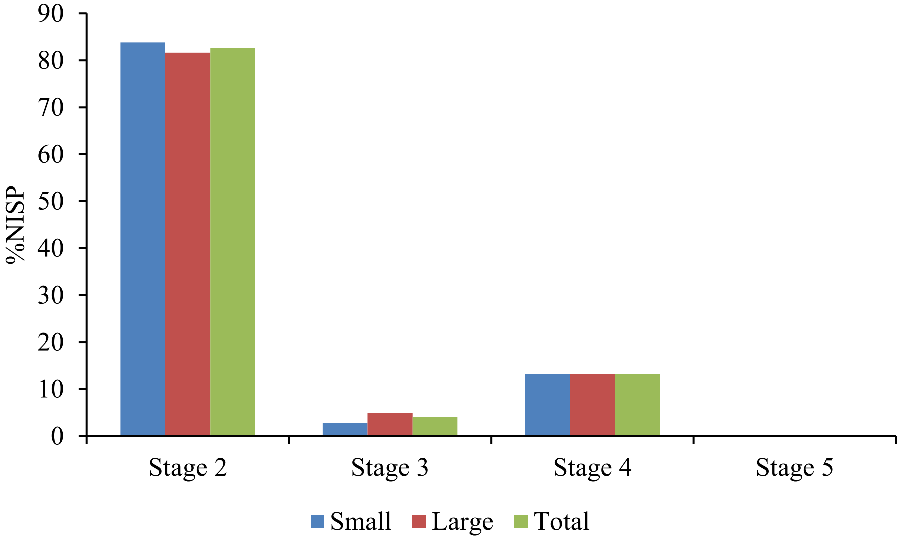


Figure 7.5. Bone Weathering Stages in the Magubike Faunal Assemblage.

The Magubike faunal assemblage overall exhibited a low frequency of specimens with rounded edges. Rounded fracture edges were recorded on a total of 503 specimens (8.77%) of the total bone sample (Table 8.1). As for specimens identified to skeletal parts, very few pieces exhibited fracture edge-rounding (*n*=145, 4.59% of the total NISP), which is mostly attributed to the effects of pedogenic processes or geological movement of the sediments down the archaeological sequence, high degree of bone fragmentation by hominin butchering activities and burning within the rockshelter (Tables 7.11-7.18, 7.23, 7.24, 8.2; Figures 7.14-7.16). The high intensity of burning habitually makes bones more friable and encourages edge damages (Stiner et al. 1995, Stiner 2005).

A considerable number of specimens in the Magubike faunal assemblage had concretions cemented on their cortical surfaces and in the marrow cavities (Figure 5.4). Two factors can explain this including the possible constant damp conditions inside the rockshelter or repeated episodes of wetting and drying in a sheltered environment. About 2,248 (34.23% specimens of the total sample) exhibited carbonate concretions of various degrees of coverage. Nonetheless, the overall proportion of the carbonate-affected specimens is low when compared to that reported by Collins (2009:143), whereby approximately 90% of the total MSA faunal specimens were affected. The difference in the proportions may be attributed to the differential exposure to direct rain and sunlight of the area excavated so far under the rockshelter overhang, spatial distribution of bone fragments inside the rockshelter, and may lie in the sample sizes studied (Table 8.2; Figures 3.7 and 5.3). A total of 65 of the identified skeletal parts (NISP) exhibited calcareous encrustations of between 75 to 99 % of their total cortical surface area that potentially reduced the surface area observable for the detection of bone surface modifications. A few specimens (*n*=33) were heavily encrusted on their cortical surfaces to the extent that masked any possibility for the detection of bone surface modifications. Taking this observation into consideration fragments with > 75% of their total surface cortical areas covered by concretions were also omitted in the study of bone surface modifications and tallies (Table 8.1).

The number of identified small compact bones in the Magubike faunal assemblage is relatively low (NISP=23, 0.6% of the total NISP). The ratio of the complete (CO) and almost complete (ACO), to the fractured (FR) small compact bones, is evidently high. The average Completeness Index for the Magubike faunal assemblage is 91.3% suggesting has undergone minimal postdepositional attrition (Marean 1991; Villa et al. 2004). Only two small compact bones were recorded as fractured (see Table 7.2 below for the details). The subsections below provide detailed taphonomic and zooarchaeological results for the Magubike faunal assemblage.

Table 7.2. Completeness Index of the Magubike Faunal Assemblage.

Size	Total Compact Bones	NISP CO+ACO	%CO+ACO	NISP FR	%FR
Small (1-2)	8	7	87.5	1	12.5
Large (3-4)	15	14	93.33	1	6.67
Total (1-4)	23	21	91.3	2	8.7

7.3. Skeletal Part Representation

A total of 6,568 specimens mainly belonging to the terrestrial mammals were analyzed from Magubike rockshelter. Out of the total sample, 3,131 specimens were categorized as unidentifiable and 3,436 specimens were confidently identified to skeletal parts (Tables 7.3 and 7.8). The identification rate was equal to 52.32% (Table 8.2). The number of identified specimens per m^3 of sediments is 525. Taxonomic representation is high and the major five anatomical segments of complete carcasses of the small and large-sized animals are also represented (Tables 7.3, 7.6; Figure 7.6).

Overall skeletal part representation in the Magubike faunal assemblage displays prevalence for the postcranial elements (Tables 7.3 and 7.6). The ratio of 0.27 is usually understood for a complete bovid carcass and is predicted to be frequently higher for the small-sized animals because they are regularly transported whole and relatively lower for the large-sized carcasses (Yellen 1977, 1991). The ratio of the cranial to postcranial bones for the entire assemblage is 0.11. The ratio for the small and large-sized animal subsamples is 0.13 and 0.10 respectively, which are also very low and suggest the skulls probably were not regularly transported back to the rockshelter for further processing. Skulls are typically bulky and are of low nutritional values so are frequently discarded at the butchery sites (Binford 1978, 1981; Oliver 1993; Bunn et al. 1988; Bunn and Kroll 1986; Bunn and Ezzo 1993; O'Connell et al. 1988a, 1990, 1992; Lupo 1994, 2001, 2006; Stiner 1991a, 1994; Monahan 1998; Lupo and O'Connell 2002). The low presentation of cranial elements may also be attributed to the differential preservation of the elements as a function of their bone mineral density and the noted high degree of bone fragmentation in the faunal assemblage (Lyman 1994; Stiner 1994; Lam et al. 1999).

Skeletal parts from the major five anatomical segments of a complete carcass as defined in Chapter 5 are represented in varying proportions (see Tables 7.3, 7.6; Figure 7.6). A close look at an overall skeletal part representation in the Magubike faunal assemblage irrespective of the animal size class reveals 36.85% (NISP=1,250), are from the upper limb appendicular bones (upper limb bones and intermediate limb bones) followed closely by axial elements (vertebrae, ribs, pelves, and scapulae) by 36.43%

(NISP=1,236). Among the upper appendicular limb bones, the intermediate limb bones (radius and tibia) are better represented by 24.11% (NISP=818). The upper limb bones (humerus and femur) typically with the highest amount of meat attached make up only 12.74% (NISP=432). Much like in the Loiyangalani faunal assemblage, the axial and upper appendicular limb bones overall dominate in the Magubike faunal assemblage accounting for 73.27% (NISP=2,486). This is in accord with the ethnoarchaeological findings reported by Lupo and O'Connell (2002:88, Table 1) for a Hadza campsite faunal assemblage whereby a combination of the upper limb bones, intermediate limb bones, and axial elements accounted for approximately 72% of the total NISP. This also suggests an existence of the foraging strategy that was more oriented towards the maximization of meat brought back to the rockshelter (Yellen 1977; Binford 1978, 1981; Bunn et al. 1988; Lupo 2006; O'Connell et al. 1988a, 1990; Monahan 1998; Bartram and Marean 1999). The same general picture is also apparent in the small and large-sized carcass subsamples (see Table 7.6 below for the details).

The cranial bones (horns, skulls, maxillae, mandibles, and dentition) and lower limb bones (metapodials, carpals, and tarsals) are less frequent represented in the Magubike faunal assemblage and are represented by a combined percentage of approximately 27% (NISP=907). Small and large-sized animal subsamples also share analogous quantitative pattern (Tables 7.3 and 7.6). The overall skeletal part representation is relatively complete and contrasts the Klasies River MSA faunal assemblage "head-and-foot" dominated pattern reported by Binford (1984). For the same reason like for the Loiyangalani faunal assemblage, an alternative explanation must be considered. As shown graphically in Figure 7.6 below skeletal part representation is also fairly complete for both animal size subsamples as measured by %MAU and mostly appears to correlate with hominin selective transport of the carcass parts (Binford 1978, 1981; Metcalfe and Jones 1988; Marean 1998; Marean and Frey 1997; Marean and Kim 1998; Marean and Assefa 1999; Marean et al. 2000, 2004; Bartram and Marean 1999). Details on skeletal part representation by animal size and per major five anatomical segment of a complete carcass are provided in Table 7.6 below.

Rib shaft fragments are the most abundant identified skeletal parts making up almost 30% of the total NISP at Magubike rockshelter. Much like in the Loiyangalani faunal assemblage, isolated teeth are also represented in relatively higher proportion (7.22%) of the total NISP followed distantly by the mandibles (1.12%) and skull fragments (1.62%). The first and third phalanges are represented by a combined percentage of 3.3. The third phalange is the least represented only with a total NISP of 4 elements. Carpals and tarsals are also very rare (Table 7.3). Identified skeletal parts are also relatively more evenly distributed in the small-sized animal subsample (E=0.72) as measured by NISP counts as is the case in the Loiyangalani faunal sample. The large-sized animals yielded an evenness value of 0.70.

Long bones typically with the high amount of meat and marrow remarkably dominate the postcranial sample (NISP=1,659; 54.27% of the total postcranial sample) that also can be interpreted as a result of hominin preferential transport (Binford 1978, 1981; Metcalfe and Jones 1988; Stiner 1990, 1994). Among the long bones, tibia dominates (NISP=637) followed by the femur and metatarsal (Tables 7.3 and 7.4). Tibia is also overall better represented than the rest of the long bones (%MAU=100). Tibia fragments are characteristically ease to identify to skeletal parts based on the angulations on its shaft (Barba and Domínguez-Rodrigo 2005; Pickering et al. 2003, 2005, 2006). Other long bones including the radius, metacarpal, and humerus were identified in relatively moderate proportions (see Tables 7.3 and 7.4).

Long bone midshaft fragments are the most ubiquitous of the identified specimens in the Magubike faunal assemblage, and their epiphyseal ends are remarkably less frequent (Table 7.4). Characteristically midshaft fragments are much denser and best survive both post-discard carnivore-ravaging and density-mediated attrition (Marean and Spencer 1991; Marean et al. 1992; Lyman 1994; Lam et al. 1999). As detailed in Table 7.4 below long bone midshaft portions also have higher NISP, MNE, MAU, and %MAU values than their epiphyseal portions. The ratio of the epiphyses (*n*=76) to the midshaft fragments (*n*=1,580), excluding the complete bones is 0.048 for the entire Magubike faunal assemblage. For the small and large-sized animal subsamples, the ratio is 0.058 and 0.039 respectively (Table 7.4). Of note, the ratios do not fall within the range of the values reported in the experimental hammerstone fractured faunal samples that often range between 0.33 and 0.70, and are also well below to that of 0.19 for a hyena den suggesting the presence of strong destructive taphonomic processes that have postdepositionally affected the faunal assemblage (see Monahan 1996:101; Table 3).

The ratio of the proximal (low-density portion) to the distal (high-density portion) of the humerus and tibia also provide an index of the degree of post-discard attrition the Magubike faunal assemblage has suffered (*sensu* Binford 1981:219). This is also too low and is only at 0.14. The distal portions of the humerus and tibia are represented by relatively higher frequencies (17 and 4 respectively) than their corresponding proximal portions (0 and 1 respectively) by NISP counts again suggesting Magubike faunal assemblage has endured considerable post-burial attrition (Table 7.4). The poor representation of the long bone epiphyseal portions may be correlated to an amalgamation of the non-cultural processes including the impact of post-discard carnivore ravaging and density-mediated attrition.

To gauge the degree of deletion of epiphyseal ends in the Magubike faunal assemblage, long bone portions representation were also correlated to both against their corresponding bone portion-specific %survivorship values from a carnivore-ravaged faunal sample and against their BMD values (Lyman 1994; Lam et al. 1999; Marean and Spencer 1991; Marean et al. 1992). The relationship between the two groups of data yielded strong positive and statistically significant relationships for both animal size subsamples (Spearman's rho: small-sized, r_s=0.730, p=0.025; and the large-sized carcasses, r_s=0.843, p=<0.010). Besides, the relationship is also strong positive and statistically significant correlated between long bone portions representation against their corresponding BMD values (Spearman's rho: small-sized, r_s=0.523, p=0.026; and for the large-sized carcasses, r_s=0.738, p=<0.010). Therefore, the apparent low representation of the epiphyseal ends in the Magubike faunal assemblage significantly mirrors the impact of both post-discard carnivore intervention and density-mediated attrition (see Table 7.4 below for the details).

Based on the average %MAU values provided in Table 7.4 below, the distal epiphyseal portions of the humerus (3.58%) and radius (2.74%) are slightly better represented in the Magubike faunal assemblage. Other long bones are represented in relatively lower proportions having average representations ranging between 0.3% and 1.6% in both animal size classes. The proximal humerus and distal metacarpal are totally missing in both animal size classes. For the small-sized carcasses, the element with the highest representation of the epiphyseal ends is the distal humerus (%MAU=4.49) followed by the distal radius with a %MAU value of 2.81. The proximal and distal parts of the metacarpal are also totally missing as well as the proximal humerus and distal metatarsal in the small-sized animals subsample. The element with the highest representation of the epiphyseal portions in the large-sized animals subsample is the proximal humerus and distal radius (%MAU=2.67) followed closely by the proximal femur and metatarsal each with an average %MAU value of 2.

To evaluate MSA hominins preferential transport of the carcass parts at Magubike rockshelter, %MAU values considering all elements were correlated against their corresponding standardized food utility index (SFUI) values. Figure 7.7 below shows bivariate scatterplots between the two sets of data for both small (size 1-2) and large-sized (size 3-4) carcass subsamples.

A plot between %MAU and SFUI values for the small-sized carcasses subsample yielded a weak positive but statistically insignificant correlation coefficient (Spearman's rho: r_s=0.015, p=0.957). The results suggest MSA hominins selectively transported the protein-rich carcass parts back to the rockshelter for further processing and consumption (Tables 7.3, 7.7; Figure 7.7). However, a moderate positive statistically insignificant correlation coefficient between %MAU and BMD values is recorded for the small-sized animal subsample (Spearman's rho: r_s=0.423, p=0.013). The results indicate the original skeletal part abundance of the small-sized animals is biased by density-mediated attrition significantly (Figure 7.8).

For the large-sized carcasses subsample, a plot between %MAU and SFUI values, a weak positive and statistically insignificant correlation coefficient is recorded (Spearman's rho: r_s=0.013, p=0.961). The results also suggest MSA hominins selectively transported the carcass parts with higher nutritional values back to the rockshelter (Figure 7.7). However, the correlation of %MAU against BMD values yielded a strong positive and statistically very significant correlation coefficient for the large-sized animal bones subsample (Spearman's rho: r_s=0.514, p=<0.010). The results also demonstrate the original abundance of the large-sized animal bones also has been significantly conditioned by their densities (Figure 7.8).

In order to evaluate the potential influence of post-discard carnivore ravaging on skeletal part abundance in the Magubike faunal assemblage, %MAU values were also correlated against %survivorship values of corresponding element and portions derived from the experimental studies involving carnivore ravaging of the carcass parts (Marean and Spencer 1991; Marean et al. 1992). Weak positive and statistically insignificant correlations in both animal size classes are recorded (Spearman's rho: small-sized, r_s=0.089, p=0.680 and for the large-sized carcasses, r_s=0.147, p=0.493). The results suggest a presence of minimal carnivore intervention on the Magubike faunal assemblage but overall not significant. The inference is also attested by the relatively high frequency of the less-dense and high-grease content elements that are typically attractive to carnivore ravaging including ribs, vertebrae, and pelves (see Table 7.3). In initially carnivore ravaged faunal assemblages; these frequently survive in low proportions (Blumenschine 1986a, b; Blumenschine and Marean 1993; Marean and Spencer 1991; Marean et al. 1992; Capaldo 1995; Faith and Behrensmeyer 2006; Pickering and Domínguez-Rodrigo 2006; Domínguez-Rodrigo and Organista 2007).

In order to further investigate MSA hominins possible encounter of prey, field processing, and selective transport of the carcass parts, the high-survival-elements set MAU values were used to calculate the Shannon Evenness Index (*E*) as outlined in Chapter 5 above (Tables 5.4 and 7.3). Small-sized carcasses subsample yielded a value of 0.75, which represents an uneven distribution of skeletal parts with a strong bias towards the high-survival-elements. Following Faith and Gordon (2007:875-877) guideline, the value falls very close to unbiased transport strategy associated with greater distance transportation of the carcass parts in direct relationship to their food economic utility (Tables 5.4, 7.7; Figure 7.7). The uneven value for the small-sized carcasses subsample also can be attributed to the impact of post-discard carnivore ravaging and the differential preservation of skeletal parts as a function of their bone mineral density as remarked above (Blumenschine 1986a, b; Marean and Spencer 1991; Marean et al. 1992; Lyman 1994; Capaldo 1995; Lam et al. 1999; Faith and Gordon 2007: 875-877; Faith et al. 2009: 250).

Large-sized carcasses subsample gave an evenness value of 0.81. This is also an uneven distribution of the high-survival-elements. It also denotes an unbiased strategy that reflects transport of the carcass parts in direct proportion to their economic utility that also involved long distance back to the rockshelter. The relatively low evenness value for the large-sized (size 3-4) carcasses at Magubike rockshelter compared to that of a comparable animal size class at the Loiyangalani site (predominantly a flat site) is not surprising given the transport constraints they pose and the nature of the Iringa Region terrain mostly characterized by the hilly and undulating topography making difficulties to transverse the landscape carrying the heavy load of the carcass parts (Kelly 2007).

However, the fact that the sample sizes used in the calculation of the evenness indices are relatively high for both small (MNE=390) and for large-sized (MNE=459) animals certainly unbiased transport strategy of the carcass parts was common at Magubike rockshelter. The evenness indices do not appear to reflect the impact of faunal sample sizes considered and their associated bias (Faith and Gordon 2007; 875-877; Faith et al. 2009:250).

Table 7.7 below presents the Shannon Evenness Index (*E*) values and Spearman's rho results between %MAU of the high-survival-elements set against their standardized food utility (SFUI values). In both animal size classes, the relationships are strong and positive correlated. Of note, the correlation coefficient for the large-sized animals subsample is very statistically significant. The coefficient of determination r^2 ranges between 0.25 and 0.62 (Table 7.7). The overall picture emerging from skeletal part representation in the Magubike faunal assemblage mostly reflects MSA hominins selective transport of the high-meat and marrow-yielding carcass parts (Tables 7.3, 7.6; Figures 7.6 and 7.7). Later carnivore ravaging and density-mediated attrition played a part in biasing the original skeletal abundance deposited at the site (Figure 7.8).

The most represented animals group in the Magubike rockshelter faunal assemblage by NISP counts are large-sized (size 3-4) animals, which also appear to have been the main hunted prey. Large-sized animals also dominate the MNI counts (MNI=115, NISP=1,942). Small-sized animals are relatively less frequent as represented by both NISP and MNI counts making up only 42.76% and 49.12% respectively (Tables 4.1, 7.3 and7.5).

Table 7.3. Skeletal Part Representation in the Magubike Faunal Assemblage.

Element	Small				Large			
	NISP	MNE	MAU	%MAU	NISP	MNE	MAU	%MAU
Cranium	28	28	14	15.73	10	10	5	6.67
Mandible	16	10	5	6.67	39	11	5.5	7.33
Teeth	124	-	-	-	121	-	-	-
Atlas	12	12	12	13.48	13	13	13	17.33
Cervical	18	18	3.6	4.04	17	17	3.4	4.33
Thoracic	18	18	1.38	1.55	26	26	2	2.67
Lumbar	18	18	3	3.37	25	25	4.17	5.56
Sacrum	3	3	0.6	0.67	11	11	2.2	2.93
Rib	323	51	1.96	2.15	657	42	1.61	2.15
Scapula	14	10	5	5.62	36	11	5.5	7.33
Humerus	21	15	7.5	8.42	28	15	7.5	10
Radius	94	63	31.5	35.39	57	47	23.5	31.33
Ulna	30	28	14	15.73	1	1	0.5	0.67
Metacarpal	9	3	1.5	1.69	120	23	11.5	15.33
Magnum	-	-	-	-	2	2	1	1.33
Sesamoid	-	-	-	-	4	4	0.5	0.67
Pelvis	15	10	5	5.61	29	10	5	6.67
Femur	179	69	34.5	38.76	204	106	53	70.67
Tibia	427	182	91	100	209	150	75	100
Astragalus	-	-	-	-	5	5	2.5	3.33
Calcaneum	4	4	2	2.25	1	1	0.5	0.67
Cuneiform	2	2	1	1.12	1	1	0.5	0.67
Metatarsal	55	20	10	11.23	254	97	48.5	64.67
Phalanx 1	25	25	3.13	3.52	48	48	6	8
Phalanx 2	14	14	1.75	1.97	22	22	2.75	3.67
Phalanx 3	2	2	0.25	0.28	2	2	0.25	0.33

Table 7.4. Long Bones NISP, MNE, MAU, %MAU by Animal Size.

Element/Size	Small				Large			
	NISP	MNE	MAU	%MAU	NISP	MNE	MAU	%MAU
Humerus, Proximal	-	-	-	-	1	-	-	-
Humerus, Shaft	10	7	3.5	3.93	21	11	5.5	7.33
Humerus, Distal	11	8	4	4.49	6	4	2	2.67
Radius, Proximal	2	1	0.5	0.56	1	1	0.5	0.67
Radius, Shaft	86	57	28.5	32.02	52	42	21	28
Radius, Distal	6	5	2.5	2.81	4	4	2	2.67
Metacarpal, Proximal	-	-	-	-	1	1	0.5	0.67
Metacarpal, Shaft	4	3	1.5	1.69	111	22	11	14.67
Metacarpal, Distal	5	-	-	-	8	-	-	-
Femur, Proximal	4	2	1	1.12	4	3	1.5	2
Femur, Shaft	173	65	32.5	36.52	200	103	51.5	68.67
Femur, Distal	2	2	1	1.12	-	-	-	-
Tibia, Proximal	2	2	1	1.12	-	-	-	-
Tibia, Shaft	421	178	89	100	209	150	75	100
Tibia, Distal	4	2	1	1.12	-	-	-	-
Metatarsal, Proximal	4	2	1	1.12	7	3	1.5	2
Metatarsal, Shaft	48	18	9	10.11	246	93	46.5	62
Metatarsal, Distal	3	-	-	-	1	1	0.5	0.67

Table 7.5. NISP and MNI by Animal Size.

Count	Size 1	Size 2	Size 3	Size 4	Total
NISP	483	968	1,184	758	3,393
MNI	34	77	68	47	226

Table 7.6. NISP by Major Anatomical Sections and Animal Size.

Region	Size 1	Size 2	Size 3	Size 4	Total
CRA	21	147	137	33	338
AXL	164	257	521	294	1,236
ULL	82	118	151	81	432
ILB	202	349	183	84	818
LLB	14	97	192	266	569
Total	483	968	1,184	758	3,393

Table 7.7. Shannon Evenness Indices and Correlation Coefficients between %MAU of the High-Survival-Elements Set vs. SFUI Values.

Animal Size	MNE	Evenness	r_s
Small (1-2)	390	0.75	0.500(p=0.207)
Large (3-4)	459	0.82	0.786 (p=0.021)

Table 7.8. Other Taxa Identified in the Magubike Faunal Assemblage.

Taxa	Element	NISP
Bird	Coracoid	1
	Tibio-tarsus	11
	Carpo-metacarpus	3
	Femur	14
	Humerus	3
	Radius	2
	Vertebra	2
	Digit III	1
Hyena	Mandible	3
Rodent	Tooth	3

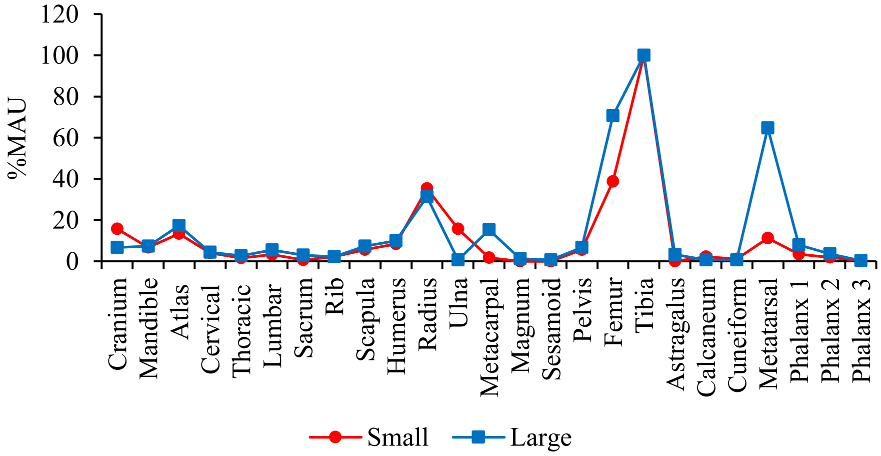


Figure 7.6. Skeletal Part Abundance by %MAU and Animal Size.

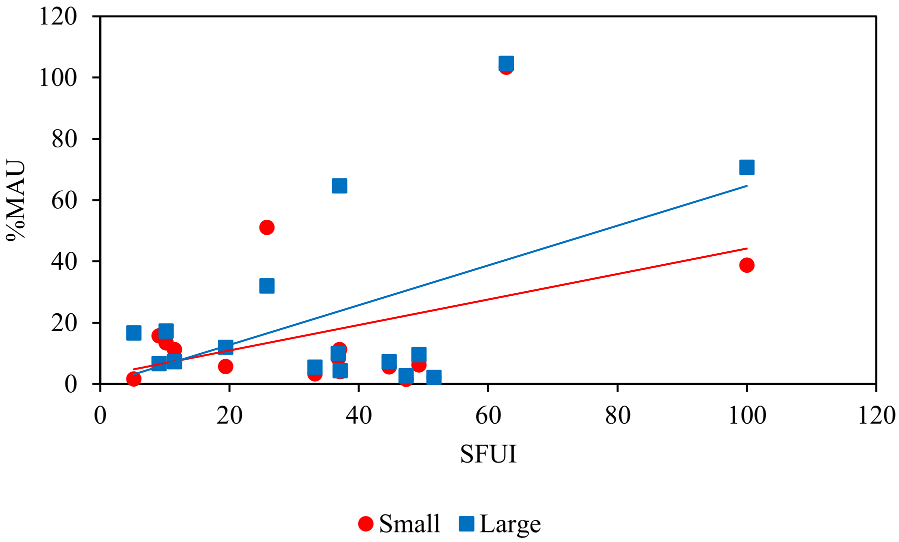


Figure 7.7. Bivariate Scatterplot between %MAU and SFUI for Small and Large-sized Animals.

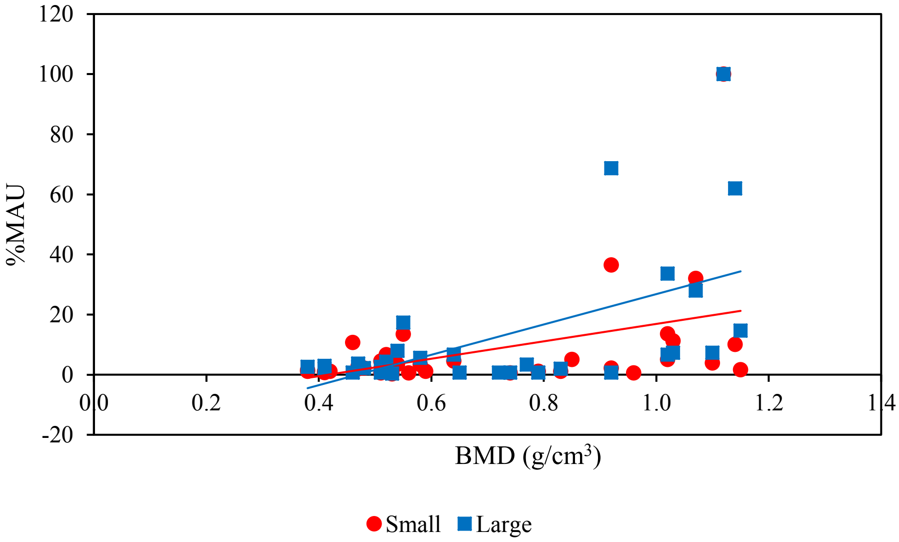


Figure 7.8. Bivariate Scatterplot between %MAU and BMD for Small and Large-sized Animals.

7.4. Taxonomic Composition and Diversity

Bovids mainly represented by fragmentary skeletal parts, are the most numerous mammal classes identified in the Magubike faunal assemblage, which corroborates well the species richness of the Iringa Region (Coryndon et al. 1972; Crema 1987). Identified skeletal parts assigned to animal size classes also appear to be evenly spread in the faunal assemblage between animal size 1 and 4 by both NISP and MNI counts with size 3 bovids being the most ubiquitous (Tables 4.1 and 7.5). Table 7.5 above shows the medium-sized animals (size 3 bovids) that weigh up to 300 kilograms are the most ubiquitous comprising almost 35% of the total NISP (MNI=68), which also suggests the MSA hominins preferentially targeted them. Size 2 bovids are the second most copious group with about 29% (MNI=77) followed by size 4 accounting for 22% (MNI=47) of the total NISP. Overall, the large-sized animals (size 3-4 bovids) are the most abundant in the Magubike faunal assemblage accounting for approximately 60% of the total site NISP and about 51% of the total MNI counts (Table 7.5).

Taxa identified in the Magubike faunal assemblage are also based on a very few isolated teeth and distinctive features of some skeletal parts. These were mainly identified using Rikki Walker's (1985) guidebook and comparative skeleton collections. They include warthog (*Phacochoerus africanus*), impala (*Aepycerous melampus*), Thompson's gazelle (*Eudorcas thomsoni*), buffalo (*Syncerus caffer*), topi (*Damaliscus korrigum*) and Grant's gazelle (*Nanger granti*). Other taxa marginally identified include hare (*Lepus capensis*), dik (*Madoqua kirkii*) and zebra (*Equus burchellii*). Suids are the second most frequent taxon in the faunal assemblage, which may suggest MSA hominins active hunting of the aggressive prey (Table 7.9). Remains of medium-sized bird were also identified but were very fragmented so could not be identified beyond class level. However, bone surface modifications indicate a high possibility that birds were regularly exploited at the site (see Table 7.11).

Carnivore remains are mainly represented by one left and two right mandibular fragments with premolars and molars confidently identified to spotted hyena (*Crocuta crocuta*) with a total MNI of 2. Large carnivore tooth marks are also documented on the fossil bone fragments, which may also suggests the possibility they resided within the rockshelter or sporadically, used it as a den or other type of refuge. Nevertheless, the ratio of carnivore to the ungulate is negligible and suggests they did not intensively use the site for denning (Cruz-Uribe 1991; Brain 1980, 1981; Lam 1992; Pickering 2002; Villa et al. 2004; Kuhn et al. 2010). This is also reflected in the overall scarcity of the large carnivore damage inflicted on the bone fragments (see Tables 7.14, 7.19-7.22; Figures 7.12 and 7.13). The presence of hyena remains in the Magubike faunal assemblage can be considered at best to be accidental as they are habitually attracted to human habitations and may have died there naturally (Bunn et al. 1988, 1991; Bunn 1993; Kroll and Price 1991; Bartram 1993; Bartram et al. 1991; Bartram and Marean 1999; Lupo 1995; Marean 1998; Lupo and O’Connell 2002).

Rodents (*Thryonomys swinderianus*) are also represented mainly by their dentition with a total MNI of 2. Isolated hominin teeth, beads, stone artefacts, modified bone fragments throughout the archaeological sequence attest the long-term hominin presence at Magubike rockshelter (Willoughby 2005, 2012a, b; Collins 2009; Collins and Willoughby 2010; Alexander 2010; Biittner 2011; Bushozi 2011; Miller and Willoughby 2014; Werner and Willoughby 2017).

Table 7.9. Major Faunal Groups Documented at Magubike Rockshelter.

Taxa	NISP	%NISP
Bovid	3,324	96.74
Suid	57	1.66
Equid	3	0.09
Hare	9	0.26
Hyena	3	0.09
Rodent	3	0.09
Bird	37	1.08
Total	3,436	100

7.5. Mortality Profile

Mortality profile data for the Magubike faunal assemblage is mainly established from the epiphyseal fusion of a relatively few ageable skeletal parts mostly long bone fragments (Tables 7.4 and 7.10). As was the case for the Loiyangalani faunal assemblage, mortality profile datasets also give a very general age estimation of individuals at death at the site due to the apparent incomplete nature of the bulk of the skeletal parts (Table 8.2). Remarkably very few specimens preserved their epiphyseal ends. A total of 99 specimens had one of their epiphyseal portions (proximal or distal) preserved that could be scored for stages of epiphyseal fusion.

Out of the total available sample, 87 specimens had their proximal or distal epiphyseal ends fused, and the remaining 12 were classified as unfused. Using the guideline provided in Chapter 5, full epiphyseal fusion as a threshold for maturity, about 15.4% in the small-sized animals subsample are juveniles, and 84.6% are prime-adults by NISP counts. For the case of the large-sized animals subsample, only 10% are juveniles. The percentage of prime-aged individuals, which provide high yields in terms of meat and marrow, is 90% by NISP counts (Table 7.10). Epiphyseal fusion by MNI counts of each animal size and age class also demonstrates the same broad age structure of being heavily dominated by prime-adults, which also suggests MSA hominins selective hunting of the more profitable age class (Klein 1982; Klein and Cruz-Uribe 1983, 1984; Stiner 1990, 1991a, 1991b, 1994; Gaudzniski and Roebroeks 2000). In addition, bone surface modifications and mode of fragmentation in the faunal assemblage suggest MSA hominins had early access to their complete carcasses (see Tables 7.13, 7.15, 7.22; Figures 7.9 and 7.10).

Of note, the proportion of prime-adults in the Magubike faunal assemblage is overall not consistent with those drawn from a living population in which the percentage is usually below 20% (Klein and Cruz-Uribe 1984; Estes 1991; Owen-Smith 2006). Accordingly, prime-adults mortality estimates are probably rather conservative and should be treated with caution. The sample size of specimens available for analysis certainly has mediated mortality profile reconstruction for the Magubike faunal assemblage (Table 7.10). The overall underrepresentation of the juveniles may also suggest presence of a strong taphonomic bias introduced by carnivore ravaging, density-mediated attrition, and may also mirror the extent and intensity of fragmentation in the faunal assemblage studied (Klein and Cruz-Uribe 1984; Blumenschine 1986a, 1986b, 1987, 1991; Marean 1995; Munson 2000; Munson and Marean 2003). Nevertheless, mortality profile data for the Magubike faunal assemblage broadly serves to illustrate a specialized hunting strategy by MSA hominins mostly biased towards the prime-adults. Besides mortality profile data suggest at least over 70% of the ungulates hunted had an age of above one and two years for the antilopini (such as Thompson’s gazelle, Grant’s gazelle, and dik-dik) and alcelaphini (such as in wildebeest, topi, and hartebeest) respectively (Klein and Cruz-Uribe 1984).

Table 7.10. Epiphyseal Fusion Data for the Magubike Faunal Assemblage.

Size/ Class	Juvenile		Prime-Adult	
	NISP	MNI	NISP	MNI
Size 1	3	1	8	1
Size 2	3	-	25	5
Size 3	6	1	28	3
Size 4	-	-	26	3
Total	12	2	87	12

7.6. Bone Surface Modifications

The overall excellent state of preservation of the bone cortical surfaces in the Magubike faunal assemblage permitted the detection of different bone surface modification classes attributable to both human and nonhuman agents (Tables 7.1, 7.2, 8.1; Figures 7.3, 7.5 and 8.1). A total of 1,130 specimens displayed at least a single type of human or nonhuman-induced surface modification. The majority of the bone surface modifications were recorded on the identified skeletal parts. Tables 7.11 and 7.19 below summarize the types and incidences of bone surface modifications in the faunal assemblage.

7.6.1. Human-Induced Modifications

Different bone surface modifications attributable to human reduction and processing of the animal carcasses into consumable parts were recorded. They include cut marks, percussion marks and burning and collectively establish the MSA hominins involvement with the bones while still in their nutritive state at the site. Percussion marks are by far the most recorded type of the human-induced surface modifications. Cut marks and traces of burning are relatively less frequent (Tables 7.11-7.18).

A total of 330 specimens were cut-marked, 241 on identified skeletal parts and 89 on unidentified specimens resulting from the removal of meat from the carcasses. The overall percentage of cut marks on mammalian identified skeletal parts is 7.62% (teeth excluded). For the small and large-sized animal subsamples, the percentage is 3.99% and 10.27% respectively (Tables 7.11, 7.12; Figure 7.9). The marked difference in the overall percentages for the small and large-sized animals mainly may be related to the differential field processing of their carcasses (Yellen 1977, 1991; Binford 1978, 1981; Bunn and Kroll 1986; Bunn et al. 1988; Lyman 1987a; O'Connell et al. 1988a, 1990, 1992; Oliver 1993; Lupo 1994, 2001, 2006; Lupo and O'Connell 2002; Monahan 1998; Nilssen 2000). Other factors may include the impact of concretions that may have potentially obscured cut marks inflicted on bone fragments cortical surfaces (Table 8.1). The low percentages may also be associated with the general high fragmentary nature of the faunal assemblage that also might have depressed the cut marks tallies (Bartram 1993; Abe et al. 2002; Lupo and O'Connell 2002; Domínguez-Rodrigo 2003; Domínguez-Rodrigo et al. 2007d; Organista et al. 2016; Otárola-Castillo 2010).

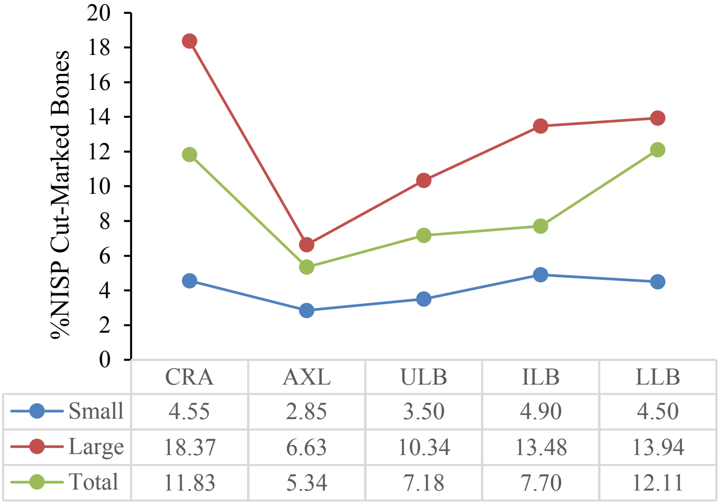
Cut marks are virtually recorded over the entire carcass, and their distribution suggests step-by-step episodes of processing from skinning to bone marrow extraction (see Table 7.11; Figure 7.9). The rib, tibia, metatarsal, and femur have the highest number of specimens bearing cut marks. Cut marks recorded on the majority of the mandibles are ascribed to the skinning episode. Two mandibles belonging to the large-sized animals also preserved cut marks along both their inner and outer face suggest retrieving of the tongue (Nilssen 2000). Skinning is also inferred from the cut marks inflicted on the cranium and on metapodials. A single cut mark was also noted on a tibio-tarsus of a medium sized bird and is certainly interpreted was made during dismemberment (Table 7.11). Approximately 65% of the total cut-marked specimens in the Magubike faunal assemblage were preserved on the long bones. Tables 7.11-7.14 below provide details on the incidences of cut marks in the faunal assemblage.

Skeletal parts bearing cut marks (NISP cut-marked) in the Magubike faunal assemblage are strongly and positively correlated with the NISP of each skeletal part in both animal size classes (Spearman's rho: small-sized, r_s= 0.672, p=<0.010; and for the large-sized carcasses, r_s=0.913, p=<0.010). The results suggest cut-marked bone fragments in the faunal assemblage are also related to the sample size considered and can be used dependably in the reconstructions of prehistoric human butchery behaviour (Lyman 1987b, 1994:301-303). The relationship between cut marks bearing bones (NISP cut-marked) against their corresponding economic utility (SFUI values) also yielded strong positive and statistically significant correlation coefficient for the small-sized carcasses subsample (Spearman's rho: r_s= 0.686, p=0.020). However, results for a pair-wise correlation is moderate positive and statistically insignificant for the large-sized carcasses subsample (Spearman's rho: r_s=0.217, p=0.498). The results also may be interpreted the small-sized animals were relatively butchered more intensively at Magubike rockshelter (Lyman 1987b, 1994).

All major five anatomical segments of a complete carcass also bear cut marks, which entails the MSA occupants of the rockshelter possessed detailed knowledge of the anatomy of their prey and efficiently processed them to retrieve edible resources. Figure 7.9 below shows the proportions of cut-mark bearing bones (NISP cut-marked/NISP) by major anatomical segments and animal size. Overall, cut marks are more abundant on the lower limb bones (LLB) by approximately 12% followed closely by cranial bones by 11.83% which is to be expected as skinning is usually a necessary preceding butchery process in carcasses processing (Binford 1978, 1981; Lyman 1987a, 1994; Nilssen 2000; Galán and Domínguez-Rodrigo 2013). The intermediate limb bones (ILB) also have slightly more specimens bearing cut marks (7.7%) than the upper limb bones (ULB) by 7.18% of the total cut-marked specimens in the assemblage. The axial bones also preserved relatively lower proportion of cut-marked specimens only by 5.34%. In addition, very few cut marks were also recorded on the cranial bones (see Figure 7.9).

There is also some notable difference in the proportions of cut marks bearing elements across a complete carcass between the small and large-sized animal subsamples. The difference is also very statistically significant (two sample *t*-test: t=5.1573, p=0.0067). As seen in Figure 7.9 below, the proportions of specimens bearing cut marks in the small-sized carcasses subsample are comparatively very low and do not exceed 5% across the major five anatomical segments of a complete carcass. Of note, the intermediate limb bones (ILB) by 4.9% followed closely by cranial bones by 4.55% have the highest proportions of the cut-marked specimens. The upper limb bones (ULB) and the axial elements have lower proportions of 3.5% and 2.85% respectively in the small-sized carcasses subsample. There are also relatively more cut marks-bearing elements from the cranial by 18.37% and on lower limb bones (LLB) by 13.94% in the large-sized animals subsample (Figure 7.9). The upper limb bones (ULB) have slightly fewer specimens bearing cut marks than the intermediate limb bones (ILB) with respective percentages of 13.48% and 10.34%.

With regards to the proportions of cut marks on the major six long limb bones, the upper appendicular limb bones (ULB and ULB) that are typically the high meaty-bearing elements bear cut marks in relatively high combined percentage of 14.88% (7.18% and 7.7% for the ULB and ILB respectively). The lower limb bones (LLB) that are the none-meaty bearing elements only bear 12.11% of the total cut-marked specimens. Both small and large-sized carcass subsamples also appear to show a similar quantitative picture. The overall proportion of cut marks in the Magubike faunal assemblage is consistent with hominin primary (early) access to the high-meat bearing long limb bones (Binford 1981; Potts and Shipman 1981; Bunn 1982, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Oliver 1994; Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2007c; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014).



	CRA	AXL	ULB	ILB	LLB
Small	4.55	2.85	3.50	4.90	4.50
Large	18.37	6.63	10.34	13.48	13.94
Total	11.83	5.34	7.18	7.70	12.11

Figure 7.9. Proportions of Cut-Marked Bones by Major Anatomical Segments and Animal Size in the Magubike Faunal Assemblage.

Of the total cut-marked specimens in the Magubike faunal assemblage, 158 were preserved on the long bone fragments and these were more prevalent on the large-sized animals (Tables 7.11-7.14). A total of 122 were recorded on midshaft sections that are typically covered by more meat and the remaining 36 on epiphyseal (proximal or distal) ends. The proportion of cut-marked midshaft fragments ranges between 2 and 13% (see Table 7.13 for the details). The majority of cut marks on long bone fragments are consistent with filleting/deboning (Tables 7.11-7.14, 8.4; Figures 7.9 and 7.10). The midshaft sections of the metacarpal (13.18%) and humerus (6.12%) are the most cut marked in the assemblage. The proportions of cut marks on the major six long bone midshafts in the small and large-sized animal subsamples also appear to vary, and the difference is statistically significant (two sample *t*-test: *t*=2.8118, *p*=0.0482).

Much like for the Loiyangalani faunal assemblage, the lower limb bones (LLB) midshafts in the Magubike sample are also more cut-marked than both the upper limb bones (ULB) and the intermediate limb bones (ILB) combined (Table 7.13). In addition, the intermediate limb bones (ILB) are also more cut-marked than the upper limb bones (ULB) but only involving all animal size classes (size 1-4) and on the small-sized (size 1-2) animals subsample which may also suggests MSA hominins scavenged nutritionally depleted carcasses (Binford et al. 1988; Domínguez-Rodrigo 1997a-c, Domínguez-Rodrigo and Barba 2005, 2007c; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014). However, the relatively high proportions of cut-marked midshaft sections on the lower limb bones (LLB) can be interpreted mainly as the result of preparation for hammerstone breakage (Binford 1978, 1981; Lyman 1987a, 1994; Nilssen 2000; Pobiner 2007; Galán and Domínguez-Rodrigo 2013). The fact that, the intermediate limb bones (ILB) are also identified relatively more than the upper limb bones (ULB) in the faunal assemblage can also explains the observed pattern (Tables 7.3 and 7.6). Nonetheless, the combined percentage of cut marks on the upper and intermediate limb bones (ULB and ILB) in the large-sized (size 3-4) carcasses subsample is more consistent with hominin first access to their complete carcasses (Tables 5.5 and 7.13). Of note, the upper limb bones (ULB) in the large-sized animals subsample also bear a relatively high proportion of cut-marked midshaft fragments than the intermediate limb bones (ILB).

The assemblage mean percentage of cut marks on long bone midshafts on all animal size classes (size 1-4) in the Magubike faunal assemblage is 7.36%. Expressing the value into the small (size 1-2) and large-sized (size 3-4) carcass subsamples, the percentage is 3.44% and 10.89% respectively. Table 7.13 below provides details on the incidences of cut marks on long bones by element, anatomical section on which they occur and by animal size.

When the percentage of cut marks bearing midshaft fragments on all animal size classes (size 1-4) is compared to published experimental and ethnoarchaeological calibrated faunal samples, the value of nearly 7.4% falls slightly outside the range of variation documented in experimental simulations modeling hominin primary (early) access to fully-fleshed carcasses (Tables 5.5, 7.13; Figure 7.10). In hominin-first access to fully-fleshed carcasses foraging scenarios, midshafts are commonly cut-marked in the range of between 10 and 30% depending on the size of the animal involved and the intensity of carcass processing (Marean et al. 2000; Lupo and O'Connell 2002; Pante et al. 2012; Domínguez-Rodrigo et al. 2014). Of note, the value is also slightly lower to all assemblage mean percentages reported by Blumenschine (1988, 1995) and Pante and colleagues (2012), but falls within their corresponding 95% confidence limits in their hominin-only experimental simulations (Tables 5.5, 7.13; Figure 7.10). The value is also low when compared to that of 16.6% and 47.5% and falls outside their corresponding 95% confidence limits provided by Capaldo (1995, 1997, 1998) and Domínguez-Rodrigo (1997a-c) respectively in their hominin-only experimental simulations (Tables 5.5 and 7.13). Besides, the value is also well below to that of 23.6% and outside the 95% confidence limits of the faunal assemblage butchered by the Hadza (Lupo and O'Connell 2002). The value is also low to that of 13.5% but also outside the corresponding 95% confidence limits in Capaldo's hominin-to-carnivore experimental simulations (Capaldo 1995, 1997, 1998). Besides, the value falls within the 95% confidence limits range involving all animal size groups (size 1-4) and subsamples in the hominin-only experimental simulations (see Table 5.5). But, the value is well below to that of 15.5% from the new cut marks estimates recently reported by Domínguez-Rodrigo and Barba (2007c) for the FLK 22 *Zinj* archaeological faunal assemblage (Tables 7.13, 8.4; Figure 7.10). The differences between the two archaeological faunal assemblages may mostly mirror the faunal sample sizes studied and the nature of the sites compared (Leakey 1971; Bunn 1982; Potts 1988; Domínguez-Rodrigo and Barba 2007a).

For the small-sized (size 1-2) carcasses subsample, the percentage of 3.44% falls well outside the range of variation in all reported experimental studies simulating hominin primary (early) access to fully-fleshed carcasses (Tables 5.5, 7.13; Figure 7.10). The value is also lower to that of 10.3% for a comparable animal size class (size 1-2) provided by Blumenschine (1988, 1995) and Pante and colleagues (2012) but falls within the corresponding 95% confidence limits of 3.1 ± 17.6 in their hominin-only experiments, which suggest primary access to their fully-fleshed carcasses. However, the value also falls within the 95% confidence limits range of the hominin-only experiments involving large-sized (size 3-4) animals, but not with the hominin-to-carnivore experimental simulations (Tables 5.5 and 7.13). In addition, the value is also notably low when compared to that of 11.9% and 24.3% for the comparable animal size subsamples in the FLK 22 *Zinj* and ST Site Complex archaeological faunal assemblages respectively (see Tables 7.13, 8.4; Figure 7.10).

For the case of the large-sized (size 3-4) carcasses subsample, the percentage of approximately 11% of cut-marked midshaft fragments falls within the range of variation reported in experimental and ethnoarchaeological studies that replicate hominin primary (early) access to fully-fleshed carcasses (Tables 5.5, 7.13; Figure 7.10). However, the value does not strictly match the 20.1% but falls in the middle of the corresponding 95% confidence limits of 0.0 ± 40.0 reported by Blumenschine (1988, 1995) and Pante and colleagues (2012) for a comparable animal size class in their hominin-only experimental simulations. The value is also slightly below to that of 12.3% but falls in the middle of a comparable animal size group 95% confidence limits of 7.7 ± 16.9, in the hominin-to-carnivore experiments and therefore may suggest primary (early) access to their intact carcasses (Tables 5.5 and 7.13). Of note, the value also falls very close to that involving all animal size classes (size 1-4) in the hominin-only experimental simulations denoting consistency with the general model of hominin first access to the complete carcasses. However, the value is slightly lower to the new cut marks estimate of 17.2% (as opposed to 11% in the Magubike faunal sample) for a comparable animal size subsample in the FLK 22 *Zinj* faunal assemblage (Tables 7.13, 8.4; Figure 7.10).

As remarked above the midshafts of the upper appendicular limb bones (ULB and ILB) frequently offer little edible resources after carnivore consumption i.e. marginal foraging returns. In the potential MSA hominins, passive scavenging scenarios of the carcasses defleshed and abandoned by large carnivores at Magubike rockshelter, these elements are not expected to bear cut marks in high proportions i.e. on the “hot zones”. When the proportions of cut marks are compared against tooth marks on the upper limb bones (ULB) and intermediate limb bones (ILB) in the Magubike faunal assemblage, a clear pattern comes out. In general, their “hot zones” are clearly more cut-marked than tooth-marked. The distribution of the proportions of cut marks versus tooth marks on all animal-size (size 1-4) carcasses in the Magubike faunal assemblage is as follows: on the ULB 5.79% vs. 1.16%, and on ILB 5.08% vs.1.40% respectively. The same quantitative picture is also apparent in both animal size class subsamples. For the small-sized carcasses: on the ULB 2.0% vs. 1.0%, and on ILB 3.65% vs. 1.15% respectively; and on the large-sized carcasses: on the ULB 9.05% vs. 1.29%, and on ILB 7.89% vs. 1.88% respectively (see also Tables 7.13 and 7.21 for the details). The consistent high percentages of cut marks suggest MSA hominins at Magubike rockshelter also extracted large amount of flesh from relatively complete carcasses rather than retrieved scraps of meat from them (Binford 1981; Potts and Shipman 1981; Bunn 1982, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1994; Oliver 1993; Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2007c; Pickering Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014). Accordingly, the hypothesis that MSA hominins habitually scavenged marginal scraps of meat from the carnivore hunted and ravaged carcasses is also not supported at Magubike rockshelter.

The incidences of cut marking in the Magubike faunal assemblage are consistent with MSA hominin, and not carnivore having had the primary (early) access to fully-fleshed carcasses. Figure 7.10 below shows the percentages of cut marks on long bone midshafts in the Magubike faunal assemblage compared to several experimental and ethnoarchaeological calibrated faunal samples simulating hominin primary (early) access to fully-fleshed (HO) and secondary (late) access to the carcasses defleshed by carnivore (C-H), and to a meticulously reanalyzed FLK 22 *Zinj* archaeological faunal assemblage.

Table 7.11. Human-Induced Modifications in the Magubike Faunal Assemblage.

Element/Size	Cut Marks		Percussion Marks	Burning
	Small	Large		
Cranium	1	-	-	4
Mandible	1	9	2	2
Atlas	1	-	-	-
Cervical	-	1	-	-
Thoracic	-	-	-	2
Lumbar	-	-	-	2
Rib	9	47	-	14
Scapula	1	4	-	-
Humerus	1	3	6	1
Radius	5	4	35	-
Metacarpal	-	19	28	1
Pelvis	1	2	-	-
Femur	6	21	128	8
Tibia	22	32	197	12
Metatarsal	5	40	76	5
Sesamoid	-	-	-	1
Phalanx 1	-	3	-	-
Phalanx 2	-	2	-	-
Bird-Humerus	-	-	-	1
Bird-Tibio-tarsus	1	-	-	-
Indeterminate	89	-	231	42
Total	143	187	703	95

Table 7.12. Hominin-Induced Modifications by Animal Size.

Animal Size	Cut Marks	Percussion Marks	Burning	Total
Size 1	17	50	11	78
Size 2	36	152	18	206
Size 3	94	128	17	239
Size 4	93	142	8	245
Total	240	472	52	768

Table 7.13. Proportions of Cut Marks on Long Bones by Element, Anatomical Sections and Animal Size.

Element/ Size	Epiphyseal		Midshaft		
	Small	Large	Small	Large	Total
Humerus	1/21(4.76)	2/28(7.14)	0/21(0.00)	1/28(3.57)	1/49(2.04)
Radius	0/94(0.00)	0/57(0.00)	5/94(5.32)	4/57(7.02)	9/151(5.96)
Metacarpal	0/9(0.00)	2/120(1.67)	0/9(0.00)	17/120(14.17)	17/129(13.18)
Femur	2/179(1.12)	1/204(0.49)	4/179(2.23)	20/204(9.80)	24/383(6.27)
Tibia	8/427(1.87)	15/209(7.18)	14/427(3.28)	17/209(8.13)	31/636(4.87)
Metatarsal	1/55(1.82)	4/254(1.57)	4/55(7.27)	36/254(14.17)	40/309(12.94)
ULB	3/200(1.50)	3/232(1.29)	4/200 (2.00)	21/232(9.05)	25/432(5.79)
ILB	8/521(1.54)	15/266(5.64)	19/521(3.65)	21/266(7.89)	40/787(5.08)
LLB	1/64(1.56)	6/374(1.60)	4/64(6.25)	53/374(14.17)	57/438(13.01)
Total	12/785(1.53)	24/872(2.75)	27/785(3.44)	95/872(10.89)	122/1,657(7.36)

Numerator is the total of cut-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

Table 7.14. Cut Marks, Percussion Marks and Tooth Marks on Long Bones by Animal Size and Anatomical Sections.

Animal Size	Total Long Bones	Epiphyseal		Midshaft		
		CM	TM*	CM	PM**	TM*
Small (1-2)	785	12	1	27	200	8
Large (3-4)	872	24	1	95	266	11
Total (1-4)	1,657	36	2	122	466	19

*Tooth marks include pits and scores

**Percussion marks include notches, striae and pit

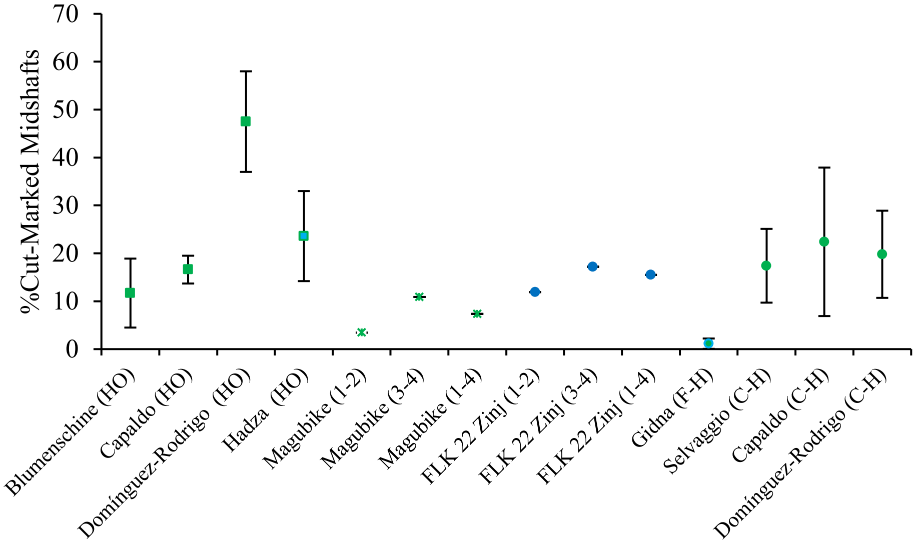


Figure 7.10. Cut-Marked Long Bone Midshafts in the Magubike Faunal Assemblage Compared to Several Experimental, Ethnoarchaeological, and Archaeological Samples.

A total of 703 specimens bearing percussion marks were also recorded mainly on identified skeletal parts and a few on unidentified specimens (Table 7.11). Notches are the most frequent type of the hammerstone percussion marks registered (*n*=660) indicative of the MSA hominins deliberate opening of long bones medullary cavities to extract the within-bone nutrients. Other types of percussion marks were also identified but in relatively small proportions including striae fields (*n*=33) and percussion pits (*n*=10). No notches resulting from carnivore teeth static loading to access bone marrow were registered in the Magubike faunal sample (Blumenschine and Selvaggio 1988, 1991; Capaldo and Blumenschine 1994; Blumenschine 1995; Galán et al. 2009). The mandibles and phalanges that also contain a small marrow cavity were also cracked open and extracted for marrow (Tables 7.11 and 7.17).

Percussion marks on long bone fragments in the Magubike faunal assemblage were also consistently recorded on their midshaft sections (Tables 7.14 and 7.15). The proportion of percussion marks ranges between 12 and 33%. Overall the femur and tibia exhibited higher proportions of the percussion marks bearing specimens by more than 30% (see Table 7.15 for the details). The femur is also the element with the highest proportion of percussion marks (29.05%) followed closely by tibia (28.34%) in the small-sized animals category. The metacarpal preserves no percussion marks. For the case of the large-sized animals subsample again tibia has the highest proportion (36.36%) but followed by the femur (36.27%). The difference in the proportions of percussion marks on the major six long bone midshaft fragments in the small and large-sized animal subsamples is very statistically significant (two sample *t*-test: *t*=4.0784, *p*=0.0096). Tables 7.11, 7.14 and 7.15 below provide details on the incidences of percussion marks by element and animal size.

Unlike in the Loiyangalani faunal assemblage, the midshaft sections of the upper limb bones (ULB), which characteristically have larger medullary cavities bear the majority of percussion marks in the Magubike faunal assemblage accounting for 30.55% followed closely by the intermediate limb bones (ILB) by 29.35% (Binford 1978, 1981; Jones and Metcalfe 1988; Blumenschine and Madrigal 1993; Morin 2007). The lower limb bones (LLB) bear 25.12% of the total percussion marks bearing elements in the faunal assemblage (Table 7.15).

The assemblage mean percentage of percussion marks on long bone midshafts on all animal size classes (size 1-4) in the Magubike faunal assemblage is 28.12%. On the small (size 1-2) and large-sized (size 3-4) carcass subsamples, the percentage is 25.48% and 30.5% respectively (Tables 7.15 and 8.4). The results also suggest the long bones of the large-sized animals were heavily harvested for marrow than did those of the small-sized animals that naturally contain limited body fat (Binford 1978, 1981; Jones and Metcalfe 1988; Gifford-Gonzalez 1989; Blumenschine and Madrigal 1993; Bartram and Marean 1999; Morin 2007).

The percentage of percussion marks on long bone midshafts on all animal size classes (size 1-4) of 28.12% in the Magubike faunal assemblage falls within the range of variation documented in experimental studies replicating foraging scenarios where the bones were broken by hammerstone to extract marrow (Tables 5.5 and 7.15). In hominin-first access to both fully-fleshed carcasses to extract bone marrow, the percentage of percussion marks on midshafts frequently range between 10 and 30% also depending on the animal size involved (Marean et al. 2000; Pante et al. 2012; Domínguez-Rodrigo et al. 2014). The value is also slightly higher than those involving all animal size groups (size 1-4) reported by Blumenschine (1995), Pante and colleagues (2012), and Capaldo (1995, 1997, 1998) in their experimental simulations that include both hammerstone-only and hammerstone-to-carnivore (Tables 5.5 and 7.15). Of note, the value is well below to that of 49.2% and falls outside the corresponding 95% confidence limits of 42.2 ± 55.8 in the hammerstone-only experiments provided by Marean and colleagues (2000). The value is also slightly lower to that 33.7%, but falls at the bottom end of the corresponding 95% confidence limits of 27.4 ± 38.6 also provided by Marean and colleagues (2000) in their hammerstone-to-carnivore experimental simulations (Tables 5.5 and 7.15). Besides, the value also falls within the 95% confidence limits range for all animal sizes (size 1-4) and subsamples in both hammerstone-only and hammerstone-to-carnivore experimental simulations conducted by Blumenschine (1995), Pante and colleagues (2012). Of note, the value is also higher when compared to that of 24.5% and 19.7% in the FLK 22 *Zinj* and ST Site Complex archaeological faunal assemblages respectively (Tables 7.15 and 8.4).

For the small-sized (size 1-2) carcasses, the percentage of percussion marks on midshaft fragments of 25.48% also falls within the known range of 10 to 30% known for the hammerstone fractured long bone samples (Tables 5.5 and 7.15). The value is also slightly below those provided by Blumenschine (1995), Pante and colleagues (2012), but falls in the middle of their corresponding 95% confidence limits for the comparable animal size subsamples in their hammerstone-only and hammerstone-to-carnivore experimental simulations. Nonetheless, the value is also within the 95% confidence limits range involving all animal size groups (size 1-4) and subsamples in the hammerstone-only and hammerstone-to-carnivore experiments (Tables 5.5 and 7.15). Also, the value is relatively low to that of 37.3% in FLK 22 *Zinj* archaeological faunal assemblage but well above that of 19.2% in the ST site Complex for a comparable animal size subsamples (Tables 7.15 and 8.4).

For the case of the large-sized (size 3-4) carcasses, the percentage of percussion marks on midshafts of 30.5% also falls within the known range of variation (Tables 5.5 and 7.15). However, the value is slightly below to that of 33% for a comparable animal size class in the hammerstone-only but well above in the hammerstone-to-carnivore experiments reported by Blumenschine (1995), Pante and colleagues (2012), and Capaldo (1995, 1997, 1998). Besides, the value is also well above that of 20.4% and 22.2% for comparable animal size subsamples in the FLK 22 *Zinj* and ST Site Complex archaeological faunal assemblages respectively (Tables 7.15 and 8.4).

Percussion marks incidences in the Magubike faunal assemblage strongly indicate MSA hominins enjoyed early access and extracted marrow from intact long bones. The inference is also attested by strong positive correlation coefficients between %MAU values of the marrow bearing bones against their corresponding Unsaturated Marrow Index (UMI values) generated by Morin (2007). In both animal size classes, the correlation coefficients are very strong positive and statistically very significant (Spearman's rho: for small-sized, r_s=0.741, p=<0.010; and for the large-sized carcasses, r_s=0.922, p=<0.010). Interest in marrow extraction is also confirmed by the high proportions of the long bone fragments bearing green fractures, Type 1 shafts and by an average FFI score of ≤ 2 for the entire Magubike faunal assemblage that is widely attributed to the hammerstone dynamic loading (sees Tables 7.11, 7.16, 7.17, 7.23, 7.24; Figures 7.11 and 7.14-7.16).

Table 7.15. Proportions of Percussion Marks on Long Bone Midshafts by Element and Animal Size.

Element/Size	Small	Large	Total
Humerus	2/21(9.52)	4/28(14.28)	6/49(12.24)
Radius	16/94(17.02)	18/57(31.58)	34/151(22.52)
Metacarpal	0/9(0.00)	28/120(23.33)	28/129(21.70)
Femur	52/179(29.05)	74/204(36.27)	126/383(32.90)
Tibia	121/427(28.34)	76/209(36.36)	197/636(30.97)
Metatarsal	9/55(16.36)	66/254(25.98)	75/309(24.27)
ULB	54/200(27.00)	78/232(33.62)	132/432(30.55)
ILB	137/521(26.29)	94/266(35.34)	231/787(29.35)
LLB	9/64(14.06)	104/374(27.81)	113/438(25.80)
Total	200/785(25.48)	266/872(30.50)	466/1,657(28.12)

Numerator is the total of percussion-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

Table 7.16. Spearman's rho between %MAU against UMI Values.

Animal Size	n	r_s	p
Small (1-2)	11	0.741	< 0.01
Large (3-4)	13	0.922	< 0.01

n=number of skeletal parts considered in the correlation.

Phalanges are often considered as low-yield food items, and their processing may repeatedly imply hominin subsistence stress (Binford 1978, 1981; Marean 1991; Marean and Spencer 1991; Marean et al. 1992; Stiner 1994). The first and second phalanges in Magubike faunal assemblage make up of 109 elements (3.1% of the total NISP). Of the total sample, only 22 were complete, and the rest were fractured. Longitudinally and transversely fractured phalanges were recorded at the rates of 64.22% and 15.6% respectively of the total sample (see Table 7.17 for the details). Morphology of the longitudinally fractured phalanges denotes green fracture typically with clean break edges like those commonly occur on long limb bones when fractured fresh (see Figure 7.11). Transversely fractured phalanges in the faunal assemblage are attributed to the postdepositional fragmentation resulting from sediment compaction and/or rockfall (Oliver 1989; Villa and Mahieu 1991; Karr and Outram 2012).

Table 7.17. Fragmentation of the First and Second Phalanges.

Animal Size	Element	Complete	Mode of Fragmentation	
			Longitudinally Split	Transversely Split
Small (1-2)	1st Phalange	6	15	5
	2nd Phalange	4	8	2
Large (3-4)	1st Phalange	8	33	7
	2nd Phalange	4	15	3
Total (1-4)	-	22	70	17

Figure 7.11. Longitudinally and Transversely Fractured Phalanges.

A total of 97 specimens in the Magubike faunal assemblage were also recorded burnt at different degree stages (Tables 7.11, 7.12 and 7.18). Burnt bones account for about 1.6% of the total NISP. Concretions on some specimens as remarked above made it hard to detect and discriminate burnt bone fragments by colors. Specimens with such typical conditions were omitted in the counts. The majority of the burnt bones (63.5%) measured 1-2 cm followed by size class 2-3 cm accounting for 29.3% of the total burnt specimens. The average maximum length of the burnt bones in the Magubike faunal assemblage is 1.97 cm. Burning traces were more prevalent on long bone midshaft fragments (*n*=26) and less frequently noted on epiphyseal ends (*n*=2). Traces of burning on long bone fragments were noted on both their inside and outside surfaces, which suggests the burning occurred during both roasting and after meat stripped off the bones also conceivably were tossed into hearth (Speth and Tchervnov 2001, 2007). Other options to be considered may include accident burning and use of bones as fuel. It is important to note the burnt bone fragments (NISP-burnt) in the Magubike faunal assemblage are also strong positive and statistically significant correlated against their food utility (SFUI) values (Spearman's rho: r_s=0.708, p=0.022). One medium sized bird humerus also exhibited burning traces (Table 7.11). Table 7.18 below presents the incidences of burning and burning stages in the Magubike faunal assemblage.

Table 7.18. Burnt Bones in the Magubike Rockshelter Faunal Assemblage.

Count	> 50% carbonized	< 50% calcined	> 50 % calcined	Fully calcined	Total
NISP	5	19	13	17	54
Indeterminate	3	22	3	15	43
Total	8	41	16	32	97

7.6.2. Nonhuman-Induced Modifications

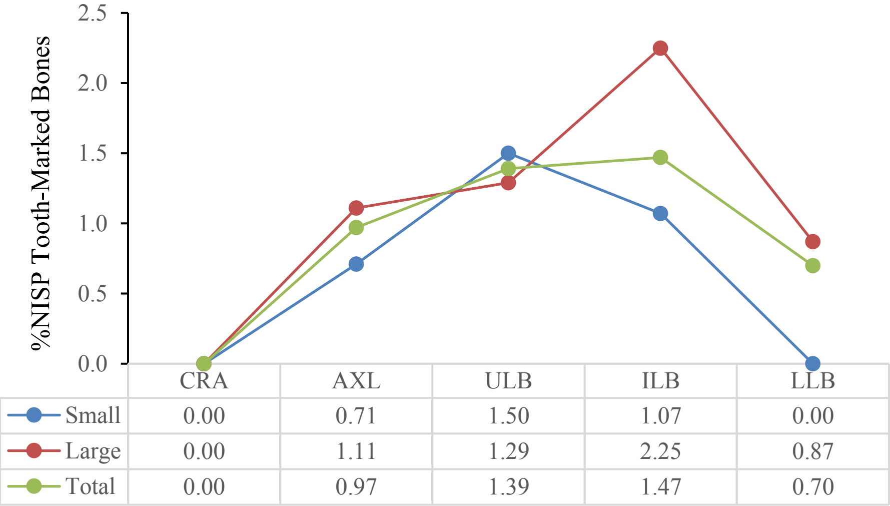
Magubike faunal assemblage also preserves a wide range of nonhuman surface modifications that include large carnivore tooth marks, rodent gnaw marks, root-etching, biochemical and trample marks. Tooth marks were relatively more frequent on the identified skeletal parts in the assemblage. Table 7.19 below summarizes the types and frequencies of nonhuman bone surface modifications recorded in the faunal assemblage.

Tooth marks were recorded on a total of 50 specimens, which also suggests carnivores discovered and scavenged bone fragments discarded at Magubike rockshelter (Tables 7.13, 7.19-7.22; Figures 7.12 and 7.13). Carnivore damage on fossilized bone fragments mainly included tooth scores and pits, with the totals of 31 and 19 respectively. Spotted hyenas (*Crocuta crocuta*) are responsible for the damage as attested by the dimensions of the tooth marking inflicted (Selvaggio and Wilder 2001; Domínguez-Rodrigo and Piqueras 2003; Domínguez-Rodrigo et al. 2012). Hyena skeletal remains were also identified in the Magubike faunal assemblage (see Tables 7.8 and 7.9).

Carnivore tooth marks on identified skeletal parts are markedly very low, despite the scrupulous inspection of all specimens with the aid of a microscope (Tables 7.19, 7.20 and 8.1). Nonetheless, tooth marks were recorded on bone fragments from all animal size classes (Tables 4.1, 7.19 and 7.20). The overall percentage of tooth marks on identified skeletal parts is also noticeably very low and only by < 1.5% (teeth excluded) and suggests the carnivores played a marginal role in modification of the bone fragments at the site.

Ribs displayed the highest incidences of tooth marking followed by tibia (Table 7.19). Other skeletal parts including humerus, radius, femur, pelvis, first phalanx and metapodials were also tooth-marked but at relatively low frequencies (between 1 and 3 tooth-marked specimens each). Unfortunately, skeletal parts bearing tooth marks in the Magubike faunal assemblage is markedly very low (*n*=34) for a detailed evaluation of their distribution across a complete carcass and animal size (Tables 7.19 and 7.20). As seen graphically in Figure 7.12 below, the proportions of tooth marks (NISP tooth-marked/NISP) in the Magubike faunal assemblage do not exceed 2.5% across the major five anatomical segments of a complete carcass. Despite this observation, they appear to be preferentially (but overall not in high proportions) inflicted on the intermediate limb bones (ILB) by 1.47% and on the upper limb bones (ULB) by 1.39%. The lower limb bones (ULB) bear 0.7% of the total tooth-marked elements. The overall incidences of tooth marks in the faunal assemblage obviously suggest minor carnivore intervention on bones deposited at the site.

The proportions of tooth marks inflicted on the major six long limb bones are also generally very low and do not exceed 2% in the faunal assemblage. Of note, the upper appendicular limb bones (ULB and ILB), which are the high-meaty bearing elements, are tooth-marked by a combined percentage of < 3. On the other hand, the lower limb bones (LLB) have a proportion of < 1% of the tooth-marked elements (Table 7.21).



	CRA	AXL	ULB	ILB	LLB
Small	0.00	0.71	1.50	1.07	0.00
Large	0.00	1.11	1.29	2.25	0.87
Total	0.00	0.97	1.39	1.47	0.70

Figure 7.12. Proportions of Tooth-Marked Bones by Major Anatomical Segments and Animal Size in the Magubike Faunal Assemblage.

With regards to the elements with high amount of meat, only a total of 21 long bone fragments in the Magubike faunal assemblage were tooth-marked. Tooth marks were recorded preferentially on the midshaft sections (n=19), and only two on the epiphyseal (proximal and distal) ends. Overall the element with the highest proportion of tooth marks bearing specimens on its midshaft sections is the humerus (4.08%), and the rest have proportions of < 1.6% (see Table 7.21 for the details). However, the difference in the proportions of tooth marks on major six long bone midshaft fragments between the small and large-sized animal subsamples is not statistically significant (two sample t-test: t=1.0280, p=0.3511).

The mean percentage of tooth marks on long bone midshafts on all animal size classes (size 1-4) in the Magubike faunal assemblage is 1.12%. In the case of the small and large-sized animal carcasses, the percentage is 1.02% and 1.26% respectively. Details of tooth marks on long bones by element, anatomical section on which they occur, and animal size are provided in Table 7.21 below.

The percentages of tooth marks on long bone midshafts on all animal size classes (size 1-4), as well as those on both the small (size 1-2) and large-sized (size 3-4) carcass subsamples in the Magubike faunal assemblage are markedly very low and are only roughly by < 1.5% (Table 7.21). The percentages are also not consistent with all the values reported in experimental studies that simulate carnivore first access to fully-fleshed carcasses and whole-bone-to-carnivore (WB-C) foraging scenarios (Tables 5.5, 7.21 and 8.4; Figure 7.13). In addition, the values also fall well outside all the corresponding 95% confidence limits (see Table 5.5 for the details). In carnivore primary access situations (CO), the percentage of tooth marks is often above 75% on the midshaft fragments, and those in the whole-bone-carnivore (WB-C) are usually above 50% (Capaldo 1995, 1997, 1998; Marean et al. 2000; Lupo and O'Connell 2002; Pante et al. 2012; Domínguez-Rodrigo et al. 2014).

The proportions of tooth marks on long bone midshafts in the Magubike faunal assemblage also fall well outside the range of variation in the experimental studies that simulate hominid-to-carnivore (H-C) foraging scenarios with the percentages repeatedly between 5 and 15% on all long bone midshaft fragments (Blumenschine 1986a, b, 1995; Capaldo 1995, 1997, 1998; Marean et al. 2000; Lupo and O'Connell 2002; Pante et al. 2012). Carnivores habitually have minimal interest on the nutritionally depleted bone fragments discarded at hominin campsites (Blumenschine 1988, 1995; Blumenschine and Marean 1993; Bunn et al. 1991; Capaldo 1995, 1997, 1998; Bartram 1993; Bartram et al. 1991; Selvaggio 1994a, b, 1998; Domínguez-Rodrigo 1997a-c; Marean et al. 2000; Lupo and O'Connell 2002). Comparing the percentages of tooth marks to the new estimates in the FLK 22 *Zinj* archaeological faunal assemblage, reported by Domínguez-Rodrigo and

Barba (2006, 2007b), again all values are also very low. Besides, the values are also notably too low when compared to those in the ST Site Complex archaeological faunal assemblage (see Tables 7.21 and 8.4).

The proportions of tooth marks on the "hot zones" of the upper appendicular limb bones (ULB and ILB) that are thoroughly defleshed by carnivore in primary access to fully-fleshed carcasses are also notably very low and only range between 1 and 1.4% (see Table 7.21 for the details). Besides, the axial elements also bear relative low proportions of tooth marks (see Table 7.22). Consequently, the unswerving high proportions of cut marks on these elements support the idea that MSA hominins at Magubike rockshelter accessed them prior to the large carnivores (Binford 1981; Binford et al. 1988; Potts and Shipman 1981; Bunn 1982, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Oliver 1994; Domínguez-Rodrigo 1997a-c, 1999a, 2002; Domínguez-Rodrigo and Barba 2007c; Domínguez-Rodrigo and Pickering 2003; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008; Domínguez-Rodrigo et al. 2007a, b; Gidna et al. 2014).

Of note, the percentages of tooth marks on long bone midshafts in the Magubike faunal assemblage can be only accommodated by the 95% confidence limits of 0.2 ± 10 for the small-sized animal subsample reported by Blumenschine (1995:33, Table 3) in his hammerstone-to-carnivore experiments (see Tables 5.5 and 7.21). Therefore, the values are fairly consistent with foraging scenarios reported whereby carnivore scavenged defleshed and demarrowed bone fragments at hominin habitation sites (Gifford-Gonzalez 1989; Kroll and Price 1991; Bunn 1983, 1993; Bunn et al. 1991; Lupo 1995; Marean et al. 2000; Lupo and O'Connell 2002).

Given the notable overall low proportions of tooth marks in the Magubike faunal assemblage, carnivore secondary (late) access to the defleshed and demarrowed bone fragments possibly following MSA hominins temporary abandonment of the rockshelter is a better explanation of their role at the site (Tables 7.13, 7.19-7.22; Figures 7.12 and 7.13). The low percentages of tooth marks bearing elements may also be related to the roasting, which potentially made the bone fragments discarded at Magubike rockshelter less attractive to carnivores (Gifford-Gonzalez 1989; Bunn et al. 1991; Bartram 1993; Bartram et al. 1991; Lupo 1995; Marean 1998). Furthermore, it is also argued the continuous presence of hominin at Magubike rockshelter may have also post-discard conditioned the amounts of scavengeable edible resources for the bone crunching carnivores (Cruz-Uribe 1991; Lam 1992; Pickering 2002; Villa et al. 2004; Kuhn et al. 2010).

Table 7.19. Nonhuman-Induced Modifications in the Magubike Rockshelter Faunal Assemblage.

Element/Size	Tooth Marks		Rodent Marks	Root Marks	Biochemical Marks	Trample Marks
	Small	Large				
Cranium	-	-	1	-	-	-
Rib	2	9	6	-	2	2
Humerus	1	2	-	-	-	-
Radius	2	1	1	-	-	-
Metacarpal	-	2	-	-	1	-
Pelvis	1	-	-	-	-	-
Femur	2	1	1	1	8	-
Tibia	4	5	3	-	7	1
Metatarsal	-	1	2	-	3	2
Phalanx 1	-	1	-	-	-	-
Indeterminate	16	-	16	1	4	3
Total	28	22	30	2	25	8

Table 7.20. Nonhuman-Induced Modifications by Animal Size.

Animal Size	Tooth Marks	Rodent Marks	Root Marks	Biochemical Marks	Trample Marks
Size 1	5	2	1	6	1
Size 2	8	4	-	7	1
Size 3	15	4	-	2	1
Size 4	6	4	-	6	3
Total	34	14	1	21	6

Table 7.21. Proportions of Tooth Marks on Long Bones by Element, Anatomical Sections and Animal Size.

Element/Size	Epiphyseal		Midshaft		
	Small	Large	Small	Large	Total
Humerus	1/21(4.76)	0/28(0.00)	0/21(0.00)	2/28(3.57)	2/49(4.08)
Radius	0/94(0.00)	0/57(0.00)	2/94(2.13)	1/57(1.75)	3/151(1.99)
Metacarpal	0/9(0.00)	0/120(0.00)	0/9(0.00)	2/120(1.67)	2/129(1.55)
Femur	0/179(0.00)	0/204(0.00)	2/179(1.12)	1/204(0.49)	3/383(0.78)
Tibia	0/427(0.00)	1/209(0.48)	4/427(0.94)	4/209(1.91)	8/636(1.26)
Metatarsal	0/55(0.00)	0/254(0.00)	0/55(0.00)	1/254(0.39)	1/309(0.32)
ULB	1/200(0.50)	0/232(0.00)	2/200(1.00)	3/232(1.29)	5/432(1.16)
ILB	0/521(0.00)	1/266(0.38)	6/521(1.15)	5/266(1.88)	11/787(1.40)
LLB	0/64(0.00)	0/374(0.00)	0/64(0.00)	3/374(0.80)	3/438(0.68)
Total	1/785(0.13)	1/872(0.11)	8/785(1.02)	11/872(1.26)	19/1,657(1.12)

Numerator is the total of tooth-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

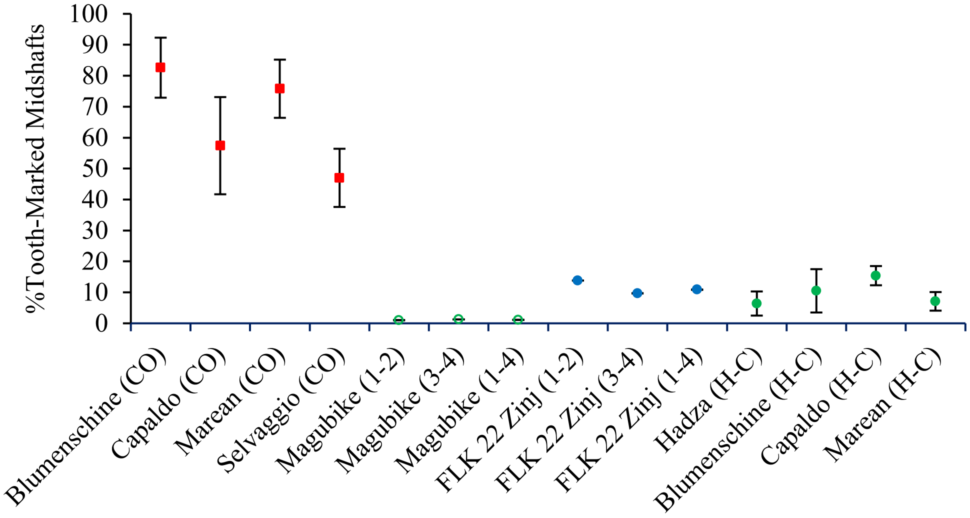


Figure 7.13. Tooth-Marked Long Bone Midshafts in the Magubike Faunal Assemblage Compared to Several Experimental, Ethnoarchaeological, and Archaeological Samples.

Table 7.22. Proportions of Tooth-Marks vs. Cut-Marks on the Axial Elements.

Element/ Size	Small		Large		Total	
	TM	CM	TM	CM	TM	CM
Ribs	2/323(0.62)	9/323(2.79)	9/657(1.37)	47/657(7.15)	11/980(0.10)	56/980(5.71)
Vertebrae	0/69(0.00)	1/69(1.45)	0/92(0.00)	1/92(1.09)	0/161(0.00)	2/161(1.24)
Scapulae	0/14(0.00)	1/14(7.14)	0/36(0.00	4/36(11.11)	0/50(0.00)	5/50(10.00)
Pelves	1/15(6.67)	1/15(6.67)	0/29(0.00)	2/29(6.90)	1/44(2.27)	3/44(6.82)
Total	3/421(0.71)	12/421(2.85)	9/814(1.11)	54/814(6.33)	12/1235(0.97)	66/1235(5.34)

Numerator is the total of tooth and cut-marked specimens for each skeletal part. Denominator is the total NISP of each skeletal part. Percentages are in parentheses.

A total of 31 specimens (< 1% of the total NISP) exhibited rodent gnaw marks, which were preferentially located on edges and protuberances of the bones mostly of the large-sized animals (Tables 7.19 and 7.20). Rodents often gnaw old bones to wear down their constantly growing incisors. Rodent remains were also identified in the Magubike faunal assemblage and mostly comprised of their dentition (Table 7.8).

Two specimens also exhibited traces of root marks noted as thin channels with a zigzag form (Fisher 1995). The presence of root marks bearing specimens may suggest vegetation sometime proliferated on the ground inside the rockshelter but did not penetrate to great depths. The fact that the large part of the rockshelter is protected from direct rain and sunlight may also explain the near absence of root-etched specimens in the faunal assemblage (Figures 3.7 and 5.3).

Biochemical marks that characteristically mimic tooth marks were noted on a total of 25 specimens. Criteria to discriminate the biomechanical marks from carnivore tooth marks are provided in Domínguez-Rodrigo and Barba (2006, 2007a, b). Traces of trampling resulting from friction of bones against sandy sediments were also recorded on a total of eight specimens (Tables 7.19 and 7.20). None of these could be mistaken for cut marks (Potts and Shipman 1981; Behrensmeyer et al. 1986). No instances of post-mortem pathologies or infection, and traces of carnivore digestion were also registered in the Magubike faunal assemblage.

7.7. Patterns of Long Bone Fragmentation

Virtually all long bones in the Magubike faunal assemblage were fractured and are mostly represented by fragments with < 25% of their original lengths (Tables 7.4 and 7.23). Among the long bones sample, only 3 survived complete, and only a single specimen retained > 50% of its original shaft length. Besides, mandibles, as well as the first and second phalanges, were also cracked open and extracted for the small amount of marrow they contain (Tables 7.11, 7.17; Figure 7.11).

Long bone circumference shaft types as defined by Bunn (1982, 1983) are also recorded in the faunal assemblage. Long bone fractured by hominin through hammerstone dynamic loading often result in high proportion of the Type 1 shafts (Figure 7.14). The relatively high proportion of Type 1 shafts also suggest the studied faunal assemblage is an unbiased by selective retention of the more diagnostic specimens (Payne 1972; Turner 1989; Marean and Kim 1998; Marean et al. 2000, 2004). Type 2 and 3 shafts, which are the distinguishing feature of the carnivore-generated faunal assemblages, are less frequent (Table 7.23; Figure 7.14). The ratio of Type 2 and 3 shafts, to the Type 1 shafts is 0.09, which falls just outside the lowermost end of the range of between 0.44 and 0.10 as reported by Bunn (1982, 1983). The value merits attributing long bones breakage at Magubike rockshelter mostly to the anthropogenic activities as opposed to carnivore and/or sediment compaction. Figure 7.14 below presents the proportions of Bunn's (1982, 1983) shaft types compared to several experimental calibrated faunal samples.

Long bone fragments fracture morphologies analysis in the Magubike faunal assemblage also demonstrate the prevalence of oblique angles (77.82%), curved or V-shaped outlines (77.65%), and an overall predominance of the smooth edges (77.84%) implying the majority were fractured while still fresh certainly during marrow extraction (Bunn 1982, 1983; Villa and Mahieu 1991; Villa et al. 2004; Marean et al. 2000; Pickering and Egeland 2006). Overall, diagenetic breakage does not appear to have significantly mediated the faunal assemblage. Right angle and transverse outline fractures potentially resulting from sedimentation compaction and/or rockfall are rare and do not exceed 20%. As remarked above, burning within the rockshelter may have also hastened skeletal parts breakability and in turn, may have amplified the diagenetic fragmentation (Stiner et al. 1995; Stiner 2005). Approximately 5% of the total sample also exhibited both green and dry breakages. The overall percentages of the fracture classes (angles and outlines) do not vary considerably in the small and large-sized animal subsamples. Figures 7.15 and 7.16 below show the proportions of fracture angles and fracture outlines in the Magubike faunal assemblage plotted against several calibrated experimental faunal samples with known nature and degree of fragmentation (Villa and Mahieu 1991; Villa et al. 2004; Marean et al. 2000; Pickering and Egeland 2006). The proportions of green breakage in the Magubike faunal assemblage fall within the spectrum of the hammerstone fractured and well above the Sarrians archaeological faunal assemblage postdepositionally fractured via sediment compaction (Villa and Mahieu 1991; Villa et al. 2004).

Fracture Freshness Index (FFI) scores explain further the phases during which bones fragmentation occurred at Magubike rockshelter (Outram 2001, 2002). Among the long bones as well as the first and second phalanges sample, only 25 specimens survived complete (Tables 7.17 and 7.23). Table 7.24 below provides cumulative FFI scores and averages for the entire Magubike faunal assemblage and by animal size. The majority of the specimens had FFI scores of ≤ 2 with a cumulative frequency of approximately 82%, with 75.37%, 3.34%, and 3.28% of the specimens awarded scores of 0, 1 and 2 respectively. The overall FFI scores and averages suggest the bulk of the bone fragments were deliberately broken in fresh state certainly to gain access to bone marrow. The inference is also supported by the prevalence of percussion marks on the high marrow-bearing long bones and intentional fragmentation of the phalanges (Tables 7.11, 7.14-

7.17). There is also a considerable number of specimens in the faunal assemblage that exhibited mixed fractures (FFI score of 3) indicative were broken while the bones were progressively becoming dry mostly as the result of sediment compaction and/or rockfall (Table 7.24). Specimens expressing an unfresh profile (FFI score of 6) that typically occur on the completely dry bones accounted for only 15% of the total sample. An average FFI score for the entire Magubike faunal assemblage is 1.13, and for the small and large-sized animal subsamples, the median scores is 1.39 and 0.91 respectively (see Tables 7.24 for the details). The overall mode of fragmentation of bones in the Magubike faunal assemblage mostly mirrors anthropogenic activities as opposed to the diagenetic (dry) breakage by sediment compaction and/or rockfall.

Table 7.23. Long Bones Fracture Morphologies by Animal Size in the Magubike Faunal Assemblage.

Fracture Morphologies		Small	Large	Total
Fracture Angle	Oblique	537(71.41%)	712(83.47%)	1,249(77.82%)
	Right Angle	157(20.88%)	110(12.90%)	267(16.64%)
	Intermediate	58(7.71%)	31(3.63%)	89(5.55%)
Fracture Outline	V-Shaped	538(70.98%)	720(83.53%)	1,258(77.65%)
	Transverse	162(21.37%)	112(12.99%)	274(16.91%)
	Intermediate	58(7.55%)	30(3.48%)	88(5.43%)
Fracture Edge	Smooth	540(71.24%	721(83.64%)	1,261(77.84%)
	Jagged	218(28.76%)	141(16.36%)	359(22.16%)
Shaft Length Proportion	< 0.25	774(98.60)%	871(99.89%)	1,645(99.28%)
	< 0.5	7(0.89%)	1(0.11%)	8(0.48%)
	< 0.75	1(0.13)%	-	1(0.06%)
	Complete	3(0.38%)	-	3(0.18%)
Shaft Circumference	< 0.5	692(88.15%)	827(94.84%)	1,519(91.17%)
	> 0.5	21(2.68%)	23(2.64%)	44(2.66%)
	Complete	72(9.17%)	22(2.52%)	94(5.67%)

Table 7.24. FFI Scores Cumulative Frequencies and Averages by Animal Size.

FFI Score	Small		Large		Total	
	NISP	%NISP	NISP	%NISP	NISP	%NISP
0	569	70.33	741	79.76	1310	75.37
1	31	3.83	27	2.91	58	3.34
2	36	4.45	21	2.26	57	3.28
3	2	0.25	12	1.29	14	0.81
4	1	0.12	7	0.75	8	0.46
5	11	1.36	12	1.29	23	1.32
6	159	19.65	109	11.73	268	15.42
Total	809	100	929	100	1,738	100
Average FFI Score	1.39		0.91		1.13	

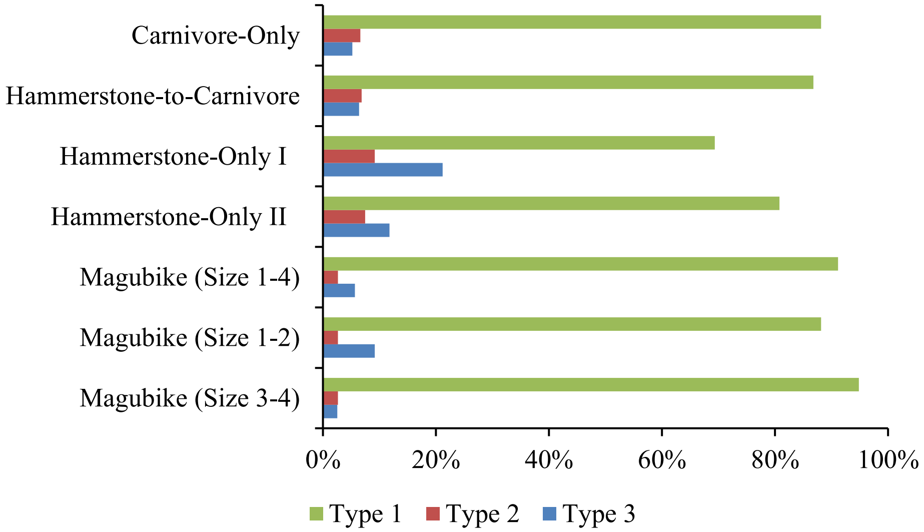


Figure 7.14. Long Bone Shaft Types in the Magubike Faunal Assemblage Compared to Several Experimental Samples.

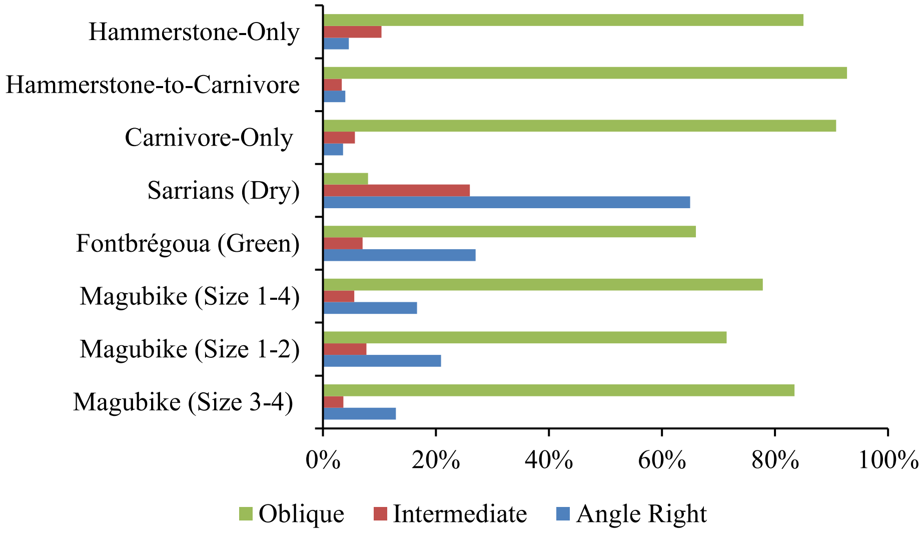


Figure 7.15. Long Bone Fracture Angles in the Magubike Faunal Assemblage Compared to Several Experimental and Archaeological Samples.

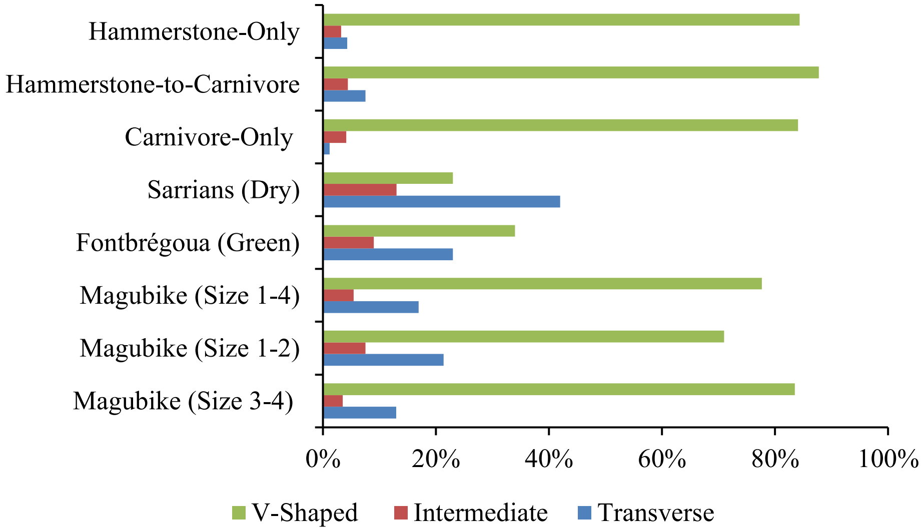


Figure 7.16. Long Bone Fracture Outlines in the Magubike Faunal Assemblage Compared to Several Experimental and Archaeological Samples.

7.8. Analysis of the Magubike Rockshelter MSA Lithic Assemblage

The analysis of the MSA lithic assemblage from the 2012 excavations is still underway by Professor Pamela R. Willoughby and Joseph J. Werner. However, results for test pit 12 are currently available and are summarized below. Overall, the lithic assemblage from test pit 12 displays the same broad characteristics noted in previous studies at the site (see Alexander 2010; Biitiner 2011; Bushozi 2011; Willoughby 2012b; Werner 2014; Werner and Willoughby 2017 for the details). Locally sourced quartz (47%) is the main raw material used in stone tool manufacture followed closely by the nonlocal sourced metamorphic rocks (44%) possibly from the streambeds and other secondary sources. Other raw materials used in low proportions include chert by 8% and quartzite by approximately 6% (Werner and Willoughby 2017).

Techno-typological analysis of the MSA lithic assemblage demonstrates stone tools manufacture was mostly done locally, as suggested by the artefact classes as there are also countless fragments of cores (chips and chunks), unfinished pieces and whole unretouched flakes, which imply the decortification took place at the site. Lithic assemblage organization analysis also demonstrates bipolar core technology was the main operative schemes used (Willoughby 2012b; Werner 2014; Werner and Willoughby 2017). The MSA lithic assemblage also includes a broad range of stone tool classes including whole, unmodified flakes and blades. Trimmed pieces (=tools) are notably rare. Others include an assortment of scrapers, lineal flakes that are categorized as blades and points that can be linked to the hunting, butchery, and carcass processing activities at the site (Knecht 1997; Shea 2006, 2009). Classic Levallois cores are rare. However, flakes with Levalloisian-like core preparation pattern typically with multifaceted platforms and radial or converging dorsal flakes are abundant (Werner and Willoughby 2017).

Three possible separate MSA hominin areas of occupations have been recorded within and around the rockshelter with each exhibiting apparent different raw materials preferences (apart from quartz and quartzite) in stone tools production that also characteristically differ distinctively in colors (Willoughby 2012b). Werner and Willoughby (2017: 258) have recently attributed the disparity in the raw materials use to differential access to the raw material sources through time and may also reflect different foraging patterns by different MSA hominin groups. Besides, this can also be well explained by modern hunter-gatherers behaviour who often tends to scatter their activities across the landscape rather than confining within a single locality (see also Binford 1982; Bower 1986; Mabulla 1996).

CHAPTER 8

DISCUSSIONS AND INTERPRETATION OF RESULTS

8.1. Introduction

This chapter integrates the results presented in the preceding two chapters to infer a broader picture on MSA hominin foraging ecology and predatory behaviour. Results are evaluated and discussed in the wider context of the debate on the emergence of modern human behaviour with a focus on the exploitation of the faunal resources. The diet breadth model, experimental, and ethnoarchaeological guided the interpretations of the results. However, before delving into in-depth discussions, comprehensive taphonomic profiles, and deposition histories of the two MSA faunal assemblages studied are summarized below.

8.2. Taphonomic Profile of the Studied Faunal Assemblages

The subsection summarizes some of the notable taphonomic characteristics of the studied faunal assemblages. The potential of the faunal samples to answer the paleoanthropological research questions underscored in Chapter 1 is also accentuated below. As has been remarked above, one of the key goals of the taphonomic studies is to get a solid understanding of the impact of different attritional taphonomic processes that may have affected the faunal assemblages under study (Behrensmeyer 1978, 1991; Behrensmeyer and Hill 1980; Brain 1981; Shipman 1981; Lyman 1987b, 1994; Bonnichsen and Sorg 1989; Gifford 1991; Kidwell and Behrensmeyer 1993; Marean 1995; Bar-Oz and Dayan 2003; Bar-Oz and Munro 2004; Fernández-Jalvo and Andrews 2016). Different pre-and-post depositional processes are noted to have affected the faunal samples including bone fragmentation, bone weathering, abrasion, root-etching, and concretions (see Tables 8.1 and 8.2 below for the details). These significantly influenced the analysis and may have dictated the interpretations and conclusions reached by this study. The high degree of fragmentation and postdepositional destructive taphonomic processes in a fossil faunal assemblage frequently decrease the number of specimens which can be identified to skeletal parts, depress tallies of surface modifications (such as cut marks, percussion marks, and tooth marks) and may also preclude attempts to make robust and meaningful inferences regarding prehistoric human behaviour (Behrensmeyer 1978, 1991; Brain 1981; Klein and Cruz-Uribe 1984; Grayson 1984; Lyman 1987b, 1994, 2008; Marean 1995, 1998; Marean and Kim 1998; Bartram 1993; Monahan 1996; Bartram and Marean 1999; Abe et al. 2002; Lupo and O'Connell 2002; Wolverton 2002; Domínguez-Rodrigo 2003; Domínguez-Rodrigo et al. 2007d; Bar-Oz 2004; Bar-Oz and Dayan 2003; Bar-Oz and Munro 2004; Stiner 2005; Thompson 2005).

One of the striking taphonomic aspects of the Loiyangalani and Magubike MSA faunal assemblages is the high degree of fragmentation mostly as a result of the anthropogenic activities and to a lesser extent arose from the diagenetic breakage (Tables 6.11-6.17, 6.22, 6.23, 7.11-7.18, 7.23, 7.24; Figures 6.4, 6.5, 6.15, 6.16, 6.20-6.22, 7.4, 7.11 and 7.14-7.16). Fragmentation of specimens is typical for the majority of the Stone Age faunal assemblages. Zooarchaeologists working on Stone Age faunal assemblages frequently face this inescapable challenge (Bunn 1981, 1982, 1983, 1986; Klein and Cruz-Uribe 1984; Turner 1989; Marean and Kim 1998; Marean and Assefa 1999; Bartram and Marean 1999; Marean et al. 2000, 2004; Badenhorst and Plug 2010; Reynard 2011). Complete specimens were remarkably rare in both faunal assemblages

(Tables 6.2, 6.17, 6.22, 7.2, 7.17, 7.23 and 8.2). Only 177 complete specimens (< 2% of the total samples) were recorded including mainly of a few isolated teeth, carpals, tarsals, phalanges, and long bones. The maximum length of specimens also emphasizes the intensity of fragmentation in both faunal assemblages with approximately 49% of the total specimens clustering between 2 and 5 cm and with an average maximum length estimate of 2.16 cm. Of note, specimens that measure > 5 cm in maximum length were notably rare (see Figures 6.1, 6.2, 7.1 and 7.2). Besides, both faunal assemblages also do not differ much in having specimens measuring > 5 cm. Magubike has a slightly higher percentage (2.6%), and Loiyangalani has only 1.8%. By way of contrast, the majority of specimens recovered from hyena dens frequently fall above 5 cm in maximum length (Brain 1981:53).

From a taphonomic and a qualitative standpoint, both faunal assemblages are relatively well-preserved with the majority of the specimens being highly fossilized and uniformly dark-brown in color (Tables 6.1, 7.1, 8.1; Figures 6.3-6.6, 6.15, 6.16, 6.19, 7.3-7.5, and 7.11). This is mainly attributed to the sediments pH at the Loiyangalani site and the nature of the site at Magubike rockshelter. Taphonomically, the qualities of bone cortical surfaces from the upper and middle levels of the archaeological sequences were notably excellent, and those from the lowermost levels were poorly preserved (desquamated). At the macroscopic level, specimens in the Loiyangalani faunal assemblage are relatively well-preserved compared to those in the Magubike sample (Figures 6.4, 6.5, 6.15, 6.16, 7.4 and 7.11). Fluvial activities also have played some role in dispersing the bone fragments at the Loiyangalani site in their unsaturated (dry) state, which consequently generated a considerable number of specimens with rounded and polished fracture edges typical of the water-rolled (Table 8.1). However, fluvial disturbance of the faunal assemblage overall did not play a significant role even though the Loiyangalani site is located along a floodplain setting (see Figures 6.7-6.9 above). Results also show the faunal assemblage is not winnowed out by fluvial action. The fact that small-sized specimens are also represented in relatively high percentage suggests low-energy deposition setting of the Loiyangalani MSA faunal assemblage (Shipman and Rose 1983; Behrensmeyer 1975a, b, 1982; Pante and Blumenschine 2010). Root marks on bone cortical surfaces were also frequent in the Loiyangalani faunal sample (Tables 6.18, 6.19 and 8.1). For the case of the Magubike faunal assemblage, a considerable number of specimens were cemented by concretions (Table 8.1; Figure 5.4). Concretions potentially obscured some classes of bone surface modifications during the analysis especially the less conspicuous ones (Stiner 2005). Bone weathering profile is also relatively equivalent in both faunal assemblages. The majority of the specimens studied mainly fall into four weathering stages namely stages 2 to 5 with the majority exhibiting stages 2 and 4 (see Tables 6.1, 7.1; Figures 6.6, 7.5 and 8.1).

As it has been emphasized in Chapter 5, Loiyangalani and Magubike have yielded abundant faunal remains in clear association with the stone tools mainly characteristic of the Middle Stone Age techno-complex (Tables 5.1, 5.2 and 8.2). Magubike has also yielded isolated hominin skeletal remains from its MSA and Iron Age deposits (Willoughby 2012a, b). It is also rather rare to find well-preserved fossilized faunal remains in open-air MSA sites in East Africa like the Loiyangalani site (Marean 1990b, 1996; Marean and Assefa 2005; Assefa 2002, 2006; Thompson et al. 2004; Thompson 2005; Steele and Klein 2009) and hominin remains are frequently rare (Bräuer 1989, 2008; Clark 1989; Willoughby 2007; Klein 2009; Grine 2016). Despite the presence of a substantial number of specimens affected by root marks and concretions, the bulk had well-preserved cortical surfaces (approximately 75% of the total specimens), and the majority were not weathered beyond stage 2 suggesting were sealed rapidly and not exposed to additional destructive diagenetic taphonomic processes. The majority of the analyzed specimens also composed of the green fractured fragments (Figures 6.20-6.22 and 7.14-7.16). The amount of dry bone breakage resulting from sediment compaction and animal trampling is also marginal in both faunal assemblages (see Tables 6.22, 6.23, 7.23 and 7.24). Postdepositional fragmentation in archaeological faunal assemblages as measured by the attrition of the small compact bones is also negligible (see Tables 6.1 and 7.2). Accordingly, this justifies the potential of the two faunal assemblages considered for this study to address issues of wider implications to the understanding of the MSA hominin foraging ecology and questions related to the manifestations of modern human behaviour.

Table 8.1. Destructive Taphonomic Processes Recorded in the Loiyangalani and Magubike Faunal Assemblages.

Site	Count*	Bad Preserved	Abraded	Root-etched	Weathering Stage > 2	Concretion Covered
Loiyangalani	Total	21.90%	18.05%	18.68%	26.40%	5.06%
	NISP	12.77%	10.99%	20.52%	16.32%	5.01%
Magubike	Total	26.31%	8.77%	0.03%	30.99%	34.23%
	NISP	13.14%	4.59%	0.03%	17.24%	32.42%

*Teeth excluded.

Table 8.2. Studied Specimens from the Loiyangalani Site and Magubike.

Site	Identifiable (%)	Unidentifiable (%)	Complete (%)	Fragment (%)
Loiyangalani	2,070 (64.89)	1,120 (35.11)	99 (3.1)	3,091 (96.9)
Magubike	3,436 (52.32)	3,131 (47.68)	78 (1.19)	6,489 (98.81)

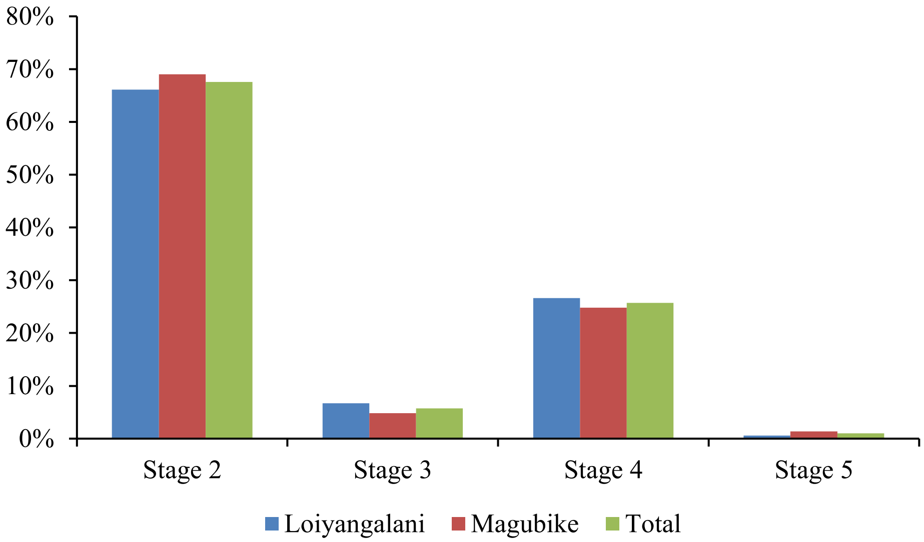


Figure 8.1. Bone Weathering Stages in the Loiyangalani and Magubike Faunal Assemblages.

8.3. Loiyangalani and Magubike Faunal Assemblages Formation History

Unraveling archaeological faunal assemblage formation history is one of the essential tasks in zooarchaeological studies; this is needed before proceeding to make higher-level inferences on prehistoric human behaviour. An accurate identification of the key taphonomic agent is always not a straightforward matter, as different agents and natural processes frequently accumulate faunal remains in the archaeological sites (Schiffer 1983). Caves and rockshelters (in this case Magubike) are frequently suspect of having had multiple agents of accumulations including hominin, carnivore (hyena, leopard, jackal), rodent, porcupine, owl and running water (Behrensmeyer and Hill 1980; Cruz-Uribe 1991; Behrensmeyer 1991; Brain 1980, 1981; Payne 1983; Shipman 1981; Andrews 1990; Stiner 1991a, b, 1994; Lam 1992; Pickering 2002; Villa et al. 2004; Kuhn et al. 2010). In such contexts taphonomic analysis of the archaeological faunal assemblage frequently must begin with the discrimination of the anthropogenic from the possible non-human contributors.

Identification of the key taphonomic agent in the accumulation of the archaeological faunal assemblage largely rests on several lines of evidence that may include the thickness of the deposits and the distinctive taphonomical and zooarchaeological characteristics of the faunal assemblage under consideration (Schiffer 1983; Behrensmeyer 1991; Gifford 1991; Bar-Oz and Dayan 2003; Bar-Oz and Munro 2004; Villa et al. 2004). Artefact types, skeletal part representation, mortality profile, and the extent and intensity of fragmentation of the faunal assemblage can aid in the identification of some characteristics that are ascribed to the anthropogenic activities (Vrba 1980; Brain 1981; Schiffer 1983; Stiner 1990, 1991a, b, Villa and Mahieu 1991; Villa et al. 2004). Fresh bones in old deposits, well-articulated skeletons, carnivore damage, rodent gnaw marks, traces of burrowing animals are all indicative of the nonhuman contributors.

Bone surface modifications provide the solid foundation to gauge the relative contribution of both hominin and carnivore in the accumulation of the archaeological faunal assemblage (Bonnichsen and Sorg 1989; Blumenschine 1995; Capaldo and Blumenschine 1994; Fisher 1995; Fernández-Jalvo and Andrews 2016; Thompson et al. 2017). Cut marks and percussion marks resulting from meat retrieval and bone marrow extraction are frequently cited as an excellent quantitative measure of hominin contribution to the faunal assemblage (Binford 1978, 1981; Bunn 1981, 1982, 1983; Blumenschine and Selvaggio 1988, 1991; Blumenschine 1995; Marean and Spencer 1991; Marean et al. 1992; Domínguez-Rodrigo 1999a; Thompson et al. 2017). Burnt bones especially in caves and rockshelters also denotes hominin activities (Stiner et al. 1995; Stiner 2005). On the other hand, tooth marks are the best indicator of carnivore involvement with the faunal assemblage (Binford 1981; Blumenschine and Marean 1993). Taphonomic analyses of the Loiyangalani and Magubike MSA faunal assemblages demonstrate hominin, large carnivore, and rodents actively processed them while still in their nutritive state (see Tables 6.11-6.23, 7.11-7.24; Figures 6.13-6.18, 6.20-6.23, 7.9-7.13 and 7.14-7.16).

Previous studies of the Loiyangalani and Magubike archaeological assemblages have highlighted some aspects of site formation. On the basis of the techno-typological aspects of the lithic assemblage, Loiyangalani has been interpreted as “a complex ephemeral hunting site” representing “series of discrete campsites” similar to what have been excavated from the Beds I and II at Olduvai Gorge, Tanzania (Leakey 1971; Bower 1985:42; Bower and Gogan-Porter 1981:9). Previous studies have also interpreted the site as a multifaceted accumulation of faunal remains in which both hominin and carnivore were also actively involved (Gifford-Gonzalez 1985:52; Marean 1996:3; Thompson et al. 2004:5-6; Thompson 2005:69-77). Nonetheless, the combined taphonomical and zooarchaeological results have consistently implicated the MSA hominins as the principal taphonomic agent in the modification and collection of the faunal remains at the site.

Willoughby and her colleagues have interpreted Magubike as a residential basecamp where the occupants of the rockshelter also performed different economic and social activities within and around it (Willoughby 2012a, b; Miller and Willoughby 2014; Werner and Willoughby 2017). The inference is corroborated by the evidence of hominin continuous use of the site as attested by the thickness of the archaeological deposits, artefact types, modified bones and traces of burning which together entail Magubike rockshelter was a hot spot for anthropogenic activities for several thousands of years. Studies of the faunal assemblage have also identified hominin as the key taphonomic agent in the modification and accumulation of the bones. This is corroborated by the cut marks and percussion marks inflicted albeit few and by the overall green fragmentation and intentional burning of the bone fragments (Collins 2009:219).

Building on previous analyses of the Loiyangalani and Magubike faunal assemblages, the new taphonomic and zooarchaeological analyses also afford additional discussions on the aspects of their formation histories. As remarked above, different lines of evidence are considered below with the main goal to highlight the formation of the MSA faunal assemblages. Overall, the faunal assemblages displayed numerous characteristics that are more typical of the hominin-generated accumulations (Brain 1980, 1981; Vrba 1980; Shipman 1981; Bunn 1983; Behrensmeyer 1991; Cruz-Uribe 1991; Stiner 1991a; Villa and Mahieu 1991; Villa et al. 2004; Lam 1992; Pickering 2002; Bar-Oz and Dayan 2003; Bar-Oz and Munro 2004; Kuhn et al. 2010; Thompson et al. 2017). The depths of the archaeological deposits at both sites are 2 m deep (Figures 3.5 and 3.8). Unearthed archaeological assemblages are also rich and more diverse and include fossilized animal and hominin bones and stone tools that are evenly distributed down the archaeological sequences with the notable high concentrations from their MSA deposits. The artefacts recovered at both sites also include objects of hominin personal adornment (Thompson et al. 2004; Miller and Willoughby 2014).

The Loiyangalani and Magubike MSA faunal assemblages were also subjected to detail taphonomic and zooarchaeological analyses as detailed in Chapter 6 and 7. Results indicate high nutritional skeletal parts dominate in both (Tables 6.3, 6.6, 7.6 and 7.3). The age structure analysis of the hunted mammalian prey also exhibits a prevalence of the prime-aged adults in a rate of more than 70% at both sites (Tables 6.10 and 7.10). Bone surface modifications including cut marks, percussion marks, and burnt bones are also abundant compared to both the large carnivore-induced damage and rodents gnaw marks (Tables 6.11-6.17 and 7.11-7.18). Cut marks are also more abundant on the high-meaty bearing long bones. Besides, the high marrow-bearing long limb bones demonstrate MSA hominins fractured them before carnivore intervention (Tables 6.15 and 7.15; Figure 6.15). The inference is attested by the overall low proportion of complete long bones and high degree of bone fragmentation in both faunal assemblages. Furthermore, the majority of the long bone fragments exhibit green fractures by more than 75% and are also dominated by Type 1 shafts (see Tables 6.22, 6.23, 7.23 and 7.24; Figures 6.20-6.22 and 7.14-7.16). Besides, burnt bones confirm further MSA hominins involvement with the faunal remains at both sites (Tables 6.11, 6.12, 7.11, 7.12 and 7.18).

Characteristic markers of the carnivore-generated faunal accumulations including the presence of carnivore remains in high number, digested bones, head and foot dominated skeletal part profile, mortality profile dominated by the juveniles and old individuals, high numbers of complete long bones are markedly less abundant in both faunal assemblages (Brain 1980, 1981; Vrba 1980; Behrensmeyer 1991; Cruz-Uribe 1991; Stiner 1991a; Villa et al. 2004; Lam 1992; Pickering 2002; Domínguez-Rodrigo and Organista 2007; Kuhn et al. 2010; Thompson et al. 2017). Carnivore remains are very rare (< 1% of the total samples). The ratios of the carnivore to the ungulate as measured by both NISP and MNI counts are also negligible (Tables 6.3, 6.8, 6.9, 7.3, 7.8

and 7.9). Additionally, there are absolutely no signs of carnivore denning behaviour such as the presence of juvenile hyena remains and gastrically etched bones in either faunal assemblage (Cruz-Uribe 1991; Lam 1992; Blumenschine and Marean 1993; Pickering 2002; Kuhn et al. 2010; Villa et al. 2004).

Carnivore actions in the Loiyangalani and Magubike faunal assemblages are mainly documented by the presence of tooth pits and tooth scores (Tables 6.14 and 7.14). The overall carnivore damage input on the identified skeletal parts is very low and only at approximately < 6% and < 1.5% in the Loiyangalani and Magubike faunal assemblage respectively (Tables 6.18-6.21 and 7.19-7.22). The proportions of tooth marks are frequently very high in the faunal assemblages solely generated by carnivores (Binford 1978, 1981; Blumenschine 1986a, b, 1988, 1995; Marean and Spencer 1991; Marean et al. 1992; Blumenschine and Marean 1993; Capaldo 1995; Domínguez-Rodrigo 1999a). The rarity of the carnivore damage may be certainly interpreted played a minor role in modification and accumulation of the MSA faunal assemblages. Rodents also can be ruled out as a significant modifier and accumulator of the bone fragments as only < 0.5% of all specimens displayed rodent gnaws marks (Tables 6.18, 6.19, 7.19 and 7.20). As elaborated above fluvial activity is also ruled out as a significant agent in the configuration of the Loiyangalani faunal assemblage (see Figures 6.7-6.9 above). In both faunal assemblages, specimens with signs of edge abrasion are also less frequent. The prevalence of the small specimens measuring < 4 cm in maximum dimension also suggests minimal postdepositional disturbances of the faunal assemblages (see Figures 6.1, 6.2, 7.1 and 7.2).

When considered together, the lines of evidence summarized above converge to implicate the MSA hominins as the key taphonomic agent in modification and accumulation of the faunal assemblages. Accordingly, Loiyangalani site and Magubike can be largely viewed as the places to which the carcass parts were repeatedly brought by MSA hominins for further processing and food sharing, like modern hunter-gatherers do (Binford 1978, 1981; Isaac 1971, 1978; Winterhalder 1997; Stiner et al. 2009).

Having highlighted the formation histories of the Loiyangalani and Magubike faunal assemblages, long-term aspects of MSA hominin foraging ecology are explored below, guided by the diet breath and predictions set forth in Chapter 4, and in doing so, I return to the paleoanthropological research questions underscored in Chapter 1. The results presented in the preceding two chapters are summarized and integrated. It should be noted the archaeological faunal assemblages considered for this study characteristically represent time-averaged accumulations resulting from both hominin and carnivore predation and certainly from numerous foraging episodes for a period reporting (in this case during the MSA). Kidwell and Behrensmeyer (1993:4) define time-averaging as the process by which the organic remains from different time intervals come to be preserved together. Time-averaging usually affects archaeological faunal assemblages but mostly have the high impact on the fluvial accumulated assemblages (Behrensmeyer 1982, 1991). Of note, various pre-and-postdepositional taphonomic processes have also mediated the faunal assemblages before their recovery including post-discard carnivore ravaging and density-mediated attrition as detailed in Chapter 6 and 7 above (Behrensmeyer 1991; Lyman 1987b, 1994, 2003; Marean 1995).

8.4. Prey Procurement Strategies at Loiyangalani and Magubike

As highlighted in Chapter 4, diet breadth provides a robust framework to evaluate the basic prey choices made by the MSA hominins at the Loiyangalani site and Magubike rockshelter. Several approaches were considered conjointly including an appraisal of the taxonomic composition, prey diversity, relative abundance index of the small and large-sized animals and various lines of evidence related to the carcass processing as reflected in the archaeological faunal assemblages (Broughton 1999; Burger et al. 2005). Of note, taxonomic composition in both faunal assemblages is heavily biased in favour of the terrestrial mammals (see Tables 6.3, 6.8, 7.3 and 7.8). Stone Age faunal assemblages in Africa are also frequently known to contain several closely related ungulate species, which are very similar in morphology and size (Brain 1980, 1981; Bunn 1982, Bunn and Kroll 1986; Klein and Cruz-Uribe 1984). Majority of the identified skeletal parts from both sites were also confidently assigned into general animal size classes (Tables 4.1, 6.3, 6.5, 7.3 and 7.5). This is the common way to organize the basic taxonomic composition data in African zooarchaeology. The approach often helps to augment the sample size, as more specimens can be included in different taphonomic and zooarchaeological analyses and pair-wise comparisons.

As shown in the preceding two chapters, identified skeletal parts were predominantly fragmented (Table 8.2). It is also considered in this work that the NISP counts optimally represent the taxonomical abundance estimates of both economic and non-economic taxa. Very strong positive and statistically significant correlation coefficients are also registered between NISP and MNE counts of the mammalian skeletal parts identified and assigned to animal size classes (Spearman's rho:

Loiyangalani, r_s=0.901, p=<0.010; and Magubike, r_s= 0.852, p=<0.010). Accordingly, the NISP counts are preferred in this work in ranking the taxonomic abundance. The major advantage of the NISP lies in its simplicity and has the benefits of facilitating comparisons of different taphonomic and zooarchaeological aspects in the faunal assemblage (s) under consideration (Grayson 1984; Klein and Cruz-Uribe 1984; Lyman 1994, 2008). This is also the case, for the Loiyangalani and Magubike faunal assemblages given the fact that, skeletal part representation, taxonomic composition, and bone surface modifications are mainly quantified using NISP counts (see Tables 6.3-6.22 and 7.3-7.24). Of note, there are also no MNE and MNI counts for the isolated teeth, fish, and tortoise due to the high degree of fragmentation in the faunal assemblages.

From the taxonomic composition perspective, broad ranges of taxa were identified in both faunal assemblages. They represent a diverse vertebrate assemblage comprising of the small and large-sized terrestrial mammals, aquatic species and reptiles. They also include large carnivores and rodents (Tables 6.3, 6.8, 6.9, 7.3, 7.8 and 7.9). A total of 8 and 7 different taxa were identified in the Loiyangalani and Magubike faunal assemblages respectively, giving a total NTAXA of 15 (Tables 6.9 and 7.9). Of note, bovids dominate in both assemblages making up approximately 85% (of both sites NISP), which may also signify their relative high importance in the available diet spectrum at both sites. Bovids are proportionately more abundant at Magubike rockshelter than at Loiyangalani (96.74% versus 65.75% respectively as measured by NISP counts). Overall, fish remains exclusively from Loiyangalani are the second most abundant taxa making up about 10.32% of the total NISP from both sites. Other taxa are represented in relatively low proportions mostly of < 2%. Suids (1.2%) that are known to be aggressive species and equids (0.16%) are also present in both faunal samples. Tortoises (1.1%) and hares (0.16%) are similarly rare. Bird remains also occur in low proportion making up only 0.69% of both sites total NISP with more specimens being identified in the Magubike faunal assemblage (Tables 6.3, 6.8, 7.3 and 7.8). These undoubtedly constituted an important component of the diet spectrum available for the MSA hominins at both sites and might robustly underscore their foraging ecology, which is the main objective of this study.

Large carnivore remains make up only < 0.5% of the total NISP from both sites (Tables 6.3, 6.8, 7.3 and 7.8). Spotted hyena (*Crocuta crocuta*) remains were exclusively identified in the Magubike faunal sample that may also suggest they visited and/or may have occasionally resided the rockshelter (Cruz-Uribe 1991; Lam 1992; Pickering 2002; Villa et al. 2004; Kuhn et al. 2010). Crocodile remains exclusively from the Loiyangalani site are also marginally represented (Table 6.8).

A Sorenson Index following Lyman (2008) guideline was calculated to determine the degree of similarity (or lack thereof) in taxonomic composition between the Loiyangalani and Magubike MSA faunal assemblages. Then, Sorenson Index (S) was calculated as follows:

$$S = 100(2c)/(a+b) \;\ldots\ldots\ldots\; (5)$$

where a is a total number of taxa unique to the faunal assemblage A, b is the total number of taxa unique to the faunal assemblage B, and c is the number of taxa common in the faunal assemblage A and B. The value of 100 denotes all taxa are shared, and that of zero implies they are not shared. The Sorenson Index (S) of similarity for the two MSA faunal assemblages considered for this study is 66.67 or 2/3, suggesting the overall taxonomic composition is least similar taxonomically and do not appear to have been derived from the same populations (Lyman 2008). Besides, identified taxa are also not normally distributed statistically (Kolmogorov-Sminorv two sample-test D=0.300, p=0.675), but the difference for the two faunal assemblages is not statistically significant (two sample t-test: t=0.0002, p=0.9998). The difference for the two MSA faunal assemblages considered for this study appears to mirror the local prey types availability, and their distribution over the landscape (MacArthur and Pianka 1966; Stephens and Krebs 1986; Bettinger 1991; Marean 1997; Kelly 2007). The difference could also reflect the nature of the sites (an open air site versus a rockshelter), sample sizes compared, and may also mirror MSA hominins choice of the foraging habitats (patches) over the landscape (Grayson and Delpech 1998; Nagaoka 2001, 2002a, b, 2006; Lyman 2008; Bar-Oz 2004; Kelly 2007). To get a comprehensive picture on the MSA hominins fundamental foraging decisions, prey diversity, and relative abundance index were also calculated for both faunal assemblages (Table 8.3).

Prey Diversity: Richness and Evenness

Measures of prey diversity (richness and evenness) often permit to quantitatively summarize prey choices and distribution in the archaeological faunal assemblage since they make no assumptions regarding the differential economic utility values of the individual skeletal parts (Binford 1978, 1981; Metcalfe and Jones 1988; Jones and Metcalfe 1988; Grayson and Delpech 2002; Faith 2007; Faith and Gordon 2007). As remarked above, terrestrial mammals heavily dominate the Loiyangalani and Magubike MSA faunal assemblages. In this work, approximately 10,000 faunal specimens belonging to a wide diversity of taxa were analyzed (Table 8.2). Bovids are the most common ungulates and extensively contributed to the available diet spectrum available at each site. Moreover, there is also ample evidence at both sites that MSA hominins regularly hunted them, and intensively extracted for edible resources (meat, marrow, and grease) from their fully-fleshed carcasses as attested by the abundance of the anthropogenic modifications (Tables 6.11-6.17 and 7.11-7.18). Accordingly, they are considered in this study as the principal economic taxa by which MSA hominin foraging economy and hunting preferences can be robustly evaluated.

It is important to note, the number of identified specimens (NISP) is relatively higher for the Magubike faunal assemblage (NISP=3,436 vs. NISP=2,070 for Loiyangalani). Magubike also has MNI counts of the mammalian taxa of nine times more than the Loiyangalani (MNI=226 vs. MNI=25 for Loiyangalani). However, Loiyangalani has relatively higher identification rate at assemblage level of approximately 65%, and Magubike has relatively lower only by 52% (Table 8.2). As seen in Tables 6.8 and 6.9 above, Loiyangalani faunal assemblage also include aquatic and semi-aquatic taxa, but these are not registered in the Magubike faunal sample. It is also relevant to mention, the MSA faunal assemblages studied originate from two different ecological settings as described in details in Chapter 3.

According to Cruz-Uribe (1988), NISP and MNI counts of skeletal parts assigned to species/taxa level are commonly used to calculate prey diversity (richness and evenness) in archaeological faunal assemblages and those assigned to genus are usually omitted. However, the use of the NISP or MNI counts both suffers from various shortcomings. First, NISP is very sensitive to inter-taxonomic and intra-taxonomic variation of the skeletal parts. Accordingly, the high degree of fragmentation in the archaeological faunal assemblage frequently intensifies the problem by raising the NISP and depressing the MNI counts (Wolverton 2002). In this context, NISP counts may exaggerate the abundance of some taxa relative to their initial abundance deposited at the archaeological site (s) under consideration (Grayson 1984; Klein and Cruz-Uribe 1984; Lyman 1994, 2008). On the other hand, although MNI counts are not significantly affected by the inter-taxonomic variation problem, likewise can exaggerate the importance of the rare taxa/species in the archaeological faunal assemblage (s) under study. However, it is also argued that either NISP or MNI count can also frequently yield similar results (Grayson and Frey 2004; Clark and Plug 2008; Lyman 2008). Spearman's rho results confirm the relationship of the two quantification units. In both faunal assemblages the NISP and MNI counts are strong positively correlated (Spearman's rho: Loiyangalani, r_s=0.800, p=0.200; and for Magubike, r_s=0.800, p=0.200). The difference of the two units is also not quite statistically significant for the Loiyangalani faunal sample (two sample *t*-test: t=3.1084, p=0.0529). However, for the Magubike faunal sample the difference is very statistically significant (two sample *t*-test: t=5.6104, p=0.0112). Accordingly, in this study, terrestrial mammals, fish, tortoise and bird, which are the economic taxa, were included in the computation of the relative taxonomic richness (i.e. how many species are represented within an assemblage) and evenness (i.e. the proportion of each species represented in an assemblage) mainly using their NISP counts. Tables 6.8, 6.9, 7.8, and 7.9 above provide the taxonomic list of both economic and non-economic taxa identified in the Loiyangalani and Magubike faunal assemblages.

Of note, fish, tortoise and bird are mostly considered at best in this study as supplementary food resources to the MSA hominins.

Hyenas and crocodiles certainly did not contribute to the MSA hominins optimal diet at both sites, so were purposefully excluded in the analysis. Some African ethnic groups still value rodents for their flesh and so, could have been human prey. In West Africa, rodents are one of the preferred food items and are also very common in bush meat markets (Aluko et al. 2015). However, the status of rodents in the available diet spectrum at both sites is largely unclear, as they do not preserve any evidence of hominin exploitation, so they were also excluded. Rodents are considered at best as intrusive or may have been incorporated into the faunal assemblages mostly by the action of water or entered the assemblages on their own at the Loiyangalani site. Besides, rodents might have been brought in by owls or other predators, which forage on micromammals at Magubike rockshelter (Payne 1983; Andrews 1990; Aluko et al. 2015).

A comparison of the two MSA faunal assemblages regarding their prey diversity as explored through the comparison of the number of the economic taxa (NTAXA), indicates Loiyangalani has comparatively higher taxonomic diversity (*H'*=0.770) and Magubike has a markedly lower diversity (*H'*=0.169). Regarding the evenness in the taxonomic representation, again Loiyangalani site has a relatively higher value (*E*=0.430), whereas Magubike has a lower value (*E*=0.105). Overall, measures of taxonomic diversity (richness and evenness) indicate both faunal assemblages considered for this study are less pretty heterogeneous and even taxonomically (Table 8.3 below). Overall, Loiyangalani appears to be more taxonomically diverse, and Magubike is the least diverse. The relatively high richness and evenness indices for the Loiyangalani faunal assemblage can be linked to the location of the site in an ecologically favourable place near reliable water sources (Lake Magadi as well as the Loiyangalani and Mbalangeti Rivers) and along a wildlife migration corridor that consequently has led to a more enriched taxonomic composition profile. Regarding the range of the taxa exploited it can be also suggested the diet breadth at Loiyangalani was quantitatively and qualitatively broader, which also may suggest more flexible foraging strategies for the occupants of the site and was relatively narrower at Magubike rockshelter (Table 8.1 and 8.3). Besides, the measures of prey diversity (richness and evenness values) also demonstrate MSA hominin foraging economy at both sites was not dominated by a single species/taxa (Brain 1981; Bunn 1982; Grayson and Delpech 1998, 2002; Gaudzinski 2006; Faith 2007, 2008; Dusseldorp 2010, 2012). The values provided in Table 8.3 below may suggest flexibility in the procurement of different prey types or animal sizes rather than specialization on one species, taxa or an animal size class (Tables 4.1, 6.5 and 7.5).

Table 8.3. Richness, Evenness and Abundance Indices of the Large-Sized Animals in the Loiyangalani and Magubike Faunal Assemblage.

Site	Richness	Evenness	Abundance Index
Loiyangalani	0.77	0.43	0.65
Magubike	0.169	0.105	0.57

Abundance Index

An Abundance Index (AI) was also calculated following Bayham (1979) protocol to evaluate the relative importance of the small (size 1-2) and large-sized (size 3-4) prey in the available dietary spectrum at both sites. The analysis was conducted exclusively for the mammalian skeletal parts confidently assigned to animal size classes using their NISP counts (Tables 6.3, 6.5, 7.3 and 7.5). For this particular analysis fish, tortoise and bird were purposefully excluded. The use of NISP counts might potentially exaggerate the relative dietary contribution of fish at the Loiyangalani site (Clark and Kandel 2013:276). As has been recently argued by Morin (2012), tortoises are slow-moving prey that always involves lower pursuit and handling costs as well as have a relatively higher chance of capture and so potentially were routinely included in the available optimal diet spectrum in violation of the animal size rule (see also Stiner et al. 1999, 2000; Boileau 2013). Bird remains were also excluded given their overall low representations in both faunal assemblages. However, the contribution of fish, tortoise and bird to the overall MSA hominins optimal diet breadth is accounted for below.

The relative abundance index (AI) of the large-sized prey in the Loiyangalani and Magubike faunal assemblages is 0.65 and 0.57 respectively (Tables 4.1 and 8.3). The values exhibit a clear pattern biased towards a greater focus on the acquisition and exploitation of the high-yield prey, which provided high energetic returns relative to search, pursuit and handling costs as predicted by the diet breadth model above (Stephens and Krebs 1986; Bettinger 1991; Pianka 2000; Kelly 2007; Broughton et al. 2011). As remarked in the preceding two chapters, medium-sized (size 3 bovids) animals that weigh up to 300 kilograms form the bulk of the hunted prey accounting for approximately 45%

and 35% of the total NISP counts in the Loiyangalani and Magubike faunal assemblages respectively (Tables 4.1, 6.5 and 7.5). Additionally, size 4 bovids were also hunted in significant high quantities with the proportions of 20% and 22% at the Loiyangalani site and Magubike rockshelter respectively.

Small-sized (size 1-2) animals were also hunted but in relatively low proportions in the region of between 30 and 40% at the Loiyangalani site and Magubike rockshelter respectively (Tables 6.3, 6.5, 7.3, 7.5 and 8.3). These were added into the optimal diet to maximize the foraging activities when the large-sized (size 3-4) animals and high ranked prey became harder to find them over the landscape, which is broadly consistent with an expansion of the diet breadth (Stiner and Munro 2002; Stiner et al. 1999, 2000; Kelly 2007). Hares (*Lepus capensis*) exploitation is mainly inferred by green fracture of their long bones at Magubike rockshelter suggesting MSA hominins also occasionally exploited them. Medium-sized birds at both sites also appear to represent prey of the MSA hominins a phenomenon that may also mirror a broadening of the diet breadth (Tables 6.8, 6.9, 7.8, 7.9 and 7.11).

Successful hunting blind spots are usually situated near the water sources and near natural features such as rock outcrops (Behrensmeyer 1987; Hayness 1988; Driver 1990, 1995; O'Connell et al. 1992; Lupo 1994; Lupo and O'Connell 2002; Marean 1997). Small and large-sized ungulates are habitually attracted to the locations of this nature. Both Loiyangalani and Magubike are strategically located near rivers. The Loiyangalani site was strategically positioned between the grassland and woodland ecotone margins, between two reliable water sources (Lake Magadi and the Loiyangalani and Mbalangeti Rivers), and along a wildlife migration route (Bower 1977, 1981; Maddock 1979;

McNaughton 1988, 1990; Holdo et al. 2011). This possibly permitted the prehistoric humans to monitor prey movements (probably from the Makati Hills west of the site) and to intercept them past the site (Behrensmeyer 1987; Driver 1990, 1995; O'Connell 1997). This consequently ensured reliable opportunity to subsist through planned forays as the wildlife moved from their wet season range on the plains to their dry season range on the western part of the Serengeti National Park (Holdo et al. 2011). This also suggests the use of sophisticated weapons technology, group coordination, and anticipatory behaviour (O'Connell et al. 1992; Driver 1990, 1995; Marean 1997; Bird et al. 2009; Adler and Bar-Oz 2009). The proximity of the Loiyangalani to the quartzite Makati hills also afforded the MSA hominins with a reliable source of lithic raw material to manufacture the stone tools for hunting (Figure 3.2).

Magubike rockshelter is situated in an area typical of the landscape of the southern highlands of Tanzania, mostly characterized by the undulating topography and scatters of numerous rock outcrops (Figure 3.7). It overlooks a swampy river valley just a few kilometers east of the site, and there are also numerous natural springs gushing out fresh water all the year round nearby. The strategic location of the rockshelter at an elevated setting also made it an excellent spot to monitor and hunt ungulates moving in the river valley and to intercept the approaching prey (Behrensmeyer 1987; Driver 1990, 1995; Marean 1997; Bird et al. 2009). The rugged nature of the landscape and the presence of numerous rock outcrops near the site also afforded the MSA hominins with both cover and blind spots for successful hunting of the small and large-sized ungulates. The rockshelter also provided the MSA hominins safe haven where to transport the carcass parts for further processing and consumption, a behaviour that probably encouraged by the intentional food-sharing (Isaac 1971, 1978; Winterhalder 1997; Stiner et al. 2009).

The fact that pointed and sharp-edged flakes constitute considerable portions of the formal MSA tools at both sites suggest were pivotal for successful hunting of the ungulates (Knecht 1997; Shea 2006, 2009; Thompson et al. 2004; Bower and Mabulla 2013; Bower et al. 2012; Maíllo-Fernández et al. 2016; Willoughby 2012b; Werner and Willoughby 2017). Cut marks and percussion marks recorded in both faunal assemblages also establish the causal behavioural links between the MSA hominin technology, butchery and manipulation of the meat-bearing (Tables 6.11-6.17 and 7.11-7.18).

The age structure of the hunted prey at both sites overall shows the prevalence of the prime-adults ungulates which also suggests MSA hominins mainly focused on a specific age class at the height of their reproductive life available over the landscape (Klein 1982, 1983; Klein and Cruz-Uribe 1983, 1984; Stiner 1990, 1991a, b, 1994; Gaudzniski and Roebroeks 2000). Mortality profile datasets show that more than 70% were hunted as prime-adults, which also provided high foraging returns in terms of the nutritional resources (meat, marrow, and grease) and utilitarian resources. s. As seen in Tables 6.10 and 7.10 above the juveniles overall are underrepresented. The same quantitative pattern also prevails in the small and large-sized carcass subsamples. According to Adler and Bar-Oz (2009:130), the presence of the remains mainly of the juveniles and prime-adults coupled with the paucity of the juveniles and the absence of the old individuals (as is the case for both Loiyangalani and Magubike) reflect MSA hominins active hunting of the prey rather than the natural mortalities.

MSA hominins also enjoyed full access to the fish and tortoises at the Loiyangalani site perhaps as a supplement in a widening dietary breadth (Stiner et al. 1999, 2000). Fish and tortoise exploitation is also well documented in the course of hominin evolution and is also widely reported in the historical, ethnographical, and archaeological literature (Klein and Cruz-Uribe 1983; Speth and Tchernov 2002; Blasco 2008; Branch 2008; Marean 2010; Thompson and Henshilwood 2014a, b). Fish remains are often rare in most MSA archaeological sites in Africa but is a more pronounced activity for the LSA period (Klein 2009; Klein and Cruz-Uribe 1996, 2000). According to Richard G. Klein, the MSA hominins lacked the necessary technology consequently their rarity in numerous archaeological sites (Klein 2009). However, the presence of a few fish and tortoise remains bearing cut marks in the Loiyangalani faunal assemblage suggests MSA hominins foraged and processed them for extra source of meat and fat on a regular basis, which is also consistent with the expansion of the diet breadth (Stiner and Munro 2002; Stiner et al. 1999, 2000). Other MSA sites in sub-Saharan Africa that have documented exploitation of catfish (*Clarias* sp.) include Aduma in the Middle Awash valley and Porc-Epic both in Ethiopia and Katanda Upper Semliki Valley in the Democratic Republic of Congo (Brooks et al. 1995; Yellen et al. 2005). Two species of fish are identified at the Loiyangalani site mainly catfish *Claris* sp., and Cichlids sp., (Thompson 2004:6). The *Claris* are well adapted for survival in shallow waters and low-oxygen conditions. They often spawn up rivers and streams during the rainy seasons (December to April) as well as in very shallow pools created along the margins of the flooding rivers making them vulnerable to spearing or harpooning and even easy to catch with bare hands. Fish also could be mass-collected with the use of nets (Madsen and Schmitt 1998; Rick and Erlandson 2000). The MSA hominins probably favoured the catfish for their high amount of fat and oily taste (Prendergast 2008).

Of note, fish remains are not recorded in the Magubike taxonomic composition list. Collins (2009:230) has attributed their absence mainly to the location of the rockshelter away from the major water sources. Given the fact that there is a river rich in fish and within the reach of the occupants of the rockshelter, it is more likely were exploited at the site. Future research works can bolster this tentative hypothesis. The absence of fish remains may probably be linked to the taphonomic profile of Magubike faunal assemblage and in particular the impact of concretions on specimens as emphasized in Chapter 7, which might have rendered their skeletal parts undetectable during the analysis. Fish bones are also characteristically smaller and less hard than the mammalian bones (Wheeler and Jones 1989). Besides, burning within the rockshelter may also explain their absence (Stiner et al. 1995, Stiner 2005; Steffen and Mackie 2005).

Tortoises, which are slow moving game, are typically not dangerous to capture them when out of the water, and one just needs a simple technology to process them. These might have been always included in the optimal diet available at the Loiyangalani site and their carapaces were used as containers (Thompson 2010; Thompson and Henshilwood 2014a, b; Morin 2012). Tortoises were likely acquired from the Loiyangalani and Mbalangeti Rivers, Lake Magadi and from the areas nearby the water sources (Figure 3.1). Leopard tortoises (*Geochelone pardalis babcocki*) are commonly found in Tanzania even today (Kabigumila 1998). Tortoises also reside in shallow, slow moving or marshy freshwaters and estivate in the mud during the dry season. They also inhabit dried riverbeds, open savannah, grasslands, and scrubby areas. Large tortoise might weigh up to 13 kilograms in pristine habitats making them an excellent source of proteins for hominin (Branch 2008). Tortoise remains have been also documented in numerous MSA archaeological sites in sub-Saharan Africa such as at Blombos Cave and Pinnacle Point Cave 13B. Recent taphonomic and zooarchaeological analyses in South Africa have demonstrated MSA hominins also exploited them as additional source of calories (Thompson 2008, 2010; Thompson and Henshilwood 2014a, b).

Large land snails (*Achatina*) also constitute a significant portion of the faunal assemblage recovered in 2012 at Magubike rockshelter (Willoughby 2012a). Land snails are also slow moving creatures that can be also easily collected even by children, elderly and pregnant women (Bird and Bliege-Bird 2000). Of note, ethnographic accounts in Tanzania also demonstrate land snails are still eaten by the Makonde ethnic group (Msemwa 2002:14). These also potentially may have served also at best as a supplement source of food to the available diet spectrum at Magubike rockshelter (Lubell 2004).

8.5. Carcass Transport Strategies at Loiyangalani and Magubike

Another approach to explore MSA hominin foraging ecology involved an evaluation of the selective transport of the carcass parts from the kill to consumption sites. As detailed in Chapter 6 and 7, elements from the major five anatomical segments of a complete carcass are represented in relatively high proportions at both sites (see Tables 6.6, 7.6; Figures 6.10 and 7.6). Taken as the whole, skeletal part representations at both sites are more biased towards the elements belonging to the upper appendicular limb bones (humerus, femur, tibia and radius) and axial elements (vertebrae, ribs, pelves and scapulae), which suggest MSA hominins preferentially transported the carcass parts rich in nutritional values (Binford 1978, 1981; Metcalfe and Jones 1988). The gross pattern is consistent with the general carcass parts transport strategy practiced by the Hadza, a modern hunter-gatherers group from northern Tanzania (Bunn and Kroll 1986; Bunn et al. 1988; O'Connell et al. 1988b, 1990, 1992; Lupo 1995; Lupo 2001, 2006; Lupo and O'Connell 2002; Monahan 1998).

Skeletal part abundance involving all elements are positively correlated with their standardized food utility (SFUI) values for both animal size classes (Spearman's rho range: small-sized carcasses, r_s=0.015 to 0.018; p-values=0.950 to 0.957 and for the large-sized carcasses, r_s=0.013 to 0.115; p-values=0.672 to 0.961). The high-survival-elements that are commonly transported by hominin from butchery to consumption sites are also positively correlated to their economic utility (Spearman's rho range: small-sized carcasses, r_s=0.286 to 0.500; p-values= 0.207 to 0.535; and for the large-sized carcasses, r_s=0.335 to 0.786; p-values=0.021 to 0.417). The coefficient of determination r^2 for the small-sized carcasses ranges between 0.082 and 0.112; and for the large-sized carcasses the range is between 0.112 and 0.618 (Tables 6.7 and 7.7). This pattern is more consistent with MSA hominins strategy that was more oriented towards maximization of the foraging returns (Binford 1978, 1981; Metcalfe and Jones 1988; Faith and Gordon 2007; Marean and Cleghorn 2003; Cleghorn and Marean 2004, 2007).

The Shannon evenness indices for the high-survival-elements sets are also high (small-sized carcasses range: 0.75 to 0.79; and for large-sized carcasses, 0.82 to 0.9), which also suggest the MSA hominins at both sites transported complete or nearly complete carcasses for further processing and delayed consumption a behaviour, which is more comparable to that of the fully modern humans (Isaac 1971, 1978; Winterhalder

1997; Stiner et al. 2009). The general strategy employed by the MSA hominins is the "unbiased strategy" that involves long distance transport of the carcass parts in direct correlation to their food economic utility (Binford 1978, 1981; Faith and Gordon 2007; Faith et al. 2009). The only deviation noted is for the large-sized (size 3-4) animals at the Loiyangalani site, which were regularly procured not too far from the site (Table 6.7). The fact that the site is strategically positioned along a wildlife migration corridor made the encounters of the large-sized ungulates always high and predictable, and MSA hominins could have also ambushed them in large numbers during the wildlife migration (Marean 1997; Bird et al. 2009; Holdo et al. 2011). It is also believed the wildlife migration afforded the MSA hominins at the Loiyangalani site substantial food resources for survival based on reliable accessibility to the migratory ungulate species that normally trek over long distances for which sufficient labour forces for cooperative prey hunting and carcasses processing also could be organized at an anticipated location and time (Hayness 1988; Behrensmeyer 1987; Driver 1990, 1995; O'Connell et al. 1992; Marean 1997; Alvard 2001; Stiner et al. 2009). The carcass parts transport strategies summarized above coupled with bone surface modification datasets mirror the foraging ecology contexts in which the MSA hominins at the Loiyangalani site and Magubike rockshelter in Tanzania predated on a relative wide diversity of taxa (both terrestrial and aquatic) and also enjoyed persistent primary access to the high-meaty and marrow-bearing bones of both small and large-sized ungulates.

A common feature noted in both faunal assemblages irrespective of the animal size is the fewer representations of the cranial (horns, skulls, maxillae, mandibles, and teeth) and lower limb bones (metacarpals, metatarsals, carpals, tarsals and phalanges), which are often discarded at the butchery sites because of their inherent overall marginal nutritional values. The cranial and lower limb bones are represented by combined percentages of about 40% and 27% of the total NISP at the Loiyangalani site and Magubike rockshelter respectively (see Tables 6.3, 6.6, 7.3 and 7.6 for the details).

8.6. Carcass Processing Intensity at Loiyangalani and Magubike

Further insights regarding MSA hominin foraging ecology and predatory behaviour are gained through the examination of the carcasses processing intensity to extract the edible resources (meat, marrow, and grease). As detailed in Chapter 6 and 7 above, both human (cut marks, percussion marks, and burning) and nonhuman (tooth marks and rodent gnaw marks) bone surface modifications are recorded in both faunal assemblages.

Cut marks were recorded on mammal bone fragments ranging from animal size 1 to 4 with more numerous on the medium-sized animals (Tables 6.12 and 7.12). Skeletal parts from major five anatomical sections of a complete carcass of both small and large-sized ungulates also were cut-marked suggesting the MSA hominins processed their complete carcasses (Figures 6.13 and 7.9). The majority of specimens exhibited single and isolated cut marks and their distribution reflect several stages of carcass reduction and processing into consumable parts summarized below. Interpretation of the cut marks based on their anatomical placements on skeletal parts, the majority are ascribed to the filleting/deboning operations (Binford 1978, 1981; Lyman 1987a; Nilssen 2000; Galán and Domínguez-Rodrigo 2013). The number of cut marks-bearing bones also appears to increase with animal size, which may reflect differential field processing and extraction of the edible resources (Tables 6.11, 6.12, 7.11 and 7.12). Large-sized (size 3-4) carcasses often require intensive processing in the field before transport (Binford 1978, 1981; Bunn and Kroll 1986; Bunn et al. 1988a; Lyman 1987a; O'Connell 1988a, 1990, 1992; Gifford-Gonzalez 1989; Oliver 1993; Lupo 1994, 2001, 2006; Lupo and O'Connell 2002; Monahan 1998; Nilssen 2000). On the other hand, small-sized (size 1-2) animals often do not require exhaustive processing and defleshing at the kill sites (Yellen 1977, 1991). Of particular interest, skeletal parts bearing cut marks (NISP cut-marked) are strongly and positively correlated with the total NISP of each skeletal part involving all animal size classes (size 1-4) at both sites (Spearman's rho: Loiyangalani, $r_s= 0.821$, $p=<0.010$ and Magubike $r_s=0.902$, $p=<0.010$). Besides, cut-marked specimens are also positively correlated with the economic utility of those skeletal parts (Spearman's rho: Loiyangalani, $r_s=0.407$, $p=0.149$ and Magubike, $r_s=0.433$, $p=0.122$). The same quantitative pattern is also true for the small (size 1-2) and large-sized (size 3-4) carcass subsamples as also detailed in Chapter 6 and 7 above.

The overall proportion of cut marks on the identified skeletal parts is 10% and 8% in the Loiyangalani and Magubike faunal assemblages respectively (Tables 6.3, 6.11, 7.3 and 7.11). The proportions also range between 4% and 8%, and between 10% and 11.5% for the small (size 1-2) and large-sized (size 3-4) carcass subsamples respectively. However, it is worth retaliating the number of identified mammalian skeletal parts bearing cut marks in the Magubike faunal assemblage is high (NISP=240), whereas Loiyangalani has relatively lower incidences (NISP=128). Taking into account the ratios of the cut-marked versus tooth-marked specimens in both faunal assemblages, results suggest were inflicted on bones in generally low levels of competition settings from the carnivores (Blumenschine 1986a, b, 1987, 1991, 1995; Blumenschine and Marean 1993;

Blumenschine et al. 1994; Oliver 1994; Capaldo 1995, 1997; Domínguez-Rodrigo 1999a, 2001; Domínguez-Rodrigo and Organista 2007; Faith and Behrensmeyer 2006).

Although the proportions are less strict compared to the experimental values reported by Domínguez-Rodrigo (1997a-c) and Domínguez-Rodrigo and Barba (2005, 2007c), the high-meaty bearing long bones (ULB and ILB) midshaft sections are more cut-marked than the none-meaty bearing lower limb bones (LLB) at both sites (Tables 6.13 and 7.13). The upper and intermediate limb bones (ULB and ILB) midshaft sections that rarely retain flesh scraps post-carnivore initial defleshing also bear high proportions of cut marks than tooth marks. As detailed in Tables 6.13, 6.20, 7.13 and 7.21, the proportions of cut marks on these elements compared to tooth marks strongly suggest MSA hominins systematically extracted large amounts of meat from complete or relatively complete carcasses before carnivore intervention rather than detached scraps of meat from them (Binford 1981; Potts and Shipman 1981; Bunn 1982, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Oliver 1994; Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Barba 2005, 2007c; Pickering Domínguez-Rodrigo 2006; Pickering et al. 2008; Gidna et al. 2014).

As graphically shown in Figures 6.14 and 7.10 above, the percentages of cut-marked long bone midshafts in both faunal assemblages also match the experimental and ethnoarchaeological studies that simulate foraging scenarios in which the hominin had primary (early) access to fully-fleshed carcasses (Table 5.5). The values are also very close to the cut marks proportions reported for the FLK 22 *Zinj* faunal assemblage (Table 8.4). New cut marks estimates on long bone midshafts at FLK 22 *Zinj* site have unequivocally reasserted the classical hypothesis that the early hominins at the site were effective hunters of the ungulates (Leakey 1971; Bunn 1981, 1982, 1983, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Oliver 1994, 2015; Domínguez-Rodrigo 2002; Domínguez-Rodrigo and Barba 2005, 2006, 2007a, c; Domínguez-Rodrigo and Pickering 2003; Domínguez-Rodrigo et al. 2014; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008).

High proportions of anthropogenic bone fracturing also characterize the Loiyangalani and Magubike faunal assemblages (Tables 6.14-6.17 and 7.14-7.17). The fact that only nine long bones remained complete from both sites also suggest the MSA hominins had access to all the high marrow-bearing long bones. At both sites bones of the large-sized animals were also intensively extracted for marrow than those of the small-sized animals. The proportions of percussion marks on long bone midshaft fragments in the Loiyangalani and Magubike faunal assemblages also fall within the documented range of variation in experimental studies in which hominin had primary (early) access to the major marrow-bearing long bones to extract bone marrow (Tables 5.5, 6.15 and 7.15). The same quantitative trend is also documented for the small and large-sized animal subsamples (Table 8.4). High proportion of green fractures, coupled with very strong positive and statistically significant correlation coefficients between %MAU of the marrow-bearing bones and their corresponding unsaturated marrow index (UMI) values confirm regular marrow exploitation by the MSA foragers at both sites (Tables 6.14-6.17, 6.22, 6.23, 7.14-7.17, 7.23, 7.24; Figures 6.15, 6.16, 6.21-6.22, 7.15 and 7.16). Both faunal assemblages also exhibited high proportions of Type 1 shafts (Tables 6.22, 7.23; Figures 6.20 and 7.14). Judging from the fracture morphologies of the long bone fragments, both faunal assemblages also exhibit relatively high proportions of the oblique angles, V-shaped outlines, and smooth fracture edges by more than 70% suggesting the majority were broken while still fresh (Tables 6.22 and 7.23; Figures 6.20-6.22 and 7.14-7.16). Besides, the average FFI scores also fall within the range of the anthropogenic fractured faunal assemblages often with the value of ≤ 2 (Tables 6.23 and 7.24). Burnt bones also give additional evidence that both faunal assemblages are typically the results of the anthropogenic activities (Tables 6.11, 7.11 and 7.18).

There is evidence at both sites the mandibles as well as the first and second phalanges that also contain small stores of marrow were intentionally cracked open and extracted for marrow (Tables 6.17, 7.17; Figures 6.16 and 7.11). Splitting of the ungulate phalanges in the course of hominin evolution is also reported at Kebara cave in Israel (Bar-Yosef et al. 1992:521), at Nasal Hadera V, Hefzibah, Nev-David and el-Wad Terrace (Bar-Oz 2004:47-48), Saint Césaire in France (Morin 2004:87-88), Tangzigou in China (Jin 2010:94-95), Gran Dolina Atapuerca in Spain (Rodríguez-Hidalgo et al. 2017:101) and Klipdrift shelter in South Africa (Reynard et al. 2016:13). In fact, bone marrow extraction from skeletal parts with small packages coupled with high fragmentation of the high-marrow bearing long limb bones is also frequently cited as an evidence for intensive carcass processing i.e. wider diet breadth (Marean et al. 2000; Munro and Bar-Oz 2005; Bar-Oz and Munro 2007; Adler and Bar-Oz 2009; Pickering and Egeland 2006). According to Jin and Mills (2011:1808), fragmentation of the phalanges also in and of themselves does not necessarily mirror a decline in the foraging return rates. Accordingly, the high proportions of the green fractured long bone fragments and phalanges in the Loiyangalani and Magubike faunal assemblage denote the occupants of the sites intensively processed the hunted prey carcasses by extracting edible resources even from the relatively poor marrow stores (Tables 6.14-6.17, 6.23 and 7.14-7.17).

Bone surface modifications patterning (frequency and their distributions) in the Loiyangalani and Magubike MSA faunal assemblages document a complete sequence of carcass reduction and processing from skinning to bone marrow extraction and also suggest regular and intensive processing of the complete carcasses (Binford 1978, 1981; Lyman 1987b, 1994). The following episodes of carcass reduction and processing of the meat-bearing bones into consumable parts are documented on the small and large-sized ungulates at both sites:

i. Skinning - as attested by the recorded cut marks on the cranium, mandible, metacarpal, metatarsal and on the phalanges (Tables 6.11-6.14, 7.11-7.14; Figures 6.13 and 7.9);

ii. Disarticulation/dismemberment – as attested by the recorded cut marks on the cervical, atlas and on the major long limb bones epiphyseal ends (Tables 6.11-6.14, 7.11-7.14; Figures 6.13 and 7.9);

iii. Evisceration – as attested by the recorded cut marks on the ventral side of a few rib fragments (Tables 6.11 and 7.11);

iv. Defleshing/filleting/deboning – as attested by the recorded cut marks on the scapula, pelvis and rib as well as preferentially on the midshaft sections of the humerus, femur, tibia, and radius (Tables 6.11- 6.14, 7.11-7.14; Figures 6.13 and 7.9);

v. Marrow extraction – as attested by the distribution and proportions of percussion marks on long limb bones, mode of long bone fragments breakage and fragmentation of the first and second phalanges (Tables 6.11, 6.12, 6.14-6.17, 6.22, 6.23, 7.11, 7.12, 7.14-7.17, 7.23, 7.24; Figures 6.15, 6.16, 6.20-6.22, 7.11, and 7.14-7.16); and

vi. Meat roasting? – as indirectly inferred from the recorded burnt bones in the faunal assemblages (Tables 6.11, 6.12, 7.11, 7.12 and 7.18);

Carnivore activity in the Loiyangalani and Magubike faunal MScA assemblages is mainly determined by their damage inflicted on the fossilized bone fragments including tooth pits and score marks (Tables 6.18-6.21 and 7.19-7.22). Nonetheless, the proportions of tooth marks bearing skeletal parts appear to be very low when compared to what is known for the faunal accumulations exclusively modified by the carnivores (Blumenschine 1986a, b, 1988, 1995; Blumenschine and Marean 1993; Marean and Spencer 1991; Marean et al. 1992; Capaldo 1995, 1997, 1998; Domínguez-Rodrigo 1997a-c, 1999a; Domínguez-Rodrigo and Organista 2007; Gidna et al. 2014). Of note, the overall proportion of tooth marks on the identified skeletal parts does not exceed 6%. To be more precise, Loiyangalani has a relatively higher proportion of tooth marks bearing elements documented at a rate of 5.7% and at Magubike rockshelter the proportion is just 1%. The results may also suggest carnivore scavenging opportunities might have been relatively high at Loiyangalani, which is an open-air site (i.e. visibility is good, and cues to the defleshed and demarrowed bone fragments are both high), and was limited at Magubike which is a rockshelter. Rodent gnaw marks are also frequently higher in contexts where the bones stay on the ground for relatively longer period. However, the proportions of rodents gnaw marks on bone fragments at both sites are also very low and negligible (Tables 6.18, 6.19, 7.19 and 7.20).

With respect to the proportions of tooth marks inflicted on the axial bones, which are also often completely nutritionally depleted post-large carnivore consumption, are also notably very low. The relatively high proportions of cut marks relative to the tooth marks on these elements cannot be explained to result from the MSA hominins scavenging the nutritionally depleted axial skeletons (see Tables 6.18, 6.21, 7.19 and 7.22 above for the details). The proportions of tooth marks on the long bone midshafts at both sites are also better explained by the experimental studies that replicate hominin-to-carnivore (H-C) access to the defleshed and demarrowed bone fragments (Tables 5.5, 6.20, 7.22 and 8.4). Besides, from a comparative perspective, the proportions of tooth marks on long bone midshafts at both sites are also broadly consistent with those in the FLK 22 *Zinj* and ST Site Complex archaeological faunal assemblages (see Table 8.4 below). The new tooth marks estimates in the FLK 22 *Zinj* faunal assemblage have recently relegated the carnivore to the secondary consumers rank of the defleshed and demarrowed bone fragments at the site (Domínguez-Rodrigo and Barba 2006, 2007a, b).

Taken together, bone surface modifications in the Loiyangalani and Magubike faunal assemblages point to a persistent MSA hominins treatment of fully-fleshed carcasses of the small and large-sized ungulates. The relative high proportions of cut marks and percussion marking on the long bone midshafts in relation to low tooth marking clearly show MSA hominins enjoyed primary (early) access to both meat and marrow likely involving active hunting or power scavenging (Potts and Shipman 1981; Bunn 1982, 1996, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; Domínguez-Rodrigo and Barba 2005, 2006, 2007a-c). Of note, the combined taphonomic and zooarchaeological results also do not document MSA hominins profound differences in carcasses processing intensity between the two sites. A series of two sample *t*-tests of the proportions of cut marks and percussion marks in the Loiyangalani and Magubike MSA faunal assemblages exhibit no significant differences statistically as detailed below:

i. Proportions of cut marks across major five anatomical segments of a complete carcass (small-sized: t=1.4611, p=0.2178; large-sized: t=0.1914, p=0.8576; and on all-sizes: t=0.2643, p=0.8046);

ii. Proportions of cut marks on high vs. low-meat bearing long bones (small-sized: t=6.3922, p=0.0988; large-sized: t=1.4541, p=0.3835; and on all-sizes: t=1.7624, p=0.3286);

iii. Proportions of cut marks on major six long bone midshaft fragments (small-sized: t=1.8057, p=0.1308; large-sized: t=0.7069, p=0.5112; and on all-sizes: t=1.4088, p=0.2179);

iv. Proportions of cut marks on axial bones (small-sized: t=1.0147, p=0.3440; large-sized: t=1.5987, p=0.1539; and on all-sizes: t=1.836, p=0.1090).

v. Proportions of percussion marks on major six long bone midshaft fragments (small-sized: t=0.5845, p=0.584; large-sized: t=2.0514, p=0.0955; and on all-sizes: t=1.4422, p=0.2088).

vi. Proportions of percussion marks on high vs. low-marrow bearing long bones (small-sized: t=1.4608, p=0.3821; large-sized: t=1.4404, p=0.3863; and on all-sizes: t=1.5236, p=0.3698).

The results summarized above suggest persistent similarities in the butchery and carcasses processing. Besides, the occupants of both sites also extracted bone marrow in a consistent manner. Consequently, findings support the behavioral interpretations that

MSA hominins at the Loiyangalani open-air site and Magubike rockshelter processed the hunted prey in broad similar ways and by extension had similar capabilities in prey acquisition strategies. Besides, although the sample is small, fish and tortoise remains in the Loiyangalani faunal assemblage also displayed cut marks suggesting regular exploitation of the aquatic and semi-aquatic resources by the MSA human group in the Serengeti National Park of Tanzania (Table 6.11).

Table 8.4. Percentages of Cut Marks, Percussion Marks and Tooth Marks on Long Bone Midshaft Sections in the FLK 22 *Zinj,* ST Site Complex, Loiyangalani and Magubike Rockshelter.

Nature of Data	Sample	Size	CM	PM	TM
Archaeological Data	FLK 22 *Zinj*	(1-2)	11.9	37.3	13.8
		(3-4)	17.2	20.4	9.7
		(1-4)	15.5	24.5	10.87
Archaeological Data	ST Site Complex (Peninj)	(1-2)	24.3	19.2	4
		(3-4)	23.5	22.2	7.4
		(1-4)	24.14	19.7	4.6
This Study	Loiyangalani	(1-2)	7.7	11.06	3.37
		(3-4)	13.39	18.52	7.12
		(1-4)	11.27	15.74	5.72
This Study	Magubike Rockshelter	(1-2)	3.44	25.48	1.02
		(3-4)	10.89	30.5	1.26
		(1-4)	7.36	28.12	1.12

CHAPTER 9

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

9.1. Introduction

This chapter summarizes the research findings. Integrating the results presented in Chapter 6 and 7 and discussed in details in Chapter 8, conclusions reached are also summarized and then compared to the Later Stone Age (LSA) backdrop. The implications for the MSA hominin foraging ecology and predatory behaviour within the broader context of the debate about the emergence of modern human behaviour are also underscored. The chapter winds up with suggestions on possible future Middle Stone Age (MSA) research directions in Tanzania.

9.2. Summary of the Findings and Conclusions

Understanding the nature and timing of the emergence of modern human behaviour for a long time has been one of the essential objectives of archaeologists. The African MSA period that date in most sites between 300 and 30 kya has played a crucial role in the debate. Consequently, numerous archaeological research have been conducted aimed at addressing the manifestations of modern behaviour that provided added advantages to anatomically modern humans (*Homo sapiens)* over other indigenous hominin populations as they competed for the same resources and their eventual ability to replace them outside the African continent (Nitecki and Nitecki 1987; Mellars and Stringer 1989; Mellars et al. 2007; McBrearty and Brooks 2000; Henshilwood and Marean 2003; Hovers and Kuhn 2006; Hublin and McPherron 2009; Hublin and Richards 2009; Klein 2009; Clark and Speth 2013). Nevertheless, much of our current understanding of the MSA hominins foraging economies has relied heavily on the models developed from the cave sites along the southern Africa coast. As underscored in Chapter 1, the models have mostly characterized the overall foraging economy of the MSA hominins as being less efficient at hunting the large-sized, dangerous and prime-adult prey as well as exploitation of the aquatic and avian resources (Klein 1975, 1976, 1977, 1978, 1979, 1981, 1982, 1987, 1989, 2000, 2008, 2009). They have been also portrayed as passive scavengers of the carnivore defleshed carcasses only to enjoy scraps of meat and bone marrow surviving (Binford 1981, 1984, 1985, 1987, 1991; Binford et al. 1988). Some archaeologists have also passionately argued that efficient hunting of the ungulates, as well as efficient exploitation of the aquatic and avian resources, is a hallmark of their LSA successors (Klein and Cruz-Uribe 1984, 1996, 2000; Steele and Klein 2009).

As shown in Chapter 1, the East African region is also one of the most critical areas for the study of the transition from the Middle to the Later Stone Age (Clark 1988; Mehlman 1989; Tryon and Faith 2013; Willoughby 2007; Klein 2009). Accordingly, the region is of great importance to the study of MSA hominins past lifeways. However, research on MSA hominin foraging ecology from this area is still scanty. Faunal assemblages dating to the MSA period subjected to detailed taphonomic and zooarchaeological analyses are also still few and far between (Marean 1996; Assefa 2002, 2006; Marean and Assefa 2005; Thompson 2005; Collins 2009). This is mostly attributed to the absence of long intact archaeological sites rich in organic materials (Marean 1990b; Marean and Assefa 2005; Steele and Klein 2009). Accordingly, information on MSA hominin foraging ecology in Tanzania is also still quite limited.

The renewed rounds of archaeological excavations at the Loiyangalani open-air site in the Serengeti National Park and Magubike rockshelter in Iringa Region have unearthed new large faunal assemblages that provide an opportunity to investigate MSA hominins foraging economies in Tanzania (Tables 5.1, 5.2, 8.2; Figure 1.2). The recent excavations at Loiyangalani were initiated in 2003 and continued until 2005 and at Magubike rockshelter were conducted in 2012. Based on the taphonomic and zooarchaeological results presented in Chapter 6 and 7 and discussed in details in Chapter 8, the current study came up with the following conclusions summarized below.

Taphonomically, the MSA faunal assemblages analyzed consisting of approximately 10,000 specimens were well-preserved mainly attributed to the soil chemistry at Loiyangalani and nature of the site at Magubike rockshelter (Table 8.2; Figures 6.3 and 7.3). Bone weathering profiles are relatively equivalent in both faunal assemblages, and the majority of the specimens fall below stage 2 (Tables 6.1, 7.1; Figures 6.6, 7.5 and 8.1). Specimens in high weathering profile were also present but in relatively very low proportions. Considerable numbers of specimens were also noted to be affected by root-etching (mostly at Loiyangalani) and concretions (mainly at Magubike). However, the combined taphonomic and zooarchaeological results demonstrate post-discard attritional taphonomic processes have overall minimally affected the faunal assemblages (Table 8.1). The degree of postdepositional attrition of the faunal assemblages as measured by the fragmentation of the small compact bones is also low at both sites (Tables 6.2 and 7.2). Results have also demonstrated MSA hominins played the key role in modification and accumulation of the faunal assemblages and carnivores played a marginal role.

Zooarchaeological results detailed in Chapter 6 and 7 demonstrate MSA hominins at Loiyangalani and Magubike exploited a broad spectrum of taxa. Bovids that are also typically numerous in most Plio-Pleistocene sites in East Africa constituted the bulk of the taxa exploited. Suids which are aggressive prey and equids were also exploited but in relatively small proportions. Fish, tortoises, and birds also supplemented as the source of extra meat and fat. Taphonomical and zooarchaeological results also indicate MSA hominins preferentially focused their efforts much more on the procurement of the large-sized (size 3-4) bovids which provided most of the source of calories. The strategic location of both sites afforded the MSA hominins both with high encounters and lower search costs of the large-sized ungulates especially during heightened dry seasons and during the wildlife migration in the Serengeti National Park (Maddock 1979; McNaughton 1988, 1990; Marean 1997; Wakibara 2012; Bird et al. 2009; Holdo et al. 2011). Overall, there appears to be a greater focus on the exploitation of the medium-sized ungulates (size 3 bovids) at both sites as measured both by the NISP and MNI counts as well by the overall anthropogenic surface modifications inflicted on their bone fragments (Tables 6.5, 6.12, 7.5 and 7.12). Frequently hunted prey also included size 4 bovids.

Small-sized (size 1-2) animals were also exploited at both sites to maximize the foraging net return rates, but only in relatively small quantities (Tables 6.3, 6.5, 7.3, 7.5 and 8.3). These were added in the broadening diet breadth especially when the encounter of the large-sized (size 3-4) bovids over the landscape declined (Stephens and Krebs 1986; Bettinger 1991; Kelly 2007; Stiner and Munro 2002; Ugan 2005a, b; Bird et al. 2009; Broughton et al. 2011). The procurement of hares (*Lepus capensis*), which are fastmoving prey at Magubike rockshelter undoubtedly, needed considerable technological investment including the use of snares or nets to capture them (Madsen and Schmitt 1998; Lupo and Schmitt 2005; Stiner et al. 1999, 2000; Ugan 2005b; Wadley 2010). Successful hunting of the ungulates also necessitated developed hunting techniques and active cooperation of several hunters, a trait that is mostly correlated to the modern human behavioral complexity (Isaac 1971, 1978; Behrensmeyer 1987; Hayness 1988; Driver 1990, 1995; Marean 1997; Winterhalder 1997; Alvard 2001; Lupo and O'Connell 2002; Stiner et al. 2009). The same trait also has been reported for the Neanderthals.

With regards to the overall age structure of the hunted prey, there is also apparent evidence that MSA hominins mostly foraged on the prime-aged adults (Tables 6.10 and 7.10). Despite the limited number of the skeletal parts that could be aged for the state of fusion, the proportions of the prime-adults are above 70% at both sites. The overall estimates of the juveniles do not exceed 20% as measured both by NISP and MNI counts. Careful section of the large-sized ungulates and prime-adult individuals was crucial at Loiyangalani and Magubike to maintain the high foraging returns for survival, which is universally associated with manifestations of modern human behaviour (Kelly 2007; Stiner et al. 1999, 2000).

The upper appendicular limb bones (ULB and ILB) and axial bones typically rich in nutritional values dominate skeletal part representations at both sites and bones from the cranial and lower limb bones (LLB) are less abundant (Tables 6.3, 6.6, 7.3 and 7.6). Skeletal part abundances for both small and large-sized carcasses are also positively correlated against their economic usefulness (Figures 6.11 and 7.7). The main transport strategy used at both sites was mainly the "unbiased strategy" that involves long distance transport of the carcass parts in direct correlation to their food economic utility (Binford 1978, 1981; Metcalfe and Jones 1988; Faith and Gordon 2007; Faith et al. 2009). The evenness indices also demonstrate MSA hominins transported complete or nearly complete carcasses from the butchery sites (Tables 6.7 and 7.7). Of note, the gross skeletal part representations at both sites do not mirror the Klasies River MSA faunal assemblage whereby the "head-and-foot" elements dominated the profile (Binford 1984). Skeletal part abundances as measured by %MAU are also comparatively more complete for the small and large-sized animals at both sites (see Figures 6.10 and 7.6).

Regarding the overall carcasses processing intensity, human-induced surface modifications resulting from meat retrieval and bone marrow harvesting are also abundant in both faunal assemblages (Tables 6.11-6.17 and 7.11-7.18). Overall cut marks were more plentiful in the Loiyangalani faunal assemblage by 10%, and Magubike preserved relatively fewer cut marks by 8%. Large-sized (size 3-4) carcasses also exhibited relatively high incidences of the cut marks bearing specimens. Distribution of cut marks on the major six long bones demonstrates are also more plentiful on the upper appendicular limb bones (ULB and ILB) that are typically the high-meat bearing and less frequent on the lower limb bones (LLB) that are none-meaty bearing bones (Tables 6.13 and 7.13; Figures 6.13, 6.14, 7.9 and 7.10). The results also suggest MSA hominins at both sites more often had primary (early) access to the upper appendicular limb bones to extract the edible resources (meat and marrow) than to the lower limb bones.

The proportions of cut marks relative to the tooth marks on the "hot zones" of the upper appendicular limb bones (humerus, femur, tibia, and radius) and axial bones that often exhibit complete lack of flesh scraps post-large carnivore consumption are also notably high. Accordingly, for a normal wisdom, MSA hominins at Loiyangalani and Magubike would have no genuine economical foraging motivation to inflict cut marks on the completely exposed and meatless sections on the long bones (i.e. the "hot zones") and axial elements in such high proportions (Tables 6.21 and 7.22). Consequently, such an attempt would just dull the cutting edges of the stone tools (Bunn 2001, 2007; Pickering and Domínguez-Rodrigo 2006; Pickering et al. 2008). The proportions of cut marks on long bone midshaft fragments at both sites compared to experimental and ethnoarchaeological simulations also clearly show MSA hominins had primary (early) success to fully-fleshed carcasses of both small (size 1-2) and large-sized (size 3-4) ungulates through active hunting or confrontational scavenging involving some aggressive driving away of the primary predators (Bunn 1981, 1982, 1996, 2001, 2007; Bunn and Kroll 1986; Bunn and Ezzo 1993; O'Connell et al. 1988b; Domínguez-Rodrigo 1997a-c, 2002; Domínguez-Rodrigo and Barba 2005, 2006, 2007a-c).

Fragmentation of the long bones at Loiyangalani and Magubike also indicates MSA hominins intensively extracted them for marrow (Tables 6.14-6.16 and 7.14-7.16). Overall Magubike has more hammerstone percussion marks bearing skeletal parts by approximately 28% and Loiyangalani has relatively less frequent only by 16% (see Tables 6.11, 6.15, 7.11, 7.15 and 8.4). The results also suggest marrow extraction was fairly intensive at Magubike rockshelter compared to the Loiyangalani site in the Serengeti National Park. Percussion marks on long bones were consistently imparted on their midshaft sections that also suggest MSA hominins had access to all the long limb bones available at both sites (Tables 6.15 and 7.15). The percentages of percussion marks on midshaft fragments in both faunal assemblages also fall within the range of variation reported both in the hammerstone-only and hammerstone-to-carnivore experimental simulations samples and subsamples (Tables 5.5, 6.15, 7.15 and 8.4).

As remarked above carnivore-induced surface modifications recorded are less common in both faunal assemblages (Tables 6.18, 7.19; Figures 6.17 and 7.12). The gross estimates of the carnivore tooth marks do not exceed 6%, which also suggest they played a minor role in both modification and accumulation of the faunal assemblages. Very few specimens bearing rodents gnaw marks were also noted. As detailed in Tables 6.11, 6.21, 7.11 and 7.22 above there are also more cut marks than tooth marks on the axial elements in both faunal assemblages, which also suggest MSA hominins butchered relative intact carcasses before carnivore intervention rather than scavenged scraps of meat from them. Besides, tooth marks on the long bone midshaft fragments are also clearly below the assemblage mean percentages expected in the carnivore first foraging scenarios and suggest had secondary (late) access to the carcass parts at both sites (see Tables 6.20, 7.21, 8.4; Figures 6.18 and 7.13).

9.3. Implications for MSA hominin Foraging Ecology and Predatory Behaviour

The new taphonomic and zooarchaeological results summarized above permit to make a firm inference regarding both MSA hominin foraging ecology and predatory behaviour in Tanzania the implications of which is also accentuated below. The MSA faunal assemblages considered for this study were large and well-preserved as remarked above. Taphonomic and zooarchaeological results have implicated MSA hominins as the key taphonomic agent in both modification and accumulation of the faunal assemblages. The present study has also explicitly shown that the MSA hominins at the Loiyangalani site and Magubike rockshelter exploited a wide diversity of taxa mainly large-sized and prime-aged adult ungulates, which are typically the high-yield/high-ranked prey items and often preferentially transported their high-meat and marrow bearing long limb bones. A broad range of the small-sized animals was also exploited in the broadening diet breadth when the encounters of the high-yield/high-ranked prey declined. The diversity of prey, relative abundance of the large-sized animals and the inclusions of the small, quick, and hard to capture prey such as hare, bird as well as fish and tortoise as supplementary food items, evidently suggest an orientation that is more consistent with the expansion of the diet breadth (Stiner et al. 1999, 2000; Kelly 2007). MSA hominins at Magubike rockshelter also possibly exploited the large land snail shells (Lubell 2004; Willoughby 2012a).

There is no compelling quantitative evidence in both archaeological faunal assemblages to explicitly implicate MSA hominins as ineffective hunters and passive scavengers of the marginal scraps of meat and bone marrow that frequently survive carnivore consumption. As remarked in Chapter 8 above, the relatively high proportions of cut marks relative to tooth marks on both the axial bones and the “hot zones” of the upper appendicular limb bones (ULB and ILB) cannot be explained to result from the MSA hominins retrieval of the marginal scraps of meat that survived carnivore consumption at the Loiyangalani site and Magubike rockshelter. Only carnivore secondary (late) access to the hominin-defleshed axial and upper appendicular limb bones (ULB and ILB) can explain the proportions of tooth marks at both sites (see Tables 6.13, 6.20, 6.21, 7.13, 7.21and 7.22). To retaliate, the fact that very few high marrow-bearing long limb bones survived intact make the hypothesis that MSA hominins routinely scavenged the carnivore ravaged carcasses only to enjoy bone marrow also totally implausible at both sites (Tables 5.5, 6.14-6.16, 7.14-7.16; Figures 6.15, 6.20-6.22 and 7.14-7.16). Besides, presence of long bone fragments bearing percussion marks in such relatively high proportions also cannot be contended to have resulted from the carnivores transporting long bone fragments bearing percussion marks to the Loiyangalani site and into Magubike rockshelter (Tables 5.5, 6.14, 6.15, 7.14, 7.15 and 8.4).

As elaborated in details in the preceding two chapters, the percentages of cut marks and percussion marks on long bone midshafts at both sites are consistent with the experimental and ethnoarchaeological datasets that simulate hominin primary (early) access to the high meat-and-marrow bearing long limb bones (Tables 5.5, 6.13-6.15, 7.13-7.15, 8.4). On the other hand, percentages of tooth marks in both faunal assemblages are more consistent with the experimental studies that simulate carnivore secondary (late) access to the hominin defleshed and demarrowed bone fragments (Tables 5.5, 6.20, 7.21; Figures 6.18 and 7.13). Consequently, ineffective hunting and passive scavenging modes of meat acquisition unequivocally do not appear to be an explanation for the MSA hominins predatory behaviour at the Loiyangalani site and Magubike rockshelter.

New findings from the Loiyangalani site and Magubike rockshelter support the view that MSA hominins effectively hunted the large-sized (size 3-4) ungulates, aggressive prey, prime-adult individuals, and passive scavenging of the carnivore ravaged carcasses was not a fundamental part of their adaptive behavioral repertoire. Results from several other MSA faunal assemblages in sub-Saharan sites such as at Klasies River, Sibudu, Blombos, Die Keller Cave 1, Porc-Epic cave have also recently shown MSA hominins successfully hunted large-sized, dangerous prey, and prime adults (Milo 1994, 1998; Maren and Assefa 1999, 2005; Marean et al. 2000; Assefa 2002, 2006; Faith 2008, 2011a, b; Thompson 2008, 2010; Thompson and Henshilwood 2011; Clark 2009; Dusseldorp 2010, 2012). In fact, numerous studies of faunal assemblages in Eurasia have also confirmed effective hunting capacities for the MP hominins such as at Misliya, Hayonim cave, and Gesher Benot Ya'agov (Gaudzinski and Roebroeks 2000; Speth and Tchernov 2002, 2007; Stiner 2005; Adler et al. 2006; Adler and Bar-Oz 2009; Yeshrun et al. 2007; Rabinovich et al. 2008; Clark and Speth 2013).

The possibility for the MSA hominins passive scavenging of the carcasses resulting from natural deaths, drowning or abandoned by carnivores when the opportunities presented themselves as part of the flexible foraging adaptation cannot be entirely ruled out at both sites. However, overall it appears passive scavenging of the carnivore ravaged carcasses was not a strategy practiced on a regular basis. Both aggressive and passive scavenging modes of meat acquisition are also well documented for the modern hunter-gatherers as part of their flexible foraging strategy (Bunn et al. 1988; Bunn and Kroll 1986; Bunn 1993; O'Connell et al. 1988a, b, 1992; Capaldo and Peters 1995). Nevertheless, passive scavenging by the modern hunter-gatherers of the carcasses hunted and defleshed by other predators frequently takes place in the contexts of hunting (Villa and Lenoir 2009:61).

The MSA hominins at the Loiyangalani and Magubike appear to have possessed considerable long-term, in-depth knowledge of their territories, high adaptability, took full advantage of the local resources availability, and distribution over the landscape (Marean 1997; Kelly 2007; Bird et al. 2009). Accordingly, MSA hominin foraging ecology in Tanzania appears to be broadly consistent with those documented for the LSA faunal assemblages in sub-Saharan Africa. Gaudzinski-Windheuser and Niven (2009) recent comprehensive analyses of the MP and UP faunal assemblages in Eurasia also have found the subsistence behaviour was relatively similar between the MP and the earliest UP sites.

9.4. Recommendations for Future MSA Research Directions

Results from this study provide a basis for future MSA research in Tanzania. It is anticipated the conclusions reached in this study will spark more detailed inter-sites and possibly diachronic comparative studies at other sites with the main objective to expand the understanding of MSA hominins foraging economies and land use patterns. Of note, the present study also maintains that results from the two faunal assemblages cannot be taken as exclusive representative of the MSA hominin foraging ecology in Tanzania and calls the approach employed in this study to be expanded. Results from this study may mirror the local situations at the respective sites and the areas considered. The following further research topics are equally viable and encouraged.

- Examine more MSA faunal assemblages from sealed archaeological deposits by expanding the focus beyond the Loiyangalani site and Magubike rockshelter. The approach adopted in this study mostly guided by the diet breadth model and published experimental and ethnoarchaeological interpretive frameworks appear to be satisfactory;
- Future studies of the MSA archaeological assemblages may also look into detailed chronologies, pay attention to hominin economic behaviour as mirrored

against the high-resolution climatic records, ecological conditions and social parameters ideally spanning long archaeological sequences;

- There appears to be an occupation hiatus under the overhang at Magubike rockshelter for the LSA deposits (Figures 3.7 and 5.3). Previous studies of the lithic assemblages at the site have suggested a possible mix of the LSA and MSA materials (see Biitner et al. 2007:64; Alexander 2010:60-61; Willoughby 2012b:113). Werner and Willoughby (2017: 257), have also recently suggested the LSA may be are mixed with the Iron Age materials or have been washed out by the water action. Future works at the Magubike rockshelter certainly should consider the need to verify these tentative hypotheses. However, skeletal part representation and maximum lengths of faunal specimens do not support fluvial interferences of the MSA below and IA faunal assemblages from the top of the archaeological sequence. It is hypothesized by this study probably Magubike rockshelter went deserted during the LSA period for the reasons not yet explicitly known.
- Future research can also examine the spatial distribution of discrete hominin activity areas at Magubike rockshelter. This can be achieved by scrutinizing the distribution of the artefacts and classes at the site and the areas surrounding the rockshelter.

References Cited

Abe, Y., Marean, C.W., Nilssen, P.J., Assefa, Z., Stone, E.C., 2002. The analysis of cutmarks on archaeofauna: a review and critique of quantification procedures, and a new image-analysis GIS approach. *American Antiquity* 67(4): 643-663.

Adelsberger, K.A., Wirth, K.R., Mabulla, A.Z.P., Bowman, D.C., 2011. Geochemical and mineralogic characterization of Middle Stone Age tools of Laetoli, Tanzania, and comparisons with possible source materials. In: Harrison, T. (Ed.), *Paleontology and Geology of Laetoli: Human Evolution in Context. Geology, Geochronology, Paleoecology and Paleoenvironment*. Volume 1. Springer, Dordrecht, pp. 143-165.

Adler, D.S., Bar-Oz, G., 2009. Seasonal patterns of prey acquisition and inter-group competition during the Middle and Upper Palaeolithic of the Southern Caucasus. In: Hublin, J.-J., Richards, M.P. (Eds.), *The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence.* Springer, Dordrecht, pp. 127-140.

Adler, D.S., Bar-Oz, G., Belfer-Cohen, A., Bar-Yosef, O., 2006. Ahead of the game: Middle and Upper Palaeolithic hunting behaviours in the southern Caucasus. *Current Anthropology* 47(1): 89-118.

Aiello, L., Wheeler, P., 1995. The expensive-tissue hypothesis: the brain and digestive system in human and primate evolution. *Current Anthropology* 36: 199-221.

Aitken, M.J., Stringer, C.B., Mellars, P.A., 1992. The origin of modern humans and the impact of chronometric dating. *Philosophical Transactions: Biological Sciences* 337B(1280): 125-250.

Alexander, K.V., 2010. A typological and technological analysis of stone artifacts from the Magubike archaeological site, Iringa Region, southern Tanzania. MA thesis, University of Alberta.

Aluko, F.A., Salako, A.E., Ngere, L.O., Eniolorunda, O.O., 2015. Grasscutter: a review of the habitat, feeds and feeding, behavior and economic importance. *American Journal of Research Communication* 3(9): 96-107.

Alvard, M.S., 2001. Mutualistic hunting. In: Stanford, C.B., Bunn, H.T. (Eds.), *Meat-Eating and Human Evolution.* Oxford University Press, Oxford, pp. 261-278.

Ambrose, S.H., 1998. Chronology of the Later Stone Age and food production in East Africa. *Journal of Archaeological Science* 25: 377-392.

Andrews, P., 1995. Experiments in taphonomy. *Journal of Archaeological Science* 22: 147-153.

Andrews, P., 1990. *Owls, Caves and Fossils.* University of Chicago Press, Chicago.

Andrews, P., Cook, J., 1985. Natural modifications to bones in a temperate setting. *Man* 20(4): 675-691.

Aouadi-Abdeljaouad, N., Belhouchet, L., 2009. Middle Stone Age in Tunisia: present status of knowledge and recent advances. In: Hublin, J-J., McPherron, S. (Eds.), *Modern Origins: A North African Perspective*. Springer, Dordrecht, pp. 143-156.

Assefa, Z., 2006. Faunal remains from Porc-Epic: paleoecological and zooarchaeological investigations from a Middle Stone Age site in southeastern Ethiopia. *Journal of Human Evolution* 56(1): 1-26.

Assefa, Z., 2002. Investigation of faunal remains from Pock-Epic: a Middle Stone Age in southeastern, Ethiopia. PhD dissertation, State University of New York at Stony Brook.

Ayala, F. J., 1995. The myth of Eve: molecular and human origins. *Science* 270(5244): 1930-1936.

Badenhorst, S., Plug, I., 2011. Unidentified specimens in zooarchaeology. *Palaeontologia africana* 46: 89-92.

Bandelt, H-J., Macaulay, V., Richards, M. (Eds,). 2006. *Human Mitochondrial DNA and the Evolution of Homo sapiens.* Springer, Dordrecht.

Barba, R., Domínguez-Rodrigo, M., 2005. The taphonomic relevance of the analysis of bovid long limb bone shaft features and their application to element identification: study of bone thickness and morphology of the medullary cavity. *Journal of Taphonomy* 3: 29-42.

Barham, L.S., 2002. Backed tools in Middle Pleistocene central Africa and their evolutionary significance. *Journal of Human Evolution* 43: 585-603.

Bar-Oz, G., 2004. *Epipaleolithic Subsistence Strategies: A Zooarchaeological Perspective.* Brill Academic Publisher, Boston.

Bar-Oz, G., Dayan, T., 2003. Testing the use of multivariate inter-site taphonomic comparisons: the faunal analysis of Hefzibah in its Epipaleolithic cultural context. *Journal of Archaeological Science* 30: 885-900.

Bar-Oz, G., Munro, N.D., 2007. Gazelle bone marrow yields and Epipaleolithic carcass exploitation strategies in the southern Levant. *Journal of Archaeological Science* 34: 946-956.

Bar-Oz, G., Munro, N.D., 2004. Beyond cautionary tales: a multivariate taphonomic approach for resolving equifinality in zooarchaeological studies. *Journal of Taphonomy* 2(4): 201-220.

Bar-Yosef, O., 2007. The archaeological framework of the Upper Paleolithic revolution. *Diogenes* 214: 3-18.

Bar-Yosef, O., 2002. The Upper Paleolithic revolution. *Annual Review of Anthropology* 31: 363-93.

Bar-Yosef, O., 1998. On the nature of transitions: the Middle to Upper Paleolithic and the Neolithic Revolution. *Cambridge Archaeological Journal* 8(2): 141-163.

Bar-Yosef, O., Vandermeersch, B., Arensburg, B., Belfer-Cohen, A., Goldberg, P., Laville, H., Meignen, L., Rak, Y., Speth, J. D., Tchernov, E., Tillier, A.-M., Weiner, S., 1992. The excavations in Kebara Cave, Mt. Carmel. *Current Anthropology* 33: 497-550.

Barrett, S.R., 2000. *Anthropology: A Student's Guide to Theory and Method.* University of Toronto Press, Toronto.

Bartram, L.E., 1993. An ethnoarchaeological analysis of Kua San (Botswana) bone food refuse. PhD dissertation, University of Wisconsin Madison.

Bartram, L.E., Marean, C.W., 1999. Explaining the ''Klasies Pattern'': Kua ethnoarchaeology, the Die Kelders Middle Stone Age archaeofauna, long bone fragmentation and carnivore ravaging. *Journal of Archaeological Science* 26: 9-29.

Bartram, L.E., Kroll, E.M., Bunn, H.T., 1991. Variability in camp structure and bone food refuse patterning at Kua San hunter-gatherer camps. In: Kroll, E.M., Price, T.D. (Ed.), *The Interpretation of Spatial Patterns in Stone Age Archaeological Sites*. Plenum Press, New York, pp. 77-148.

Basell, L.S., 2008. Middle Stone Age (MSA) site distributions in Eastern Africa and their relationship to Quaternary environmental change, refugia and the evolution of *Homo sapiens. Quaternary Science Reviews* 27: 2484-2498.

Bayham, F.E., 1979. Factors influencing the archaic pattern of animal exploitation. *The Kiva* 44: 219-235.

Behrensmeyer, A.K., 1991. Terrestrial vertebrate accumulations. In: Allison, P.A., Briggs, D.E.G. (Eds.), *Taphonomy: Releasing the Data Locked in the Fossil Record.* Plenum Press, New York, pp. 291-335.

Behrensmeyer, A.K., 1987. Taphonomy and hunting. In: Nitecki, M.H., Nitecki, D.V. (Eds.), *The Evolution of Human Hunting*. Plenum Press, New York, pp. 423-450.

Behrensmeyer, A.K., 1982. Time resolution in fluvial vertebrate assemblages. *Paleobiology* 8(3): 211-227.

Behrensmeyer, A.K., 1978. Taphonomic and ecologic information from bone weathering. *Paleobiology* 4(2): 150-162.

Behrensmeyer, A.K., 1975a. The taphonomy and paleoecology of Plio-Pleistocene vertebrate assemblages east of Lake Rudolf, Kenya. *Bulletin of the Museum of Comparative Zoology* 145: 473-574.

Behrensmeyer, A.K., 1975b. Vertebrate preservation in fluvial channels. *Paleogeography, Palaeoclimatology and Paleoecology* 63(1-3): 183-199.

Behrensmeyer, A.K., Kidwell, S.M., 1985. Taphonomy's contributions to paleobiology. *Paleobiology* 11(1): 105-119.

Behrensmeyer, A.K., Hill, A., 1980. *Fossils in the Making: Vertebrate Taphonomy and Paleoecology*. University of Chicago Press, Chicago.

Behrensmeyer, A.K., Gordon, K.D., Yanagi, G.T., 1986. Trampling as cause of bone surface damage and pseudo-cutmarks. *Nature* 319: 768-771.

Benazzi, S., Douka, K., Fornai, C., Bauer, C. C., Kullmer, O., Svoboda, J., Pap, I., Mallegni, F., Bayle, P., Coquerelle, M., Condemi, S., Ronchitelli, A., Harvati, K., Weber, G.W., 2011. Early dispersal of modern humans in Europe and implications for Neanderthal behavior. *Nature* 479: 525-528.

Bettinger, R.L., 1991. *Hunter-Gatherers: Archaeological and Evolutionary Theory.* Plenum Press, New York.

Biittner, K.M., 2011. Characterization of Middle and Later Stone Age lithic artifacts from two rockshelter sites in Iringa Region, southern Tanzania. PhD dissertation, University of Alberta.

Biittner, K.M., Bushozi, P.M., Willoughby, P.R., 2007. The Middle and Later Stone Age of the Iringa Region, southern Tanzania: an introduction. *Nyame Akuma* 68: 62-73.

Biittner, K.M., Sawchuk, E.A., Miller, J.M., Werner, J.J., Bushozi, P.M., Willoughby, P.R. 2017. Excavations at Mlambalasi Rockshelter: a terminal Pleistocene to recent Iron Age record in southern Tanzania. *African Archaeological Review* 34(2): 275-295.

Binford, L.R., 1991. The human revolution: behavioural and biological perspectives on the origins of modern humans. *Journal of Field Archaeology* 18: 111-115.

Binford, L.R., 1988. Fact and fiction about the *Zinjanthropus* floor: data, arguments and interpretations. *Current Anthropology* 29(1): 123-149.

Binford, L.R., 1987. Were there elephant hunters at Torralba? In: Nitecki, M.H., Nitecki, D.V. (Eds.), 1987. *The Evolution of Human Hunting.* Plenum Press, New York, pp. 47-105.

Binford, L.R., 1985. Human ancestors: changing views of their behaviour. *Journal of Anthropological Archaeology* 4(4): 292-327.

Binford, L.R., 1984. *Faunal Remains from Klasies River Mouth.* Academic Press, New York.

Binford, L.R., 1982. The archaeology of place. *Journal of Anthropological Archaeology* 1: 5-31.

Binford, L.R., 1981. *Bone: Ancient Men and Modern Myths.* Academic Press, New York.

Binford, L.R., 1978. *Nunamiut Ethnoarchaeology*. Academic Press, New York.

Binford, L.R., 1962. Archaeology as Anthropology. *American Antiquity* 28(2): 217-225.

Binford, L.R., Bertram, J.B., 1977. Bone frequencies and attritional processes. In: Binford, L.R. (Ed.), *For Theory Building in Archaeology*. Academic Press, New York, pp. 77-153.

Binford, S.R., Binford, L.R. (Eds.), 1968. *New Perspectives in Archaeology.* Aldine, Chicago.

Binford, L.R., Mills, M.G.L., Stone, N.M., 1988. Hyena scavenging behavior and its implications for the interpretation of faunal assemblages from FLK 22 (the *Zinj* Floor) at Olduvai Gorge. *Journal of Anthropological Archaeology* 7: 99-135.

Bird, D.W., Bliege-Bird, R.L., 2000. The ethnoarchaeology of juvenile foragers: shell fish strategies among Merian children. *Journal of Anthropological Archaeology* 19: 461-476.

Bird, D.W., O'Connell, J.F., 2006. Behavioural ecology and archaeology. *Journal of Archaeology Research* 14: 143-188.

Bird, D.W., Bliege-Bird, R.L., Codding, B.F., 2009. In pursuit of mobile prey: Martu hunting strategies and archeofaunal interpretation. *American Antiquity* 74(1): 3-29.

Blasco, R., 2008. Human consumption of tortoises at Level IV of Bolomor Cave (Valencia, Spain). *Journal of Archaeological Science* 35: 2839-2848.

Blome, M.W., Cohen, A.S., Tryon, T.A., Brooks, A.S., Russell, J., 2012. The environmental context for the origins of modern human diversity: a synthesis of regional variability in African climate 150,000-30,000 years ago. *Journal of Human Evolution* 62: 563-592.

Blumenschine, R.J., 1995. Percussion marks, tooth marks, and experimental determinations of the timing of hominid and carnivore access to long bones at FLK *Zinjanthropus,* Olduvai Gorge, Tanzania. *Journal of Human Evolution* 29: 21-51.

Blumenschine, R.J., 1991. Hominid carnivory and foraging strategies and the socio-economic function of early archaeological sites. *Philosophical Transactions: Biological Sciences* 334B(1270): 211-221.

Blumenschine, R.J., 1988. An experimental model of the timing of hominid and carnivore influence on archaeological bone assemblages. *Journal of Archaeological Science* 15: 483-502.

Blumenschine, R.J., 1987. Characteristics of an early hominid scavenging niche. *Current Anthropology* 28(4): 383-407.

Blumenschine, R.J., 1986a. Carcass consumption sequences and the archaeological distinction of scavenging and hunting. *Journal of Human Evolution* 15: 639-659.

Blumenschine, R.J., 1986b. Early hominid scavenging opportunities: implications of carcass availability in the Serengeti and Ngorongoro ecosystems. British Archaeological Report International Series 283, Oxford.

Blumenschine, R.J., Madrigal, T.C., 1993. Variability in long bone marrow yields of East African ungulates and its zooarchaeological implications. *Journal of Archaeological Science* 20: 555-587.

Blumenschine, R.J., Marean, C.W., 1993. A carnivore's view of archaeological bone assemblages. In: Hudson, J. (Ed.), *From Bones to Behaviour: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains.* Carbondale: Center for Archaeological Investigations, University of Southern Illinois, pp. 273-300.

Blumenschine, R.J., Selvaggio, M.M., 1991. On the marks of marrow bone processing by hammerstones and hyaenas: their anatomical patterning and archaeological implications. In: Clark, J.D. (Ed.), *Cultural Beginnings: Approaches to Understanding Early Hominid Life-ways in the African Savanna.* Dr Rudolf Habelt GMBH, Bonn, pp. 17-32.

Blumenschine, R.J., Selvaggio, M.M., 1988. Percussion marks on bone surfaces as a new diagnostic of hominid behavior. *Nature* 333: 763-765.

Blumenschine, R.J., Marean, C.W., Capaldo, S.D., 1996. Blind tests of inter-analyst correspondence and accuracy in the identification of cut marks, percussion marks, and carnivore tooth marks on bone Surfaces. *Journal of Archaeological Science* 23: 493-507.

Blumenschine, R.J., Cavallo, J.A., Capaldo, S.D., 1994. Competition for carcasses and early hominid behavioral ecology: a case study and conceptual framework. *Journal of Human Evolution* 27: 197-213.

Bocherens, H., Drucker, D.G., Medelaine, S., 2014. Evidence for a ^{15}N positive excursion in terrestrial foodwebs at the Middle to Upper Palaeolithic transition in south-western France: implications for early modern human palaeodiet and palaeoenvironment. *Journal of Human Evolution* 69: 32-43.

Boileau, A., 2013. Maya exploitation of animal resources during the Middle Preclassic Period: an archaeozoological analysis from Pacbitun, Belize. MA thesis. Trent University.

Bonnefille, R., 1984. Palynological research at Olduvai Gorge. *National Geographic Society Research Papers* 17: 227-243.

Bonnichsen R., Sorg, M.H. (Eds.), 1989. *Bone Modification*. Center for the Study of the First Americans, Orono.

Bower, J.R.F., 2005. On “modern behaviour” and the evolution of human intelligence. *Current Anthropology* 46(1): 121-122.

Bower, J.R.F., 1977. Prehistoric cultures of the Serengeti Plain, Tanzania. *Nyame Akuma* 10: 25.

Bower, J.R.F., 1973. Seronera: excavations at a Stone Bowl site in the Serengeti National Park, Tanzania. *Azania* 8: 71-104.

Bower, J.F.R., 1986. A survey of surveys: aspects of surface archaeology in Sub-Saharan Africa. *African Archaeological Review* 4: 21-40.

Bower, J.R.F., 1985. Excavation at the Loiyangalani site, Serengeti National Park. *National Geographic Research Reports* pp. 41-56.

Bower, J.R.F., 1981. Excavations at a Middle Stone Age site, Serengeti National Park, Tanzania. *Nyame Akuma* 18: 53-55.

Bower, J.R.F., Chadderdon, T.J., 1986. Further excavations of Pastoral Neolithic sites in Serengeti. *Azania* 21: 129-133.

Bower, J.R.F., Gogan-Porter, P., 1981. *Prehistoric Cultures of the Serengeti National Park: Initial Archaeological Studies of Undisturbed Ecosystem.* Papers in Anthropology, Iowa State University, Ames.

Bower, J.R.F., Mabulla, A.Z.P., 2013. Settling in: evidence of territorial exclusion in the Late Middle Stone Age of Northern Tanzania. *Studies in the African Past* 11: 7-24.

Bower, J.R.F., Mabulla, A.Z.P., Kobusiewicz, M., 2012. Loiyangalani: a cultural isolate in the Middle Stone Age of Northern Tanzania. *Studies in African Archaeology* 11: 479-491.

Bowler, J.M., Johnston, H., Oiley, J.M., Prescott, J.R., Roberts, R.G., Shawcross, W., Spooner, N.A., 2003. New ages for human occupation and climatic change at Mungo, Australia. *Nature* 421: 837-840.

Brain, C.K., 1981. *The Hunters or the Hunted: An Introduction to African Cave Taphonomy.* University of Chicago Press, Chicago.

Brain, C.K., 1980. Some criteria for the recognition of bone-collecting agencies in Africa caves. In: Behrensmeyer, A.K., Hill, A.P. (Eds.), *Fossils in the Making: Vertebrate Taphonomy and Palaeoecology*. University of Chicago Press, Chicago, pp. 108-130.

Branch, B. 2008. *Tortoise, Terrapins and Turtles of Africa.* Struik Publishers, Cape Town.

Bräuer, G., 2008. The origin of modern anatomy: by speciation or intraspecific evolution? *Evolutionary Anthropology* 17: 22-37.

Bräuer, G., 1989. The evolution of modern humans: a comparison of the African and non-African evidence. In: Mellars, P., Stringer, C.B. (Eds.), *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans.* Princeton University Press, Princeton, pp. 123-154.

Bräuer, G., Mehlman, M.J., 1988. Hominid molar from a Middle Stone Age level at Mumba rockshelter, Tanzania. *American Journal of Physical Anthropology* 75: 69-76.

Bräuer, G., Smith, F.H. (Eds.), 1992. *Continuity or Replacement.* A Balkema, Rotterdam.

Bright, A., Ugan, A., Hunsaker, L., 2002. The effect of handling time on subsistence technology. *World Archaeology* 34(1): 164-181.

Brooks, A.S., Helgren, D.M., Cramer, J.S., Franklin, A., Rink, W.J., Schwarcz, H., Smith, J.N.L., Stewart, K., Todd, N.E., Verniers, J., Yellen, J.E., 1995. Dating and context of three Middle Stone Age sites with bone points in the Upper Semliki Valley, Zaire. *Science* 268: 548-553.

Broughton, J.M., 1999. Resource depression and intensification during the Late Holocene San Francisco Bay: evidence from the Emeryville Shellmound. PhD dissertation, University of California, Berkeley.

Broughton, J.M., Grayson, D.K., 1993a. Diet breadth, adaptive change and the White Mountain faunas. *Journal of Archaeological Science* 20: 331-336.

Broughton, J.M., Grayson, D.K., 1993b. Diet breadth, Numic expansion, White Mountain faunas. *Journal of Archaeological Science* 30: 331-336.

Broughton, J.M., O'Connell, J.F., 1999. On evolutionary ecology, selectionist archaeology, and behavioural archaeology. *American Antiquity* 64(1): 153-165.

Broughton, J.M., Cannon, M.D., Bayham, F.E., Byers, D.A., 2011. Prey body size and ranking in zooarchaeology: theory, empirical evidence and applications from the northern Great Basin. *American Antiquity* 76(3): 403-428.

Bunn, H.T., 2007. Meat made us human. In: Ungar, P.S. (Ed.), *Evolution of the Human Diet*: *The Known, the Unknown, and the Unknowable.* Oxford University Press, Oxford, pp. 191-211.

Bunn, H.T., 2001. Hunting, power scavenging, and butchering by Hadza foragers and by Plio-Pleistocene *Homo*. In: Stanford, C.B., Bunn, H.T. (Eds.), *Meat-Eating and Human Evolution.* Oxford University Press, Oxford, pp. 199-218.

Bunn, H.T., 1996. Response to Rose and Marshall. *Current Anthropology* 37: 321-323.

Bunn, H.T., 1994. Early Pleistocene hominid foraging strategies along the ancestral Omo River at Koobi Fora, *Kenya. Journal of Human Evolution* 27: 247-266.

Bunn, H.T., 1993. Bone assemblages at base camps: a further consideration of carcass transport and bone destruction. In: Hudson. J. (Ed.), *From Bones to Behaviour: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*. Center for Archaeological Investigations, Occasional Paper No. 21. Southern Illinois University, Chicago, pp. 156-168.

Bunn, H.T., 1986. Patterns of skeletal representation and hominid subsistence activities at Olduvai Gorge, Tanzania and Koobi Fora, Kenya. *Journal of Human Evolution* 15: 673-690.

Bunn, H.T., 1983. Comparative analysis of modern bone assemblages from a San hunter-gatherer camp in the Kalahari Desert. In: Clutton-Brook, J., Grison, C. (Eds.), *Animals and Archaeology: Hunters and their Prey.* British Archaeological Research International Series 163, Oxford, pp. 143-148.

Bunn, H.T., 1982. Meat-eating and human evolution: studies on the diet and subsistence Patterns of Plio-Pleistocene hominids in East Africa. PhD dissertation, University of California, Berkeley.

Bunn, H.T., 1981. Archaeological evidence of meat-eating by Plio-Pleistocene hominids from Koobi Fora and Olduvai Gorge. *Nature* 291: 574-577.

Bunn, H.T., Ezzo, J.A., 1993. Hunting and scavenging by Plio-Pleistocene hominids: nutritional constraints, archaeological patterns and behavioral implications. *Journal of Archaeological Science* 20: 365-339.

Bunn, H.T., Kroll, E.M., 1986. Systematic butchery by Plio/Pleistocene hominids at Olduvai Gorge, Tanzania. *Current Anthropology* 27: 431-452.

Bunn, H.T., Bartram, L.E., Kroll, E.M., 1991. Variability in camp structure and food refuse patterning at Kua San camps. In: Kroll, E.M., Price, T.D. (Ed.), *The Interpretation of Spatial Patterns in Stone Age Archaeological Sites*. Plenum Press, New York, pp. 77-148.

Bunn, H.T., Bartram, L.E., Kroll, E.M., 1988. Variability in bone assemblage formation from Hadza hunting, scavenging, and carcass processing. *Journal of Anthropological Archaeology* 7: 412-457.

Burger, O., Hamilton, M.J., Walker, R., 2005. The prey as patch model: optimal handling of resources with diminishing returns. *Journal of Archaeological Science* 32: 1147-1158.

Bushozi, P.G.M., 2011. Lithic technology and hunting behavior during the Middle Stone Age in Tanzania. PhD dissertation, University of Alberta.

Bushozi, P.G.M., 2003. Middle Stone Age occurrence and Hominid behavioural patterns in West Lake Natron region, Northern Tanzania. MA thesis, University of Dar es Salaam.

Butler, V.L., 2000. Resource depression on the Northwest Coast of North America. *Antiquity* 74: 649-661.

Butler, V.L., Campbell, S.K., 2004. Resource intensification and resource depression in the Pacific Northwest of North America: a zooarchaeological review. *Journal of World Prehistory* 18(4): 327-404.

Byers, D.A., Ugan, A., 2005. Should we expect large game specialization in the Late Pleistocene? an optimal foraging perspective on early Paleoindian prey choice. *Journal of Archaeological Science* 32: 1624-1640.

Byers, D.A., Broughton, J.M., 2004. Holocene environmental change, artiodactyl abundances, and human hunting strategies in the Great Basin American. *Antiquity* 69: 235-256.

Cann, R.L., Stoneking, M., Wilson, A.C., 1987. Mitochondrial DNA and human evolution. *Nature* 325: 31-36.

Cannon, M.D., 2000. Large mammal relative abundances in Pithouse and Pueblo period archaeofaunas from southwestern New Mexico: resource depression among the Mimbres-Mogollon? *Journal of Anthropological Archaeology* 19: 317-347.

Capaldo, S.D., 1998. Simulating the formation of dual-patterned archaeofaunal assemblages with experimental control samples. *Journal of Archaeological Science* 25(4): 311-330.

Capaldo, S.D., 1997. Experimental determinations of carcass processing by Plio-Pleistocene hominids and carnivores at FLK 22 (*Zinjanthropus*), Olduvai Gorge, Tanzania. *Journal of Human Evolution* 33: 555-597.

Capaldo, S.D., 1995. Inferring hominid and carnivore behavior from dual-patterned archaeological assemblages. PhD dissertation, Rutgers University, New Brunswick.

Capaldo, S.D., Blumenschine, R.J., 1994. A quantitative diagnosis of notches made by hammerstone percussion and carnivore gnawing on bovid long bones. *American Antiquity* 59 (4): 724-748.

Capaldo, S.D., Peters, C.R., 1995. Skeletal inventories from wildebeest drowning at Lakes Masek and Ndutu in the Serengeti ecosystem of Tanzania. *Journal of Archaeological Science* 22: 385-408.

Caro, T.M., Durant, S.M. 1995. The importance of behavioural ecology for conservation biology: examples from studies of Serengeti carnivores. In: Sinclair, A.R.E., Arcese, P. (Eds.), *Serengeti II: Dynamics, Management and Conservation of an Ecosystem*. University of Chicago Press, Chicago, pp. 451-472.

Cavallo, J.A., Blumenschine, R.J., 1989. Tree-stored leopard kilts: expanding the hominid scavenging niche. *Journal of Human Evolution* 18: 393-399.

Cerling, T.E., Hay, R.L. 1986. An isotopic study of paleosol carbonates from Olduvai Gorge: *Quaternary Research* 25: 63-78.

Chami, F.A., 2007. Diffusion in the studies of the African past: reflections from new archaeological findings. *African Archaeological Review* 24: 1-14.

Chami, F.A., 2006. *The Unity of African Ancient History: 3000BC to AD 500.* E & D Publishers, Dar es Salaam.

Chami, F.A., 2005. Current archaeological research in mainland Tanzania. In: Mapunda, B.B.B., Msemwa, P. (Eds.), *Salvaging Tanzania's Cultural Heritage.* Dar es Salaam University Press, Dar es Salaam, pp. 81-89.

Chami, F.A., 1998. A review of Swahili archaeology. *African Archaeological Review* 15(5): 199-218.

Chami, R.A., Chami, F.A., 2001. Narosura pottery from the southern coast of Tanzania: first incontrovertible coastal Late Stone Age pottery. *Nyame Akuma* 56: 29-35.

Chase, P.G., 1989. How different was Middle Paleolithic subsistence? a zooarchaeological perspective on the Middle to Upper Paleolithic transition. In: Mellars, P., Stringer, C.B. (Eds.), *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans*. Edinburgh University Press, Edinburgh, pp. 321-337.

Chase, P.G., 1988. Scavenging and hunting in the Middle Paleolithic: the evidence from Europe. In: Dibble, H.L., Montet-White, A. (Eds.), *Upper Pleistocene Prehistory of Western Eurasia.* University of Pennsylvania, Philadelphia, pp. 225-232.

Chase, P.G., 1983. The use of animal resources in the Mousterian of Combe Grenal, France. PhD dissertation, University of Arizona.

Chittick, H.N. (Ed.), 1974. *Kilwa: An Islamic Trading City on the East African Coast.* British Institute in Eastern Africa, Nairobi.

Chittick, H.N., 1965. *A Guide to the Ruins of Kilwa with Some Notes on other Antiquities in the Region.* Government Press, Dar es Salaam.

Clark, J.D., 1989. The origins and spread of modern humans: a broad perspective on the African evidence. In: Mellars, P., Stringer, C.B. (Eds.), *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans*. Edinburgh University Press, Edinburgh, pp. 565-588.

Clark, J.D., 1988. The Middle Stone Age of East Africa and the beginnings of regional identity. *Journal of World Prehistory* 2(3): 235-305.

Clark, J.D., 1974. *Kalambo Falls Prehistoric Site.* Volume II. Cambridge University Press, Cambridge.

Clark, J.D., 1970. Interim report on the archaeology of Malawi, Rungwe and southern Rukwa regions. *Quaternalia* 13: 350-354.

Clark, J.D., 1950. *Stone Culture of Northern Rhodesia.* South African Archaeological Society, Cape Town.

Clark, J.L., 2009. Testing models on the emergence and nature of modern human behavior: Middle Stone Age fauna from Sibudu Cave (South Africa). PhD dissertation, University of Michigan.

Clark, J.L., Kandel, A.W., 2013. The evolutionary implications of variation in human hunting strategies and diet breadth during the Middle Stone Age of southern Africa. *Current Anthropology* 54(S8): S269-S287.

Clark, J.L., Plug, I., 2008. Animal exploitation strategies during the South African Middle Stone Age: Howiesons Poort and post-Howiesons Poort fauna from Sibudu Cave. *Journal of Human Evolution* 54: 886-898.

Clark, J.L., Speth, J.D. (Eds), 2013. *Zooarchaeology and Modern Human Origins: Human Hunting Behavior during the Later Pleistocene*. Springer, Dordrecht.

Cleghorn, N., Marean, C.W., 2007. The destruction of skeletal elements by carnivores: the growth of a general model for skeletal element destruction and survival in zooarchaeological assemblages. In: Pickering, T.R., Schick, K., Toth, N. (Eds.), *Breathing Life into Fossils: Taphonomic Studies in Honor of C.K. (Bob) Brain.* Stone Age Institute Press, Bloomington, pp. 37-66.

Cleghorn, N., Marean, C.W., 2004. Distinguishing selective transport and *in situ* attrition: a critical review of analytical approaches. *Journal of Taphonomy* 2(2): 43-67.

Clutton-Brook, J., Grison, C. (Eds.), 1983. *Animals and Archaeology: Hunters and their Prey.* British Archaeological Research International Series 163, Oxford.

Cohen, A., Serjeantson, D., 1996. *A Manual for the Identification of Bird Bones from Archaeological Sites*. Archetype Publications, London.

Cohen, A.S., Stone, J.R., Beuning, K.R.M., Park, L.E., Reinthal, P.N., Dettman, D., Scholz, C.A., Johnson, T.C., King, J.W., Talbot, M.R., Brown, E.T., Ivory, S.J., 2007. Ecological consequences of early late Pleistocene megadroughts in tropical Africa. *Proceedings of the National Academy of Sciences* 104(42): 16422-16427.

Cohen, P., 1996. Fitting a face to Ngaloba. *Journal of Human Evolution* 30(4): 373-379.

Cole, G.H., Kleindienst, M.R., 1974. Further reflections on the Isimila Acheulian. *Quaternary Research* 4: 346-355.

Cole, S., 1954. The prehistory of East Africa. *American Anthropologist* 56: 1026-1050.

Collins, B.R., 2009. An initial zooarchaeological analysis of Magubike and Mlambalasi: two archaeological sites from the Iringa Region of Southern Tanzania. MA thesis, University of Alberta.

Collins, B.R., Willoughby, P.R., 2010. The faunal analysis of Magubike and Mlambalasi, two MSA-LSA archaeological sites from Iringa District, Tanzania. *Journal of Taphonomy* 8(1): 33-68.

Conard, N.J., 2008. A critical view of the evidence for a southern African origin of behavioral modernity. *South African Archaeological Society Goodwin Series* 10: 175-179.

Conard, N.J., Bolus, M., 2003. Radiocarbon dating the appearance of modern humans and timing of cultural innovations in Europe: new results and new challenges. *Journal of Human Evolution* 44: 331-371.

Cordain, L., Eaton, S.B., Miller, J.B., Mann, N., Hill, K., 2002. The paradoxical nature of hunter-gatherer diets: meat-based, yet non-atherogenic. *European Journal of Clinical Nutrition* 56: S42-S52.

Coryndon, S.C., Gentry,W., Harris, J.M., Hooijer, D.A., Maglio, V.J., Howell, F.C., 1972. Mammalian remains from the Isimila Prehistoric Site, Tanzania. *Nature* 237: 292.

Crema, E., 1987. *Wahehe: A Bantu People.* Italian Missionary Press, Bologna.

Cruz-Uribe, K., 1991. Distinguishing hyena from hominid bone accumulations. *Journal of Field Archaeology* 18: 467-486.

Cruz-Uribe, K., 1988. The use and meaning of species diversity and richness in archaeological faunas. *Journal of Archaeological Science* 15: 179-196.

d'Errico, F., Henshilwood, C., Vanhaeren, M., Niekerk, K., 2005. *Nassarius kraussianus* shell beads from Blombos Cave: evidence for symbolic behaviour in the Middle Stone Age. *Journal of Human Evolution* 48: 3-24.

Dalton, R., 2007. War of words erupts over fossil dig. *Nature* 448: 12.

Day, M.H., Leakey, M.D., Magori, C., 1980. A new hominid fossil skull (LH 18) from Ngaloba Beds, northern Tanzania. *Nature* 284: 55-56.

Deacon, H.J., 1989. Late Pleistocene paleoecology and archaeology in Southern Cape, South Africa. In: Mellars, P., Stringer, C. (Eds.), *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans*. Edinburgh University Press, Edinburgh, pp. 547-564.

Deacon, J., 1966. An annotated list of radiocarbon dates for sub-Saharan Africa. *Annals of the Cape Provincial Museum* 5: 5-84.

Deino, A.L., McBrearty, S., 2002. ^{40}Ar/^{39}Ar dating of the Kapthurin Formation, Baringo, Kenya. *Journal of Human Evolution* 42: 185-210.

Diez-Martin, F., Domínguez-Rodrigo, M., Sanches, P., Mabulla, A.Z.P., Tarrino, A., Barba, R., Prendegast, M.E., Luque, L., 2009. The Middle to Later Stone Age technological transition in East Africa: new data from Mumba rockshelter Bed V (Tanzania) and their implications for the origin of modern human behavior. *Journal of African Archaeology* 7(2): 147-173.

Domínguez-Rodrigo, M., 2009. Are all Oldowan sites palimpsests? If so, what can they tell us about hominid carnivory? In: Hovers, E., Braun, D.R. (Eds.), *Interdisciplinary Approaches to the Oldowan.* Springer, Dordrecht, pp. 129-147.

Domínguez-Rodrigo, M., 2003. On cut marks and statistical inferences: methodological comments on Lupo & O'Connell (2002). *Journal of Archaeological Science* 30: 381-386.

Domínguez-Rodrigo, M., 2002. Hunting and scavenging by early humans: the state of the debate. *Journal of World Prehistory* 16(1): 1-54.

Domínguez-Rodrigo, M., 2001. A study of carnivore competition in riparian and open habitats of modern savannas and its implications for hominid behavioral modeling. *Journal of Human Evolution* 40: 77-98.

Domínguez-Rodrigo, M., 1999a. Flesh availability and bone modifications in carcasses consumed by lions: palaeoecological relevance in hominid foraging patterns. *Palaeogeography, Palaeoclimatology, Palaeoecology* 149: 373-388.

Domínguez-Rodrigo, M., 1999b. The study of skeletal part profiles: an ambiguous taphonomic tool for zooarchaeology. *Complutum* 10: 15-24.

Domínguez-Rodrigo, M., 1997a. A reassessment of the study of cut mark patterns to infer hominid manipulation of fleshed carcasses at FLK *Zinj* 22 site, Olduvai Gorge, Tanzania. *Trabajos de Prehistoria* 54(2): 29-42.

Domínguez-Rodrigo, M., 1997b. Meat-eating by early hominids at the FLK 22 *Zinjanthropus* site, Olduvai Gorge (Tanzania): an experimental approach using cut-mark data. *Journal of Human Evolution* 33: 669-690.

Domínguez-Rodrigo, M., 1997c. Testing meat-eating in early hominids: an analysis of butchery marks on defleshed carcasses. *Journal of Human Evolution* 12(3): 169-182.

Domínguez-Rodrigo, M., Barba, R., 2007a. Five more arguments to invalidate the passive scavenging version of the carnivore-hominid-carnivore model: a reply to Blumenschine et al. (2007a). *Journal of Human Evolution* 53: 427-433.

Domínguez-Rodrigo, M., Barba, R., 2007b. New estimates of tooth-mark and percussion-mark frequencies at the FLK *Zinjanthropus* level: the carnivore-hominid-carnivore hypothesis falsified (I). In: Domínguez-Rodrigo, M., Barba, R., Egeland, C.P. (Eds.), 2007. *Deconstructing Olduvai: A Taphonomic Study of the Bed I Sites*. Springer, Dordrecht, pp. 39-74.

Domínguez-Rodrigo, M., Barba, R., 2007c. The behavioral meaning of cut marks at the FLK *Zinj* level: the carnivore-hominid-carnivore hypothesis falsified (II). In: Domínguez-Rodrigo, M., Barba, R., Egeland, C.P. (Eds.), *Deconstructing Olduvai: A Taphonomic Study of the Bed I Sites*. Springer, Dordrecht, pp. 75-100.

Domínguez-Rodrigo, M., Barba, R., 2006. New estimates of tooth mark and percussion mark frequencies at the FLK *Zinj* site: the carnivore-hominid-carnivore hypothesis falsified. *Journal of Human Evolution* 50: 170-194.

Domínguez-Rodrigo, M., Barba, R., 2005. A study of cut marks on small-sized carcasses and its application to the cut-marked bones from small mammals at the FLK *Zinj* site. *Journal of Taphonomy* 3(3): 121-134.

Domínguez-Rodrigo, M., Organista, E., 2007. Natural background bone assemblages and their ravaging stages in Olduvai Bed I. In: Domínguez-Rodrigo, M., Barba, R., Egeland, C.P. (Eds.), 2007b. *Deconstructing Olduvai: A Taphonomic Study of the Bed I Sites*. Springer, Dordrecht, pp. 201-215.

Domínguez-Rodrigo, M., Pickering, T.R., 2003. Early hominid hunting and scavenging: a zooarchaeological review. *Evolutionary Anthropology* 12: 275-282.

Domínguez-Rodrigo, M., Piqueras, A., 2003. The use of tooth pits to identify carnivore taxa in tooth-marked archaeofaunas and their relevance to reconstruct hominid carcass processing behaviors. *Journal of Archaeological Science* 30: 1385-1391.

Domínguez-Rodrigo, M., Bunn, H.T., Yravedra, J., 2014. A critical re-evaluation of bone surface modification models for inferring fossil hominin and carnivore interactions through a multivariate approach: Application to the FLK *Zinj* archaeofaunal assemblage (Olduvai Gorge, Tanzania). *Quaternary International* 322-323: 32-43.

Domínguez-Rodrigo, M., Barba, R., Egeland, C.P. (Eds.), 2007a. *Deconstructing Olduvai: A Taphonomic Study of the Bed I Sites*. Springer, Dordrecht.

Domínguez-Rodrigo, M., Egeland, C.P., Barba, R., 2007b. The hunting-versus-scavenging debate. In: Domínguez-Rodrigo, M., Barba, R., Egeland, C.P. (Eds.), 2007b. *Deconstructing Olduvai: A Taphonomic Study of the Bed I Sites*. Springer, Dordrecht, pp. 11-22.

Domínguez-Rodrigo, M., Egeland, C.P., Barba, R., 2007c. The "physical attribute" taphonomic approach. In: Domínguez-Rodrigo, M., Barba, R., Egeland, C.P. (Eds.), *Deconstructing Olduvai: A Taphonomic Study of the Bed I Sites*. Springer, Dordrecht, pp. 23-32.

Domínguez-Rodrigo, M., Egeland, C.P., Pickering, T.R., 2007d. Equifinality in carnivore tooth marks and the extended concept of archaeological palimpsests: implications for models of passive scavenging by early hominids. In: Pickering, T.R., Schick, K., Toth, N. (Eds.), *Breathing Life into Fossils: Taphonomic Studies in Honor of C.K. (Bob) Brain.* Stone Age Institute Press, Bloomington, pp. 255-267.

Domínguez-Rodrigo, M., Mabulla, A.Z.P., Bunn, H.T., 2007e. Olduvai fossils need more than one research team. *Nature* 449: 281.

Domínguez-Rodrigo, M., Gidna, A., Yravedra, J., Musiba, C.A., 2012. A comparative neotaphonomic study of felids, hyenids and canids: an analogical framework based on long bone modification patterns. *Journal of Taphonomy* 10(3-4): 147-164.

Domínguez-Rodrigo, M., Alcalá, L., Luque, L., 2009. A taphonomic study of the T1 paleosurface in Type Section (Maritanane): the ST Site Complex. In: Domínguez-Rodrigo, M., Alcalá, L., Luque, L. (Eds.), *Peninj: A Research Project on Human Origins* (1995-2005). Oxbow Books, Oxford, pp. 73-108.

Domínguez-Rodrigo, M., M., de la Torre, I., Luque, L., Alcalá, L., Mora, R., Serrallonga, J., Medina, V., 2002. The ST Site Complex at Peninj, West Lake Natron, Tanzania: implications for early hominid behavioral models. *Journal of Archaeological Science* 29: 639-665.

Domínguez-Rodrigo, M., Mabulla, A.Z.P., Luque, L., Thompson, J.W., Rink, J., Bushozi, P.G.M., Diez-Martín, F., Alcalá, L., 2008. A new archaic *Homo sapiens* fossil from Lake Eyasi, Tanzania. *Journal of Human Evolution* 54: 899-903.

Driver, J.C., 1995. Social hunting and multiple predation. In: Campana, D.V. (Ed.), *Before Farming: Hunter–Gatherer Society and Subsistence.* MASCA Research Reports, vol. 12, Philadelphia, pp. 23-38.

Driver, J.C., 1990. Meat in due season: the tuning of communal hunts. In: Davis, L.B., Reeves, B.O.K. (Eds.), *Hunters of the Recent Past*. Unwin Hyman, London, pp. 11-33.

Dusseldorp, G.L., 2012. Studying prehistoric hunting proficiency: applying optimal foraging theory to the Middle Palaeolithic and Middle Stone Age. *Quaternary International* 252: 3-15.

Dusseldorp, G.L., 2010. Prey choice during the South African Middle Stone Age: avoiding dangerous prey or maximizing returns? *African Archaeological Review* 27: 107-133.

Dwyer, P.D., 1986. Hunt in New Guinea: some difficulties for optimal foraging theory. *Man* 20: 243-253.

Efremov, I.A., 1940. Taphonomy: a new branch of paleontology. *Pan-American Geologist* 74: 81-93.

Egeland, C.P., 2012. The use of bone surface modifications to model hominid lifeways during the Oldowan. In: Domínguez-Rodrigo, M. (Ed.), *Stone Tools and Fossil Bones: Debates in the Archaeology of Human Origins.* Cambridge University Press, Cambridge, pp. 80-114.

Egeland, C.P., 2007. Zooarchaeological and taphonomic perspective on hominid and carnivore interactions at Olduvai Gorge, Tanzania. PhD dissertation, Indiana University.

Enloe, J.G., 1993. Ethnoarchaeology of marrow cracking: implications for the recognition of prehistoric subsistence organization. In: Hudson. J. (Ed.), *From Bones to Behaviour: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains*. Center for Archaeological Investigations, Occasional Paper No. 21. Southern Illinois University, Chicago, pp. 82-97.

Eren, M.I., Durant, A.J., Prendergast, M., Mabulla, A.Z.P., 2014. Middle Stone Age archaeology at Olduvai Gorge, Tanzania. *Quaternary International* 322-323: 292-313.

Estes, R.D., 1991. *Behavior Guide to African Mammals.* University of California Press, California.

Eswaran, V., 2002. A diffusion wave out of Africa. *Current Anthropology* 43: 749-774.

Excoffier, L., Langaney, A., 1989. Origin and differentiation of human mitochondrial DNA. *American Journal of Human Genetics* 44: 73-85.

Faith, J.T., 2011a. Ungulate biogeography, statistical methods, and the proficiency of Middle Stone Age hunters. *Journal of Human Evolution* 60: 315-317.

Faith, J.T., 2011b. Ungulate community richness, grazer extinctions, and human subsistence behavior in southern Africa's Cape Floral Region. *Palaeogeography, Palaeoclimatology, Palaeoecology* 306: 219-227.

Faith, J.T., 2008. Eland, buffalo, and wild pigs: were Middle Stone Age humans ineffective hunters? *Journal of Human Evolution* 55: 24-36.

Faith, J.T., 2007. Changes in reindeer body part representation at Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 34: 2003-2011.

Faith, J.T., Gordon, A.D., 2007. Skeletal element abundances in archaeofaunal assemblages: economic utility, sample size, and assessment of carcass transport strategies. *Journal of Archaeological Science* 34: 872-882.

Faith, J.T., Behrensmeyer, A.K., 2006. Changing patterns of carnivore modification in a landscape bone assemblage, Amboseli Park, Kenya. *Journal of Archaeological Science* 33: 1718-1733.

Faith, J.T., Dominguez-Rodrigo, M., Gordon, A.D., 2009. Long-distance carcass transport at Olduvai Gorge? a quantitative examination of Bed I skeletal element abundances. *Journal of Human Evolution* 56: 247-256.

Feathers, J.K., 2016. Luminescence dating of sediments from Magubike Rockshelter, Tanzania. Report from the Luminescence Dating Laboratory, University of Washington, Seattle, Washington.

Feathers, J.K., Fusch, C.J., 2005. OSL dating of Loiyangalani River sediments, Serengeti National Park, Tanzania. Report from the Luminescence Dating Laboratory, University of Washington, Seattle, Washington.

Fernández-Jalvo, Y., Andrews, P., 2016. *Atlas of Taphonomic Identifications: 1001+ Images of Fossil and Recent Mammal Bone Modification*. Springer, New York.

Ferraro, J.V., 2007. Broken bones and shattered stones: on the foraging ecology of Oldowan hominins. PhD dissertation, University of California, Los Angeles.

Finch, J., Marchant, R., Mustaphi, C.J.C., 2016. Ecosystem change in the South Pare Mountain Bloc, Eastern Arc Mountains of Tanzania. *The Holocene* 27(6): 796-810.

Finch, J., Leng, M.J., Marchant, R., 2009. Late Quaternary vegetation dynamics in a biodiversity hotspot, the Uluguru Mountains of Tanzania. *Quaternary Research* 72: 111-122.

Fisher, J.W., 1995. Bone surface modifications in zooarchaeology. *Journal of Archaeological Method and Theory* 1(1): 7-68.

Frayer, D.W., 1997. Perspectives on Neanderthals as ancestors. In: Clark, G.A., Willermet, C.M. (Eds.), *Conceptual Issues in Modern Human Origins Research*. de Gruyter, New York, pp. 220-34.

Frison, G.C., Todd, L., 1986. *The Colby Mammoth Site: Taphonomy and Archaeology of a Clovis Kill in Northern Wyoming*. University of New Mexico Press, Albuquerque.

Galán, A.B., Domínguez-Rodrigo, M., 2013. An experimental study of the anatomical distribution of cut marks created by filleting and disarticulation of long bone ends. *Archaeometr*y 55: 1132-1149.

Galán, A.B., de Juana, S., Domínguez-Rodrigo, M., 2009. A new experimental study on percussion marks and notches and their bearing on the interpretation of hammerstone-broken faunal assemblages. *Journal of Archaeological Science* 36: 776-784.

Gaudzinski, S., 2006. Monospecific or species-dominated faunal assemblages during the Middle Palaeolithic in Europe. In: Hovers, E., Kuhn, S.L. (Eds.), *Transitions Before the Transition: Evolution and Stability in the Middle Palaeolithic and Middle Stone Age*. Springer, New York, pp. 137-147.

Gaudzinski, S., Roebroeks, W., 2000. Adults only. Reindeer hunting at the Middle Palaeolithic site Salzgitter Lebenstedt, Northern Germany. *Journal of Human Evolution* 38: 497-521.

Gaudzinski-Windheuser, S., Niven, L., 2009. Hominin subsistence patterns during the Middle and Late Paleolithic in Northwestern Europe. In: Hublin, J.-J., Richards, M.P. (Eds.), *The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence.* Springer, Dordrecht, pp. 99-111.

Gibbons, A., 2011a. A new view of birth of *Homo sapiens. Science* 331: 392-394.

Gibbons, A., 2011b. Who were the Denisovans? *Science* 333: 1084-1087.

Gidna, A., Kisui, A.B., Domínguez-Rodrigo, M., 2014. An ecological neo-taphonomic study of carcass consumption in Tarangire National Park (Tanzania) and its relevance for human evolutionary biology. *Quaternary International* 322-323: 167-180.

Gifford, D., 1991. Bones are not enough: analogues, knowledge, and interpretive strategies in zooarchaeology. *Journal of Anthropological Archaeology* 10: 215-254.

Gifford-Gonzalez, D.P., 1989. Ethnographic analogues for interpreting modified bones: some cases from East Africa. In: Bonnichsen, R., Sorg, M.H. (Eds.), *Bone Modification*. Center for the Study of the First Americans, University of Maine, pp. 179-246.

Gifford-Gonzalez, D.P, 1985. The fauna from Loiyangalani site, Serengeti National Park, Tanzania. *National Geographic Reports* pp. 41-56.

Gliganic, L.A., 2011. Optically and Infrared Stimulated Luminescence Investigations of the Middle and Later Stone Age in East Africa. PhD dissertation, University of Wollongong.

Gliganic, L.A., Jacobs, Z., Roberts, R.G., Domínguez-Rodrigo, M., Mabulla, A.Z.P., 2012. New ages for Middle and Later Stone Age deposits at Mumba rockshelter, Tanzania: Optically stimulated luminescence dating of quartz and feldspar grains. *Journal of Human Evolution* 62(4): 533-547.

Goldberg, P., Mendel, R.D., 2008. Caves and rockshelters. *Encyclopaedia of Archaeology.* Volume 2, pp. 966-974.

Goodwin, A.J.H., 1931. South African Archaeology. *Man* 31: 25-26.

Goodwin, A.J.H., 1928. An introduction to the Middle Stone Age in South Africa. *South African Journal of Science* 25: 410-418.

Goodwin, A.J.H., Lowe, C. van R., 1929. The Stone Cultures of South Africa. *Annals of the South African Museum* 27: 1-289.

Gowlett, J.A.J., 1990. Archaeological studies of human origins and early prehistory in Africa. In: Robertshaw, P. (Ed.), *A History of African Archaeology.* James Currey, London, pp. 13-38.

Grayson, D.K., 1989. Bone transport, bone destruction and reverse utility curves. *Journal of Archaeological Science* 16: 643-652.

Grayson, D.K., 1984. *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas*. Academic Press, Orlando.

Grayson, D.K., Delpech, F., 2003. Ungulates and the Middle to Upper Paleolithic transition at Grotte XVI (Dordogne, France). *Journal of Archaeological Science* 30: 1633-1648.

Grayson, D.K., Delpech, F., 2002. Specialized early Upper Paleolithic hunters in southwestern France? *Journal of Archaeological Science* 29: 1439-1449.

Grayson, D.K., Delpech, F., 1998. Changing diet breadth in the early Upper Paleolithic of southwestern France. *Journal of Archaeological Science* 25: 119-1129.

Grayson, D.K., Delpech, F., 1994. The evidence for Middle Paleolithic scavenging from Couche VIII, Grotte Vaufrey (Dordogne) France. *Journal of Archaeological Science* 21: 359-375.

Grayson, D.K., Frey, C.J., 2004. Measuring skeletal part representation in archaeological faunas. *Journal of Taphonomy* 2(1): 27-42.

Grayson, D.K., Delpech, F., Rigaud, J.P., Simek, J.F., 2001. Explaining the development of dietary dominance by a single ungulate taxon at Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 28: 115-125.

Green, R.E., Krause, J., Briggs, A.W., Maricic, T., Stenzel, U., Kircher, M., Patterson, N., 2010. A draft sequence of the Neanderthal genome. *Science* 328: 710-722.

Grine, F.E., 2016. The Late Quaternary hominins of Africa: the skeletal evidence from MIS 6-2. In: Jones, S.C., Stewart, B.A. (Eds.), *Africa from MIS 6-2: Population Dynamics and Paleoenvironments.* Springer, Dordrecht, pp. 323-382.

Hammer, M.F., 1995. A recent common ancestor for human Y-chromosomes. *Nature* 378: 376-378.

Hanby, J.P., Bygott, J.D., Packer, C., 1995. Ecology, demography and behavior of lions in two contrasting habitats: Ngorongoro Crater and the Serengeti Plains. In: Sinclair, A.R.E., Arcese, P. (Eds.), *Serengeti II: Dynamics, Management and Conservation of an Ecosystem.* University of Chicago Press, Chicago, pp. 315-331.

Hansen, C.L., Keller, C.M., 1971. Environment and activity patterning at Isimila Korongo, Iringa District, Tanzania: a preliminary report. *American Anthropologist* 5: 1201-1211.

Harpending, H., Rogers, A., 2000. Genetic perspectives on human origins and differentiation. *Annual Review Genomics Human Genetics* 1: 361-385.

Harpending, H.C., Batzer, M.A., Gurven, M., Jorde, L.B., Rodgers, A.R., Sherry, S.T., 1998. Genetic traces of ancient demography. *Proceedings of the National Academy of Sciences* 95: 1961-1967.

Harpending, H.C., Sherry, S.T., Rogers, A.R., Stoneking, M., 1993. The genetic structure of ancient human populations. *Current Anthropology* 34(4): 483-496.

Harris, M., 1968. *The Rise of Anthropological Theory: A History of Theories of Culture.* Thomas Y. Crowell, New York.

Hawkes, K., 1991. Showing off: tests of a hypothesis about men’s foraging goals. *Ethnology and Sociobiology* 12: 29-54.

Hawkes, K., Bliege-Bird, R.L., 2002. Showing off handicap signaling and the evolution of men’s work. *Evolutionary Anthropology* 11: 58-67.

Hay, R.L. 1987. Geology of the Laetoli area. In: Leakey, M.D., Harris, J.M. (Eds.), *Laetoli: A Pliocene Site in Northern Tanzania.* Clarendon, Oxford, pp. 23-47.

Hay, R.L., 1976. *The Geology of Olduvai Gorge.* University of California Press, Berkeley.

Haynes, G., 1988. Mass deaths and serial predation: comparative taphonomic studies of modern large mammal death sites. *Journal of Archaeological Science* 15: 219-235.

Henshilwood, C.S., Marean, C.W., 2003. The origin of modern human behaviour: critique of the models and their test implications. *Current Anthropology* 44(5): 627-651.

Henshilwood, C.S., d’Errico, F., Watts, I., 2009. Engraved ochre from the Middle Stone Age levels at Blombos Cave, South Africa. *Journal of Human Evolution* 57: 27-47.

Henshilwood, C.S., d’Errico, F., Yates, R., Jacobs, Z., Tribolo, C., Duller, G.A.T., Mercier, N., Sealy, J.C., Valladas, H., Watts, I., Wintle, A.G., 2002. Emergence of modern human behavior: Middle Stone Age engravings from South Africa. *Science* 295: 1278-1280.

Hill, K., Kaplan, H., Hawkes, K., Hurtado, A.M., 1987. Foraging decisions among Ache hunter-gatherers: new data and implications for optimal foraging models. *Ethology and Sociobiology* 8: 1-36.

Hillson, S., 2005. *Teeth.* 2nd Edition. Cambridge University Press, Cambridge.

Hillson, S., 1999. *Mammal Bones and Teeth: An Introductory Guide to Methods of Identification.* Institute of Archaeology, London.

Hoffer, H., East, M.L., Campbell, K.L.I., 1993. Snares, commuting hyenas, and migratory herbivores: humans as predators in the Serengeti. *Symposium of Zoological Society London* 65: 347-366.

Holdo, R.M., Fryxell, J.M., Sinclair, A.R.E., Dobson, A., Holt, R.D., 2011. Predicted impact of barriers to migration on the Serengeti wildebeest population. *PLoS ONE* 6(1): e16370. doi:10.1371/journal.pone.0016370.

Horai, S., Hayasaka K., Kondo, R., Tsugane, K., Takahata, N., 1995. Recent African origin of modern humans revealed by complete sequences of hominoid mitochondrial DNAs. *Proceedings of the National Academy of Sciences* 92: 532-536.

Hovers, E., Kuhn, S.L. (Eds.), 2006. *Transitions Before the Transition: Evolution and Stability in the Middle Paleolithic and Middle Stone Age*. Springer, New York.

Howell, F.C., 1961. Isimila: a Paleolithic site in Africa. *Scientific American* 205: 118-129.

Howell, F.C., Cole, G.H., Kleindienst, M.R., Oakley, K.P., 1972. Uranium-series dating of bone from the Isimila Prehistoric Site, Tanzania. *Nature* 237: 51-52.

Hublin, J-J., 2009. The origin of Neanderthals. *Proceedings of the National Academy of Sciences* 106(38): 16022-16027.

Hublin, J-J., 1992. Recent human evolution in northwestern Africa. *Philosophical Transactions* 337B(1280): 185-191.

Hublin, J-J., Richards, M.P. (Eds.), 2009. *The Evolution of Hominin Diets: Integrating Approaches to the Study of Paleolithic Subsistence.* Springer, Dordrecht.

Hublin, J-J., McPherron, S. (Eds.), 2009. *Modern Origins: A North African Perspective*. Springer, Dordrecht.

Hublin, J-J., Ben-Ncer, A., Bailey, S.E., Freidline, S.E., Neubauer, S., Skinner, M.M., Bergmann, I., Cabec, A.L., Benazzi, S., Harvati, K., Gunz, P., 2017. New fossils from Jebel Irhoud, Morocco and the pan-African origin of *Homo sapiens. Nature* 546: 286-292.

Hudson, J. (Eds.), 1993. *From Bones to Behaviour: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains.* Center for Archaeological Investigations, University of Southern Illinois, Carbondale.

Hurtado, A.M., Hill, K., Kaplan, H., 1985. Female subsistence strategies among the Ache-hunter gatherer of eastern Paraguay. *Human Ecology* 13(1): 1-28.

Hutson, J.M., 2016. The faunal remains from Bundu Farm and Pniel 6: examining the problematic Middle Stone Age archaeological record within the southern African interior. *Quaternary International* xxx: 1-16.

Ingman, M., Kaessmann, H., Pääbo, S., Gyllenstein, U., 2000. Mitochondrial genome variation and the African origin of modern humans. *Nature* 408(6813): 708-713.

Inskeep, R., 1962. The age of the Kondoa rock paintings in the light of recent excavations at Kisese II Rockshellter. In: Mortelmans, G., Nenquin, J. (Eds.), *Actes du Ive Congres Panafricain de Prehistorie et de l' Etude du Quartenaire, Leopoldiville 1959 Annales du Musee Royale de l'Afrique Centrale Serie IN-80 (Science Humaines)* 40: Section II: 249-256.

Isaac, G.L1., 1978. The food-sharing behavior of protohuman hominids. *Scientific American* 238: 90-108.

Isaac, G.L1., 1974. Stone Age remains of Kilwa Island. In: Chittick, N., (Ed.), *Kilwa: An Islamic Trading City on the East African Coast.* British Institute in Eastern Africa, Nairobi, pp. 254-256.

Isaac, G.L1., 1971. The diet of early man: aspects of archaeological evidence from Lower and Middle Pleistocene Sites in Africa. *World Archaeology* 2(3): 278-299

Isango, J., 2007. Stand structure and tree species composition of Tanzania miombo woodlands: a case study from miombo woodlands of community based forest management in Iringa District. *Working Papers of the Finnish Forest Research Institute* 50: 43-56.

Itambu, P.M., 2013. The rock art of Iringa Region, southern Tanzania: a descriptive and comparative study. MA thesis, University of Dar es Salaam.

Jacobs, Z., Roberts, R., 2009. Were environmental or demographic factors the driving force behind Middle Stone Age innovations in southern Africa? *South African Journal of Science* 105: 333-334.

Jager, T.J., 1982. *Soils of the Serengeti Woodlands, Tanzania: Agricultural Research Reports 912.* Serengeti Research Institute, Wageningen.

Janetski, J.C., 1997. Fremont hunting and resource intensification in the Eastern Great Basin. *Journal of Archaeological Science* 24: 1075-1088.

Jin, J., 2010. Zooarchaeological and taphonomic analysis of faunal assemblages from Tangzigou, Southwestern China. PhD dissertation, the Pennsylvania State University.

Jin, J.J.H., Mills, E.W., 2011. Split phalanges from archaeological sites: evidence of nutritional stress? *Journal of Archaeological Science* 38: 1798-1809.

Jochim, M.A., 1988. Optimal foraging and the division of labour. *American Anthropologist* 90(1): 130-136.

Johnson, E., 1985. Current developments in bone technology. *Advances in Archaeological Method and Theory* 8: 157-235.

Johnson, M., 2010. *Archaeological Theory: An introduction*. 2nd Edition. Wiley-Blackwell, Chicester.

Jones, E.L., 2004. Dietary evenness, prey choice, and human-environment interactions. *Journal of Archaeological Science* 31: 307-317.

Jones, K.T., Metcalfe, D., 1988. Bare bones archaeology: bone marrow indices and efficiency. *Journal of Archaeological Science* 15: 415-423.

Jones, S.C., Stewart, B.A. (Eds.), 2016a. *Africa from MIS 6-2: Population Dynamics and Paleoenvironments.* Springer, Dordrecht.

Jones, S.C., Stewart, B.A., 2016b. Africa from MIS6-2: The florescence of modern humans. In: Jones, S.C., Stewart, B.A. (Eds.), *Africa from MIS 6-2: Population Dynamics and Paleoenvironments.* Springer, Dordrecht, pp. 1-22.

Joseph, S., 2000. Anthropological evolutionary ecology: a critique. *Journal of Ecological Anthropology* 4: 6-30.

Kabigumila, J.D.L., 1998. Aspects of the ecology and management of the tropical leopard tortoise *Geochelone pardalis babcocki* (Loveridge) in northeastern Tanzania. PhD dissertation, University of Dar es Salaam.

Kaplan, H.S., Robson, A.J., 2002. The emergence of humans: the coevolution of intelligence and longevity with intergenerational transfers. *Proceedings of the National Academy of Sciences* 99: 10221-10226.

Kaplan, H., Hill, K., Lancaster, J., Hurtado, A.M., 2000. A theory of human life-history evolution: diet intelligence and longevity. *Evolutionary Anthropology* 9: 156-185.

Karoma, N.J., 1990. On the training of archaeologists in East Africa universities: the Tanzania experience. Paper presented at the 10th Biennial meeting of the Society of Africanist Archaeologists, Gainesville, Florida.

Karoma, N.J., 1982. New evidence of Paleolithic human activities along Kilwa Coast, Southern Tanzania. University of Dar es Salaam, Dar es Salaam.

Karr, L.P., Outram, A.K., 2012. Actualistic research into dynamic impact and its implications for understanding differential bone fragmentation and survivorship. *Journal of Archaeological Science* 39: 3443-3449.

Keller, C.M., Hansen, C., Alexander, C.S., 1975. Archaeology and paleoenvironments in the Manyara and Engaruka Basins, Northern Tanzania. *Geographical Review* 65(3): 364-376.

Kelly, R., 2007. *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Percheron Press, New York.

Kendall, R.L., 1969. An ecological history of the Lake Victoria Basin. *Ecological Monograph* 39: 121-176.

Kessy, E.T., 2009. Stone Age archaeology of Tanzanian coast and adjacent islands: a review. *Journal of Indian Ocean Archaeology* 6: 36-57.

Kidwell, S.M. Behrensmeyer, A.K. (Ed,) 1993. *Taphonomic Approaches to Time Resolution in Fossil Assemblages.* Paleontological Society Short Courses in Paleontology, 6. The Paleontological Society, Iowa.

Kimaro, F., 2008. Later prehistoric cultures of Isimila site of Iringa Region. MA thesis, University of Dar es Salaam.

Klein, R.G., 2009. *The Human Career: Human Biological and Cultural Origins.* 3rd edition, University of Chicago Press, Chicago.

Klein, R.G., 2008. Out of Africa and the evolution of human behavior. *Evolutionary Anthropology* 17: 267-281.

Klein, R.G., 2000. Archaeology and the evolution of human behavior. *Evolutionary Anthropology* 9(1): 17-36.

Klein, R.G., 1995. Anatomy, behavior, and modern human origins. *Journal of World Prehistory* 9(2): 167-198.

Klein, R.G., 1992. The archaeology of modern human origins. *Evolutionary Anthropology* 1(1): 5-14.

Klein, R.G., 1989. Why does skeletal part representation differ between smaller and larger bovids at Klasies River Mouth and other archeological sites? *Journal of Archaeological Science* 6: 363-381.

Klein, R.G., 1987. Reconstructing how early people exploited animals: problems and prospects. In: Nitecki, M.H., Nitecki, D.V. (Eds.), *The Evolution of Human Hunting*. Plenum Press, New York, pp. 11-45.

Klein, R.G., 1982. Age (Mortality) profiles as a means of distinguishing hunted species from scavenged ones in Stone Age archeological sites. *Paleobiology* 8(2): 151-158.

Klein, R.G., 1981. Stone Age predation on small African bovids. *The South African Archaeological Bulletin* 36(134): 55-65.

Klein, R.G., 1979. Stone Age exploitation of animals in Southern Africa. *American Scientist* 67(2): 151-160.

Klein, R.G., 1978. Stone Age predation on large African bovids. *Journal of Archaeological Science* 5: 195-217.

Klein, R.G., 1977. Mammalian fauna from the Middle and Later Stone Age (Later Pleistocene) levels of Border Cave, Natal Province, South Africa. *The South African Archaeological Bulletin* 32(125): 14-27.

Klein, R.G., 1976. The mammalian fauna of the Klasies River Mouth Sites, Southern Cape Province, South Africa. *The South African Archaeological Bulletin* 31(123/124): 75-98.

Klein, R.G., 1975. Middle Stone Age man-animal relationships in Southern Africa: evidence from Die Kelders and Klasies River Mouth. *Science* 190(4211): 265-267.

Klein, R.G., Cruz-Uribe, K., 2000. Middle and Later Stone Age large mammal and tortoise remains from Die Kelders Cave 1, Western Cape Province, South Africa. *Journal of Human Evolution* 38: 169-195.

Klein, R.G., Cruz-Uribe, K., 1996. Exploitation of large bovids and seals at Middle and Later Stone Age sites in South Africa. *Journal of Human Evolution* 31: 315-334.

Klein, R.G., Cruz-Uribe, K., 1984. *The Analysis of Animal Bones from Archaeological Sites.* University of Chicago Press, Chicago.

Klein, R.G., Cruz-Uribe, K., 1983. The computation of ungulate age (mortality) profiles from dental crown heights. *Paleobiology* 9(1): 70-78.

Knecht, H. (Ed.), 1997. *Projectile Technology.* Springer, New York.

Kohl-Larsen, L., 1943. *Auf den Spuren des Vormenschen.* Strecker und Schröeder Verlag, Stuttgart.

Kovarovic, K.M., 2004. Bovids as paleoenvironmental indicators: an ecomorphological analysis of bovid post-cranial remains from Laetoli Tanzania. PhD dissertation, University College London.

Kovarovic, K.M., Andrews, P., Aiello, L., 2002. An ecological diversity analysis of the Upper Ndolanya Beds, Laetoli, Tanzania. *Journal of Human Evolution* 43: 395-418.

Krause, J., Fu, Q., Good, J.M., Viola, B., Shunkov, M.V., Derevianko, A.P., Pääbo, S., 2010. The complete mitochondrial DNA genome of an unknown hominin from southern Siberia. *Nature* 464: 894-897.

Krings, M., Capelli, C., Tschentscher, F., Geisert, H., Meyer, S., Haeseler, A., Grossschmidt, K., Possnert, G., Paunovic, M., Pääbo, S., 2000. A view of Neanderthal genetic diversity. *Nature Genetics* 26: 144-146.

Krings, M., Stone, A., Schmitz, R.W., Krainitzki, H., Stoneking, M., Pääbo, S., 1997. Neanderthal DNA sequences and the origin of modern humans. *Cell* 90: 19-30.

Kroll, E.M., Price, T.D. (Ed.), 1991. *The Interpretation of Spatial Patterns in Stone Age Archaeological Sites*. Plenum Press, New York.

Kruuk, H., 1972. *The spotted Hyena: A Study of Predation and Social Behavior.* University of Chicago Press, Chicago.

Kuhn, B.F., Berger, L.R., Skinner, J.D., 2010. Examining criteria for identifying and differentiating fossil faunal assemblages accumulated by hyenas and hominins using extant hyenid accumulations. *International Journal of Osteoarchaeology* 20: 15-35.

Kuhn, S.L., Stiner, M.C., 2006. What's a mother to do? The division of labor among Neanderthals and modern humans in Eurasia. *Current Anthropology* 47(6): 953-980.

Kusimba, C. M., 1999. *The Rise and Fall of Swahili States.* Altamira Press, London.

Kwekason, A.P., 2011. *Holocene Archaeology of the Southern Coast of Tanzania.* E & D Vision Publishing, Dar es Salaam.

Kwekason, A.P., Chami, F., 2003. The archaeology of Muleba, southwest of Lake Nyanza: a preliminary report, *Studies in the African Past* 3: 59-85.

Lam, Y.M., 1992. Variability in the behaviour of spotted hyenas as taphonomic agents. *Journal of Archaeological Science* 19: 389-406.

Lam, Y.M., Chen, X., Pearson, O.M., 1999. Intertaxonomic variability in patterns of bone density and the differential representation of bovid, cervid, and equid elements in the archaeological record. *American Antiquity* 64(2): 343-362.

Leakey, L.S.B., 1936a. A new fossil skull from Eyasi, East Africa discovery by a German expedition. *Nature* 138: 1082-1084.

Leakey, L.S.B., 1936b. *Stone Age Africa: An Outline of Prehistory in Africa.* Oxford University Press, Oxford.

Leakey, L.S.B., 1931. *The Stone Age Cultures of Kenya Colony*. Cambridge University Press, Cambridge.

Leakey, L.S.B., 1929. An outline of Stone Age in Kenya. *South African Journal of Science* 26: 749-57.

Leakey, M.D., 1994. *Olduvai Gorge Volume 5: Excavations in Beds III, IV and Masek, 1968-1971.* Cambridge University Press, Cambridge.

Leakey, M.D., 1983. *Africa's Vanishing Art: The Rock Painting of Tanzania.* Doubleday, New York.

Leakey, M.D., 1971. *Olduvai Gorge Excavations in Beds I and II, 1960-1963.* Volume 3. Cambridge University Press, Cambridge.

Leakey, M.D., Harris, J.M. (Eds.), (1987). *Laetoli: A Pliocene Site in Northern Tanzania*. Clarendon, Oxford.

Leakey, M.D., Hay, R.L., 1979. Pliocene footprints in the Laetoli beds at Laetoli, northern Tanzania. *Nature* 278: 317-323.

Leakey, M.D., Hay, R.L., Thurber, D.L., Protsch, R., Berger, R., 1972. Stratigraphy, archaeology, and age of the Ndutu and Naisiusiu Beds, Olduvai Gorge, Tanzania. *World Archaeology*, 3(3): 328-341.

Lee, R. B., Daly, R., 1999a. Foragers and others. In: Lee, R.B., Daly, R. (Eds.), *The Cambridge Encyclopedia of Hunters and Gatherers*. Cambridge University Press, Cambridge, pp. 1-19.

Lee, R.B., Daly, R. (Eds.), 1999b. *The Cambridge Encyclopaedia of Hunters and Gatherers*. Cambridge University Press, Cambridge.

Lee, R.B., DeVore, I. (Eds.), 1968. *Man the Hunter.* Chicago. Aldine Publishing Company.

LeMoine, G.M., MacEachern, A.S. (Eds.), 1983 *Carnivores, Human Scavengers and Predators: A Question of Bone Technology*. Proceedings of the Fifteenth Annual Conference: The Archaeological Association of the University of Calgary.

Lombard, M., 2012. Thinking through the Middle Stone Age of sub-Saharan Africa. *Quaternary International* 270: 140-155.

Lubell, D., 2004. Prehistoric edible land snails in the circum-Mediterranean: the archaeological evidence. In: Brugal. J-J., Desse, J. (Eds.), *Petits Animaux et Sociétés Humaines. Du Complément Alimentaire Aux Ressources Utilitaires. XXIVe rencontres internationales d'archéologie et d'histoire d'Antibes*. Antibes: Èditions APDCA, pp. 77-98.

Lupo, K.D., 2007. Evolutionary foraging models in zooarchaeological analysis: recent applications and future challenges. *Journal of Archaeological Research* 15: 143-189.

Lupo, K.D., 2006. What explains the carcass field processing and transport decisions of contemporary hunter-gatherers? measures of economic anatomy and zooarchaeological skeletal part representation. *Journal of Archaeological Method and Theory* 13(1): 19-66.

Lupo, K.D., 2001. Archaeological skeletal part profiles and differential transport: an ethnoarchaeological example from Hadza bone assemblages. *Journal of Anthropological Archaeology* 20: 361-378.

Lupo, K.D., 1995. Hadza bone assemblages and hyena attrition: an ethnographic example of the influence of cooking and mode of discard on the intensity of scavenger ravaging. *Journal of Anthropological Archaeology* 14: 288-314.

Lupo, K.D., 1994. Butchering marks and carcass acquisition strategies distinguishing hunting from scavenging in archaeological contexts. *Journal of Archaeological Science* 21: 827-837.

Lupo, K.D., O'Connell, J.F., 2002. Cut and tooth mark distributions on large animal bones: ethnoarchaeological data from the Hadza and their implications for current ideas about early human carnivory. *Journal of Archaeological Science* 29: 85-109.

Lupo, K.D., Schmitt, D.N., 2005. Small prey hunting technology and zooarchaeological measures of taxonomic diversity and abundance: ethnoarchaeological evidence from Central African forest foragers. *Journal of Anthropological Archaeology* 24: 335-353.

Lupo, K.D., Schmitt, D.N., 1997. Experiments in bone boiling: nutritional returns and archaeological reflections. *Anthropozoologica* 25-26: 137-144.

Lyaya, E.C., 2016. Initial Environmental audit for Makundusi facility. Department of Archaeology and Heritage Studies, Dar es Salaam.

Lyman, R.L., 2008. *Quantitative Paleozoology.* Cambridge University Press, Cambridge.

Lyman, R.L., 2003. The influence of time averaging and space averaging on the application of foraging theory in zooarchaeology. *Journal of Archaeological Science* 30: 595-610.

Lyman, R.L., 1994. *Vertebrate Taphonomy*. Cambridge University Press, Cambridge.

Lyman, R.L., 1987a. Archaeofaunas and butchery studies: a taphonomic perspective. In: Schiffer, M.B. (Ed.), *Advances in Archaeological Method and Theory*. Vol. 10. Academic Press, San Diego, pp. 249-337.

Lyman, R.L., 1987b. Zooarchaeology and taphonomy: a general consideration. *Journal of Enthnobiology* 7(1): 93-117.

Lyman, R.L., 1982. Archaeofaunas and subsistence studies. *Advances in Archaeological Method and Theory* 5: 331-393.

Mabulla, A.Z.P., 1996. Middle and Later Stone Age land-use and lithic technology in Eyasi basin, Tanzania. PhD dissertation, University of Florida.

Mabulla, A.Z.P., 1990a. Archeological reconnaissance of the Ndutu Beds, Olduvai Gorge, Tanzania. MA thesis, University of Florida.

Mabulla, A.Z.P., 1990b. Preliminary report on the archaeological survey of the Ndutu Beds, Olduvai Gorge, Tanzania. *Nyame Akuma* 33: 20-25.

Mabulla, I.A., 2014. Making sense of a fragmentary past: the rock art of Simiyu Region, Lake Victoria Basin, Tanzania. MA thesis, Universidade de Trás-os-Montes e Alto Douro.

MacArthur, R.H., Pianka, E.R., 1966. On optimal use of a patchy environment. *The American Naturalist* 100(916): 603-609.

Maddison, D.R., 1991. African origin of human Mitochondrial DNA re-examined. *Systematic Zoology* 40: 355-363.

Maddock, L., 1979. The ‘migration’ and grazing succession. In: Sinclair, A.R.E., Norton-Griffiths., M. (Eds.), *Serengeti I: Dynamics of an Ecosystem.* Chicago University Press, Chicago, pp. 104-129.

Madsen, D.B., 1993. Testing diet breadth models: examining adaptive change in the Late Prehistoric Great Basin. *Journal of Archaeological Science* 20: 321-329.

Madsen, D.B., Schmitt, D.N., 1998. Mass collecting and the diet breadth model: a Great Basin example. *Journal of Archaeological Science* 25: 445-455.

Magembe, L., 2007. Transformation of valley-bottom cultivation and its effects on Tanzanian wetlands: A case Study of Ndembera wetland area in Iringa Region. MA thesis, University of Florida.

Magori, C.C., Day, M.H., 1983. Laetoli Hominid 18: an early *Homo sapiens* skull. *Journal of Human Evolution* 12: 747-753.

Magurran, A.E., 1988. *Ecological Diversity and its Measurement.* Princeton University Press, Princeton.

Maíllo-Fernández, J.M., Masele, F., Thompson, J.C., Bushozi, P.G., Mabulla, A.Z.P., Bower, J.F.R., 2016. Loiyangalani: a Middle Stone site in Serengeti National Park. Pecha Kucha Presentation. European Society for the study of Human Evolution, 6th Annual Meeting, Madrid, Spain 14-17th September 2016.

Manega, P.C., 1993. Geochronology, geochemistry and isotopic study of the Plio-Pleistocene hominid sites and the Ngorongoro volcanic highland in northern Tanzania. PhD dissertation, University of Colorado, Boulder.

Marean, C.W., 2010. Pinnacle Point Cave 13B (Western Cape Province, South Africa) in context: the Cape Floral kingdom, shellfish, and modern human origins. *Journal of Human Evolution* 59: 425-443.

Marean, C.W., 1998. A critique of the evidence for scavenging by Neanderthals and early modern humans: new data from Kobeh Cave (Zagros Mountains, Iran) and Die Kelders Cave 1 Layer 10 (South Africa). *Journal of Human Evolution* 35: 111-136.

Marean, C.W., 1997. Hunter–gatherer foraging strategies in tropical grasslands: model building and testing in the East African Middle and Later Stone Age. *Journal of Anthropological Archaeology* 16: 189-225.

Marean, C.W., 1996. Preliminary report on the Loiyangalani faunal assemblage and future research agenda. Unpublished Report. Stony Brook, pp. 1-7.

Marean, C.W., 1995. Of taphonomy and zooarchaeology. *Evolutionary Anthropology* 4: 64-72.

Marean, C.W., 1991. Measuring the post-depositional destruction of bone in archaeological Assemblages. *Journal of Archaeological Science* 18: 677-694.

Marean, C.W., 1990a. A preliminary report on some fossil bone collected by Audax Mabulla in the summer of 1989 at Olduvai Gorge, Unpublished Report.

Marean, C.W., 1990b. Late Quaternary paleoenvironments and faunal exploitation in East Africa. PhD dissertation, University of California Berkeley.

Marean, C.W., Assefa, Z., 2005. The Middle and Upper Pleitoscene African record for the biological and behavioural origins of modern humans. In: Stahl, A.B. (Ed.), *African Archaeology.* Blackwell Publishing Limited, Oxford, pp. 93-129.

Marean, C.W., Assefa, Z., 1999. Zooarchaeological evidence for the faunal exploitation behavior of Neanderthals and early modern humans. *Evolutionary Anthropology* 8: 22-37.

Marean, C.W., Bertino, L., 1994. Intrasite spatial analysis of bone: subtracting the effect of secondary carnivore consumers. *American Antiquity* 59(4): 748-768.

Marean, C.W., Cleghorn, N., 2003. Large mammal skeletal transport: applying foraging theory in a complex taphonomic system. *Journal of Taphonomy* 1: 15-42.

Marean, C.W., Kim, S.Y., 1998. Mousterian large- mammal remains from Kobeh Cave behavioral implications for Neanderthals and early modern humans. *Current Anthropology* 39(S1): S79-S114.

Marean, C.W., Frey, C.J., 1997. Animal bones from caves to cities: reverse utility curves as methodological artifacts. *American Antiquity* 62(4): 698-711.

Marean, C.W., Spencer, L.M., 1991. Impact of carnivore ravaging on zooarchaeological measures of element abundance. *American Antiquity* 56(4): 645-658.

Marean, C.W., Dominguez-Rodrigo, M., Pickering, T.R., 2004. Skeletal element equifinality in zooarchaeology begins with method: the evolution and status of the "shaft critique". *Journal of Taphonomy* 2(2): 69-98.

Marean, C.W., Abe, Y., Frey, C.J., Randall, R.C., 2000. Zooarchaeological and taphonomic analysis of the Die Kelders Cave 1 Layers10 and 11 Middle Stone Age larger mammal fauna. *Journal of Human Evolution* 38: 197-233.

Marean, C.W., Spencer, L.M., Blumenschine, R.J., Capaldo, S.D., 1992. Captive hyaena bone choice and destruction, the schlepp effect and Olduvai Archaeofaunas. *Journal of Archaeological Science* 19: 101-121.

Marlowe, F.W., 2010. *The Hadza Hunter-Gatherers of Tanzania.* University of California Press, California Berkeley.

Marshall, L.G., 1989. Bone modification and 'the laws of burial'. In: Bonnichsen, R., Sorg, M.H. (Eds.), *Bone modification.* Center for the Study of the First Americans, University of Maine, Orono, Maine, pp. 7-24.

Martin, J.F., 1985. More on optimal foraging theory. *American Anthropologist* 87: 649-650.

Martin, J.F., 1983. Review: optimal foraging theory: a review of some models and applications. *American Anthropologist* 85: 612-629.

Martinez, G., 2009. Human chewing bone surface modification and processing of small and large prey amongs the Nunak (Foragers of Columbian Amazon). *Journal of Taphonomy* 7(1): 1-20.

Masao, F.T., 2009. A Middle Stone Age/Later Stone Age industry from Buzwagi, Kahama Shinyanga Region, Tanzania: results of cultural impact assessment. *Nyame Akuma* 70: 30-48.

Masao, F.T., 2005. Archaeological research in mainland Tanzania up to the 1990s. In: Mapunda, B.B.B., Msemwa, P. (Eds.), *Salvaging Tanzania's Cultural Heritage.* Dar es Salaam University Press, Dar es Salaam, pp. 59-80.

Masao, F.T., 1992. Middle Stone Age with reference to Tanzania. In: Bräuer, G., Smith, F.H. (Eds.), *Continuity or Replacement*. Balkema, Rotterdam pp. 99-109.

Masao, F.T., Blumenschine, R.J., Peters, C., Njau, J., 2003. Artifacts in the Kirawira stretch and other patches of the Gurumeti River in Serengeti National Park: a brief report. *Nyame Akuma* 19: 66-75.

Masele, F., 2012. Private business investments in heritage sites in Tanzania: recent developments and challenges for heritage Management. *African Archaeological Review* 29(1): 51-65.

Maslin, M.A., Brierley, C.M., Milner, A.M., Shultz, S., Trauth, M.H., Wilson, K.E., 2014. East African climate pulses and early human evolution. *Quaternary Science Reviews* 101: 1-17.

McBrearty, S., 1988. The Sangoan-Lupemban and Middle Stone Age sequence at the Muguruk site western Kenya. *World Archaeology* 19(3): 388-420.

McBrearty, S., Brooks, A.S., 2000. The revolution that wasn't: a new interpretation of the origin of modern human behavior. *Journal of Human Evolution* 39: 452-563.

McBrearty, S., Waane, S.A.C, Wynn, T., 1982. Mbeya Region archaeological survey. *Tanzania Notes and Records* 88/89: 15-32.

McBrearty, S., Wynn, T., Waane, S.A.C., 1984. Archaeological survey in Mbeya Region, Southern Tanzania. *Azania* 19: 128-132.

McDermott, F., Stringer, C., Grün, R., Wiliams, C.T., Din, V.K., Hawkesworth, C.J., 1996. New late Pleistocene Uranium-thorium and ESR dates for the Singa hominid (Sudan). *Journal of Human Evolution* 31: 507-516.

McDougall, I., Brown, F.H., Fleagle, J.G., 2005. Stratigraphic placement and age of modern humans from Kibish, Ethiopia. *Nature* 433: 733-736.

McNaughton, S.J., 1990. Mineral nutrition and seasonal movements of African migratory ungulates. *Nature* 334: 343-345.

McNaughton, S.J., 1988. Mineral nutrition and spatial concentration of ungulates. *Nature* 334: 343-345.

Mehari, A.G., Schmidt, P.R., Mapunda, B.B.B., 2014. Knowledge about archaeological field schools in Africa: the Tanzanian experience. *Azania* 49(2): 184-202.

Mehlman, M.J., 1989. Later Quaternary archaeology sequences in northern Tanzania. PhD dissertation, University of Illinois.

Mehlman, M.J., 1987. Provenience, age and associations of archaic *Homo sapiens* crania from Lake Eyasi, Tanzania. *Journal of Archaeological Science* 14: 133-162.

Mehlman, M.J., 1984. Archaic *Homo sapiens* at Lake Eyasi, Tanzania: recent misrepresentations. *Journal of Human Evolution* 13: 487-501.

Mehlman, M.J., 1979. Mumba-Hohle revisited: The relevance of a forgotten excavation to some current issues in East African Prehistory. *World Archaeology* 2(1): 80-94.

Mehlman, M.J., 1977. Excavation at Nasera Rock. *Azania* 12: 111-118.

Mellars, P., 2006. Why did modern human populations disperse from Africa ca. 60,000 years ago? A new model. *Proceedings of the National Academy of Sciences* 103(25): 9381-9386.

Mellars, P., 2005. The impossible coincidence. a single-species model for the origins of modern human behavior in Europe. *Evolutionary Anthropology* 14: 12-27.

Mellars, P., 1989. Major issues in the emergence of modern humans. *Current Anthropology* 30(3): 349-385.

Mellars, P., Stringer, C.B. (Eds.), 1989. *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans.* Princeton University Press, Princeton.

Mellars, P., Boyle, K., Bar-Yosef, O., Stringer, C.B. (Eds.), 2007. *Rethinking the Human Revolution: New Behavioural and Biological Perspectives on the Origin and Dispersal of Modern Humans.* McDonard Institute for Archaeological Research Monographs, Cambridge University.

Metcalfe, D., Jones, K.T., 1988. A reconsideration of animal body-part utility indices. *American Antiquity* 53(3): 486-504.

Miller, J.M., Willoughby, P.R., 2014. Radiometrically dated ostrich eggshell beads from the Middle and Later Stone Age of Magubike Rockshelter, southern Tanzania. *Journal of Human Evolution* 74: 118-122.

Milo, R.G., 1998. Evidence for hominid predation at Klasies River Mouth, South Africa, and its implications for the behavior of early modern humans. *Journal of Archaeological Science* 25: 99-133.

Milo, R.G., 1994. Human-animal interactions in Southern Africa prehistory: a microscopic study of bone damage signatures. PhD dissertation, University of Chicago.

Monahan, C.M., 1998. The Hadza carcass transport debate revisited and its archaeological implications. *Journal of Archaeological Science* 25: 405-424.

Monahan, C.M., 1996. New zooarchaeological data from Bed II, Olduvai Gorge Tanzania: implications for hominid behavior in the early Pleistocene. *Journal of Human Evolution* 31: 93-128.

Morgan, L.E., Renne, P.R., 2008. Diachronous dawn of Africa's Middle Stone Age: New ^{40}Ar/^{39}Ar ages from the Ethiopian Rift. *Geology* 36(12): 967-970.

Morin, E., 2012. *Reassessing Paleolithic Subsistence: The Neanderthal and Modern Human Foragers of Saint-Césaire.* University of Cambridge Press, Cambridge.

Morin, E., 2007. Fat composition and Nunamiut decision-making: a new look at the marrow and bone grease indices. *Journal of Archaeological Science* 34: 69-82.

Morin, E., 2004. Late Pleistocene population interaction in Western Europe and modern human origins: new insight based on faunal remains from Sainte-Cersaire Southwestern France. PhD dissertation, University of Michigan.

Msemwa, P., 2002. Archaeology of the Ruaha Valley, Iringa District. National Museums of Tanzania Unpublished Report. Dar es Salaam.

Mturi, A.A., 2005. The idea of archaeology teaching programme in Tanzania. In: Mapunda, B.B.B. Msemwa, P. (Eds.), *Salvaging Tanzania's Cultural Heritage,* Dar es Salaam University Press, Dar es Salaam, pp. 5-8.

Mturi, A.A., 1998. The Archaeology of Tanzania. The Open University of Tanzania, Dar es Salaam.

Mturi, A.A., 1978. Background to archaeological research in Tanzania and proposed new approach - zonal approach. Department of Antiquities, Dar es Salaam.

Mumbi, C.T., Marchant, R., Hooghiemstra, H., Wooller, M.J., 2008. Late Quaternary vegetation reconstruction from the Eastern Arc Mountains, Tanzania. *Quaternary Research* 69: 326-341.

Munro, N.D., 2004. Zooarchaeological measures of hunting pressure and occupational intensity in the Natufian: implications for agricultural origins. *Current Anthropology* 45: S5-S34.

Munro, N.D., Bar-Oz, G., 2005. Gazelle bone fat processing in the Levantine Epipalaeolithic. *Journal of Archaeological Science* 32: 223-239.

Munson, P.J., 2000. Age-correlated differential destruction of bones and its effect on archaeological mortality profiles of domestic sheep and goats. *Journal of Archaeological Science* 27: 391-407.

Munson, P.J., Garniewicz, R.C., 2003. Age-mediated survivorship of ungulate mandibles and teeth in canid-ravaged faunal assemblages. *Journal of Archaeological Science* 30: 405-416.

Munson, P.J., Marean, C.W., 2003. Adults only? a reconsideration of Middle Paleolithic 'prime-dominated' reindeer hunting at Salzgitter Lebenstedt. *Journal of Human Evolution* 44: 263-273.

Musonda, F.B., 2012. 100 years of archaeological research in Zambia: changing historical perspectives. *The South African Archaeological Bulletin* 67(195): 88-100.

Mwakalila, S., 2005. Water resource use in the Great Ruaha Basin of Tanzania. *Physics and Chemistry of the Earth* 30: 903-912.

Nagaoka, L., 2006. Prehistoric seal carcass exploitation at the Shag Mouth site, New Zealand. *Journal of Archaeological Science* 33: 1474-1481.

Nagaoka, L., 2002a. Explaining subsistence change in southern New Zealand using foraging theory models. *World Archaeology* 34: 84-102.

Nagaoka, L., 2002b. The effects of resource depression on foraging efficiency, dietary breadth and patch use in southern New Zealand. *Journal of Anthropological Archaeology* 21: 419-442.

Nagaoka, L., 2001. Using diversity indices to measure changes in prey choice at the Shag River Mouth site, Southern New Zealand. *International Journal of Osteoarchaeology* 11: 101-111.

Ndangalasi, H.J., 1999. Off-field vegetation study: Ikuwala, Mkulula, Ilambilole and Kalenga villages, Iringa Rural District, Tanzania. Paper Prepared for the SASA Conference held in Copenhagen November 17-18, 1999.

Nelson, C., 1971. A Standardized Site Enumeration System for the Continent of Africa. *The Pan-African Congress on Prehistory and the Study of the Quaternary Commission on Nomenclature and Terminology* 4: 6-12.

NEMC, 1995. An environmental profile for Iringa Region. Dar es Salaam. Environmental Information Center of the NEMC.

Newmark, W.D., 1996. Insularization of Tanzanian Parks and the local extinction of large mammals. *Conservation Biology* 10(6): 1549-1556.

Nilssen, P.J., 2000. An actualistic butchery study in South Africa and its implications for the reconstructing hominid strategies of carcass acquisition and butchery in the Upper Pleistocene and Plio-Pleistocene. PhD dissertation, University of Cape Town.

Nitecki, M.H., Nitecki, D.V. (Eds.), 1987. *The Evolution of Human Hunting.* Plenum Press, New York.

Njau, J.K., Blumenschine, R.J., 2006. A diagnosis of crocodile feeding traces on larger mammal bone, with fossil examples from the Plio-Pleistocene Olduvai Basin, Tanzania. *Journal of Human Evolution* 50: 142-162.

Noe-Nygaard, N., 1989. Man-made trace fossils on bones. *Human Evolution* 4(6): 461-491.

Norton-Griffiths, M., Herlocker, D., and Pennycuick, L. 1975. The patterns of rainfall in the Serengeti ecosystem, Tanzania. *East African Wildlife Journal* 13: 347-374.

O'Brien, T.P., 1939. *The Prehistory of Uganda Protectorate.* University of Cambridge Press, Cambridge.

O'Connell, J.F., 1997. On Plio-Pleistocene archaeological sites and central places. *Current Anthropology* 38(1): 86-88.

O'Connell, J.F., Allen, J., 2004. Dating the colonization of Sahul (Pleistocene Australia New Guinea): a review of recent research. *Journal of Archaeological Science* 31: 835-853.

O'Connell, J.F., Hawkes, K., Blurton-Jones, N.G., 1992. Patterns in the distribution, site structure and assemblage composition of Hadza kill-butchering sites. *Journal of Archaeological Science* 19: 319-345.

O'Connell, J.F., Hawkes, K., Lupo, K.D., Blurton-Jones, N.G., 2002. Male strategies and Plio-Pleistocene archaeology. *Journal of Human Evolution* 43: 831-872.

O'Connell, J.F., Hawkes, K. Blurton-Jones, N.G., 1990. Reanalysis of large mammal body part transport among the Hadza. *Journal of Archaeological Science* 17: 301-316.

O'Connell, J.F., Hawkes, K., Blurton-Jones, N.G., 1988a. Hadza hunting, butchering and bone transport and their archaeological implications. *Journal of Anthropological Research* 44: 113-161.

O'Connell, J.F., Hawkes, K., Blurton-Jones, N.G., 1988b. Hadza scavenging: implications for Plio/Pleistocene hominid subsistence. *Current Anthropology* 29(2): 356-363.

Oliver, J.S., 2015. Diagnosing bone fracture to assess early hominin behaviour, meat-eating, and socioecology at FLK-*Zinjanthropus*, Olduvai Gorge, Tanzania. PhD dissertation, Liverpool John Moores University.

Oliver, J.S., 1994. Estimates of hominid and carnivore involvement in the FLK *Zinjanthropus* fossil assemblages: some socioecological implications. *Journal of Human Evolution* 27: 267-294.

Oliver, J.S., 1993. Carcass processing by the Hadza: bone breakage from butchery to consumption. In: Hudson, J. (Ed.), *From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains,* Carbondale, IL: Southern Illinois University, Center for Archaeological Investigations, pp. 200-227.

Oliver, J.S., 1989. Analogues and site context: bone damages from Shield Trap cave (24CB91), Carbon County, Montana, U.S.A. In: Bonnichsen, R., Sorg, M.H. (Eds.), *Bone modification.* Center for the Study of the First Americans, University of Maine, Orono, Maine, pp. 73-98.

Olsen, S.L., Shipman, P., 1988. Surface modification on bone: trampling versus butchery. *Journal of Archaeological Science* 15: 535-553.

Organista, E., Pernas-Hernández. M., Gidna, A., Yravedra, J., Domínguez-Rodrigo, M., 2016. An experimental lion-to-hammerstone model and its relevance to understand hominin-carnivore interactions in the archeological record. *Journal of Archaeological Science* 66: 69-77.

Orians, G.H., Pearson, N., 1979. On the theory of central place foraging. In: Horn, D. J., Stairs, G.R., Mitchell, R.D. (Ed.), *Analysis of Ecological Systems.* Ohio State University Press, Columbus, pp. 155-178.

Otarola-Castilo, E., 2010. Differences between NISP and MNE in cut mark analysis of highly fragmented faunal assemblages. *Journal of Archaeological Science* 37: 1-12.

Outram, A.K., 2002. Bone fracture and within-bone nutrients: an experimentally based method for investigating levels of marrow extraction. In: Milner, N., Miracle, P. (Eds.), *Consuming Passions and Patterns of Consumptions.* McDonald Institute for Archaeological Research, Cambridge pp. 51-64.

Outram, A.K., 2001. A new approach to identifying bone marrow and grease exploitation: why the ''indeterminate'' fragments should not be ignored. *Journal of Archaeological Science* 28: 401-410.

Owen-Smith, N., 2006. Demographic determination of the shape of the density dependence for three African ungulate populations. *Ecological Monographs* 76(1): 93-109.

Pääbo, S., 2003. The mosaic that is our genome. *Nature* 421: 409-412.

Packer, C., Hilborn, R., Mosser, A., Kissui, B., Borner, M., Wilmshurdt, J., Mduma, S., Simclair, A.R., 2005. Ecological change group territoriality and population dynamics in Serengeti Lions. *Science* 307: 390-393.

Pante, M.C., Blumenschine, R.J. 2010. Fluvial transport of bovid long bones fragmented by the feeding activities of hominins and carnivores. *Journal of Archaeological Science* 37: 846-854.

Pante, M.C., Blumenschine, R.J., Capaldo, S.D., Scott, R.S., 2012. Validation of bone surface modification models for inferring fossil hominin and carnivore feeding interactions, with reapplication to FLK 22, Olduvai Gorge, Tanzania. *Journal of Human Evolution* 63: 395-407.

Parkinson, J.A., 2013. A GIS image analysis approach to documenting Oldowan hominin carcass acquisition: evidence from Kanjera South, FLK *Zinj,* and neotaphonomic models of carnivore bone destruction. PhD dissertation, City University of New York.

Payne, S., 1983. Bones from cave sites: who ate what? problems and a case study. In: Clutton-Brock, J., C. Grigson, C. (Eds.), *Animals and Archaeology I. Hunters and their Prey*. British Archaeological Reports International Series 163, Oxford, pp. 149-162.

Payne, S., 1972. Partial recovery and sample bias: the results of some sieving experiments. In: Higgs, E.S. (Ed.), *Papers in Economic Prehistory.* Cambridge University Press, Cambridge, pp. 49-64.

Pearson, O.M., 2008. Statistical and biological definitions of ‘‘anatomically modern’’ humans: suggestions for a unified approach to modern morphology. *Evolutionary Anthropology* 17: 38-48.

Pearson, O.M., 2004. Has the combination of genetic and fossil evidence solved the riddle of modern human origins. *Evolutionary Anthropology* 13: 145-159.

Penny, D., Steel, M., Waddell, P. J., Hendy, M.D., 1995. Improved analyses of human mtDNA sequences support the recent African origin for *Homo sapiens*. *Molecular Biology Evolution*12: 863-882.

Perkins, D., Daly, P., 1968. A hunters' village in Neolithic Turkey. *Scientific American* 219: 97-106.

Peters, C.R., Blumenschine, R.J., Hay, R.L., Livingstone, D.A., Marean, C.W., Harrison, T., Armour-Chelu, M., Andrews, P., Bernor, R., Bonnefille, R., Werdelin, L., 2008. Paleoecology of the Serengeti-Mara ecosystem. In: Sinclair, A. R. E., Packer, C., Mduma, S.A.R., Fryxell, J.M. (Eds.), *Serengeti III: Human Impacts on Ecosystem Dynamics*. Chicago University Press, Chicago, pp. 47-94.

Phillipson, D.W., 2005. *African Archaeology.* 3rd Edition. Cambridge University Press, Cambridge.

Phillipson, D.W., 1986. Life in the Lake Victoria Basin. *Nature* 320: 110-111.

Pianka, E.R., 2000. *Evolutionary Ecology.* 6th Edition. Addison Wesley Education Publishers, San Francisco.

Pickering, T.R., 2002. Reconsideration of criteria for differentiating faunal assemblages accumulated by hyenas and hominids. *International Journal of Osteoarchaeology* 12: 127-141.

Pickering, T.R., Domínguez-Rodrigo, M., 2006. The acquisition and use of large mammals carcass by Oldowan hominids in eastern and southern Africa: a selected review and assessment. In: Toth, N., Schick, K. (Eds.), The *Oldowan: Case Studies into the Earliest Stone Age.* Stone Age Institute Press, Bloomington, pp. 113-128.

Pickering, T.R., Egeland, C.P., 2006. Experimental patterns of hammerstone percussion damage on bones: implications for inferences of carcass processing by humans. *Journal of Archaeological Science* 33: 459-469.

Pickering, T.R., Marean, C.W., Domínguez-Rodrigo, M., 2003. Importance of limb bone shaft fragments in zooarchaeology: a response to “On *in situ* attrition and vertebrate body part profiles (2002), by M. C. Stiner. *Journal of Archaeological Science* 30: 1469-1482.

Pickering, T.R., Domínguez-Rodrigo, M., Egeland, C.P., Brain, C.K., 2005. The contribution of limb bone fracture patterns to reconstructing early hominin behavior at Swartkrans cave (South Africa): archaeological application of a new analytical method. *International Journal of Osteoarchaeology* 15: 247-60.

Pickering, T.R., Egeland, C.P., Domínguez-Rodrigo, M., Brain, C.K., Schnell, A.G., 2008. Testing the "shift in the balance of power" hypothesis at Swartkrans, South Africa: hominid cave use and subsistence behavior in the early Pleistocene. *Journal of Anthropological Archaeology* 27: 30-45.

Pickering, T.R., Egeland, C.P., Schnell, A.G., Osborne, D.L., Enk, J., 2006. Success in identification of experimentally fragmented limb bone shafts: implications for estimates of skeletal element abundance in archaeofaunas. *Journal of Taphonomy* 4(2): 97-108.

Pobiner, B.L., 2007. Hominin-carnivore interactions: evidence from modern carnivore bone modification and early Pleistocence archaefaunas (Koobi Fora, Kenya; Olduvai Gorge, Tanzania. PhD dissertation, Rutgers, University.

Potts, R., 1988. *Early Hominid Activities at Olduvai*. Aldine de Gruyter, New York.

Potts, R., 1983. Foraging for faunal resources by early hominids at Olduvai Gorge, Tanzania. In: Clutton-Brook, J., Grison, C. (Eds.), 1983. *Animals and Archaeology: Hunters and their Prey.* British Archaeological Research International Series 163, Oxford, pp. 51-62.

Potts, R., 1982. Lower Pleistocenes sites formation and hominid activities at Olduvai Gorge, Tanzania. PhD dissertation, Harvard University, Massachusetts.

Potts, R., Shipman, P., 1981. Cutmarks made by stone tools on bones from Olduvai Gorge, Tanzania. *Nature* 292: 577-580.

Powell, A., Shennan, S., Thomas, M.G., 2009. Late Pleistocene demography and the appearance of modern human behavior. *Science* 324: 1298-1301.

Prendergast, M.E., 2008. Forager variability and transitions to food production in secondary settings: Kansyore and Pastoral Neolithic Economies in East Africa. PhD dissertation, Harvard University.

Prendergast, M.E., Luque, L., Domínguez-Rodrigo, M., Diez-Martín, F., Mabulla, A.Z.P., Barba, R., 2007. New excavations at Mumba rockshelter, Tanzania. *Journal of African Archaeology* 5(2): 217-243.

Pulliam, H., 1974. On the theory of optimal diets. *American Naturalist* 108: 59-74.

Pyke, G., 1984. Optimal foraging theory: a critical review. *Annual Review of Ecology and Systematic* 15: 59-74.

Rabinovich, R., Hovers, E., 2004. Faunal assemblages from Amud cave: preliminary results and interpretations. *International Journal of Osteoarchaeology* 14: 287-306.

Rabinovich, R., Gaudzinski-Windheuser, S., Goren-Inbar, N., 2008. Systematic butchering of fallow deer (*Dama*) at the early middle Pleistocene Acheulian site of Gesher Benot Ya'aqov (Israel). *Journal of Human Evolution* 54: 134-149.

Ranhorn, K., Brooks, A., Masao, F.T., Yellen, J., 2013. The Middle Stone Age of southern Tanzania: preliminary survey. A Paper presented at the Paleoanthropolgical Society, April 2nd and 3rd, Hawaii, Honolulu.

Reich, D., Patterson, N., Kircher, M., Delfin, F., Nandineni, M.R., Pugach., Ko, A. M-S., Ko, Y-C., Jinam, T.A., Phipps, M.E., Saitou, N., Wollstein, A., Kayser, M., Pääbo, S., Stoneking M., 2011. Denisova admixture and the first modern human dispersals into southeast Asia and Oceania. *The American Journal of Human Genetics* 89: 516-528.

Reid, A., Njau, J.E.K., 1994. Archaeological research in Karagwe District. *Nyame Akuma* 41: 68-73.

Reitz, J., Wing, E.S., 2008. *Zooarchaeology*. 2nd Edition. Cambridge University Press, Cambridge.

Relethford, J.H., 2008. Genetic evidence and the modern human origins debate. *Heredity* 100: 555-563.

Reynard, J.P., 2011. The unidentified long bone from the Middle Stone Age Still Bay layers at Blombos Cave, Southern Cape, South Africa. Msc dissertation, University of the Witwatersrand.

Reynard, J.P., Discamps, E., Badenhorst, S., van Niekerk, K., Henshilwood, C.S., 2016. Subsistence strategies in the southern Cape during the Howiesons Poort: taphonomic and zooarchaeological analyses of Klipdrift Shelter, South Africa. *Quaternary International* 404: 2-19.

Reynolds, T.E.G., 1991. Revolution or resolution? the archaeology of modern human origins. *World Archaeology* 23(2): 155-166.

Richards, M.P., Schmitz, R.W.S., 2008. Isotopic evidence for the diet of Neanderthal type specimen. *Antiquity* 82: 553-559.

Richards, M.P., Pettitt, P.B., Trinkaus, E., Smith,F.H., Paunovic, M., Karavanic, I., 2000. Neanderthal diet at Vindija and Neanderthal predation: the evidence from stable isotopes. *Proceedings of the National Academy of Sciences* 97(13): 7663-7666.

Richter, D., Grün, R., Joannes-Boyau, R., Steele, T.E., Amani, F., Rué, M., Fernandes, P., Rayna, J-P., Geraads, D., Ben-Ncer, A., Hublin, J-J., McPherron, S.P., 2017. The age of the hominin fossils from Jebel Irhoud, Morocco, and the origins of the Middle Stone Age. *Nature* 546: 293-296.

Rick, T.C., Erlandson, J.M., 2000. Early Holocene fishing strategies on the California coast: evidence from CA-SBA-2057. *Journal of Archaeological Science* 27(7): 621-633.

Robertshaw, P., 1990a. A history of African archaeology: an introduction. In: Robertshaw, P. (Ed.), *A History of African Archaeology.* James Currey, London, pp. 3-12.

Robertshaw, P., 1990b. The development of archaeology in East Africa. In: Robertshaw, P. (Ed.), *A History of African Archaeology.* James Currey, London, pp. 76-94.

Rodríguez-Hidalgo, A., Saladié, P., Ollé, A., Arsuaga, J.L., María, J., Castro, B., Carbonell, E., 2017. Human predatory behavior and the social implications of communal hunting based on evidence from the TD10.2 bison bone bed at Gran Dolina (Atapuerca, Spain). *Journal of Human Evolution* 105: 89-122.

Rogers, A.R., Jorde, L.B., 1995. Genetic evidence on modern human origins. *Human Biology* 67(1): 1-36.

Sahle, Y., Morgan, L.E., Braun, D.R., Atnafu, B., Hutchings, W.K., 2014. Chronological and behavioral contexts of the earliest Middle Stone Age in the Gademotta Formation, Main Ethiopian Rift. *Quaternary International* 331: 6-19.

Sawchuk, E., Willoughby, P.R., 2015. Terminal Pleistocene Later Stone Age human remains from the Mlambalasi rockshelter, Iringa Region, southern Tanzania. *International Journal of Osteoarchaeology* 25(5): 593-607.

Schaller, G.B., 1972. *The Serengeti Lion: A Study of Predator-Prey Relations.* Chicago University Press, Chicago.

Schick, K.D., 1987. Modeling the formation of the early Stone Age artefact concentrations. *Journal of Human Evolution* 16: 789-808.

Schick, K.D., 1984. Processes of Paleolithic site formation: an experimental study. Ethiopia. PhD dissertation, University of Berkeley, Berkeley.

Schiffer, M.B., 1983. Toward the identification of formation processes. *American Antiquity* 48(4): 675-706.

Schmid, E., 1972. *Atlas of Animal Bones: For Prehistorians, Archaeologists and Quaternary Geologists*. Elsevier Publishing Company, Amsterdam.

Schmidt, P.R., 2005. Teaching revolutionary archaeology: African experiments in history making and heritage management. *Archaeologies* 1(2): 46-59.

Schoener, T.W., 1979. Generality of the size-distance relation in models of optimal foraging. *American Naturalist* 114: 902-914.

Scholz, C.A., Johnson, T.C., Cohen, A.S., King, J.W., Peck, J.A., Overpeck, J.T., Talbot, M.R., Brown, E.T., Kalindekafe, L., Amoako, P.Y.O., Lyons, R.P., Timothy, M., Shanahan, T.M., Castañeda, I.S., Heil, C.W., Forman, S.L., McHargue, L.R., Beuning, K.R., Gomez, J., Pierson, J., 2007. East African megadroughts between 135 and 75 thousand years ago and bearing on early-modern human origins. *Proceedings of the National Academy of Sciences* 104(42): 16416-16421.

Seitsonen, O., 2007. Middle Stone Age component at the abandoned Sonjo Buri village site, Tanzania. *Nyame Akuma* 67: 75-80.

Seitsonen, O., 2006. Archaeological research in the northern Lake Manyara Basin, Tanzania 2003-2004. *Azania* 41: 26-52.

Seitsonen, O., 2005. Stone Age observations in the Engaruka area. *Nyame Akuma* 63: 27-32.

Selvaggio, M.M., 1998. Evidence for a three-stage sequence of hominid and carnivore involvement with long bones at FLK *Zinjanthropus*, Olduvai Gorge, Tanzania. *Journal of Archaeological Science* 25: 191-202.

Selvaggio, M.M., 1994a. Carnivore tooth marks and stone tool butchery marks on scavenged bones: archaeological implications. *Journal of Human Evolution* 27: 215-228.

Selvaggio, M.M., 1994b. Evidence from carnivore tooth marks and stone-tool-butchery marks for scavenging by hominids at FLK *Zinjanthropus* Olduvai Gorge, Tanzania. PhD dissertation, Rutgers University.

Selvaggio, M.M., Wilder, J., 2001. Identifying the involvement of multiple carnivore taxa with archaeological bone assemblages. *Journal of Archaeological Science* 28: 465-470.

Sept, J., 2001. Modeling the edible landscape. In: Stanford, C.B., Bunn, H.T. (Eds.), *Meat-eating and Human Evolution.* Oxford University Press, Oxford, pp. 73-100.

Shaw, T., 1989. African archaeology: looking back and looking forward. *The African Archaeological Review* 7: 3-32.

Shea, J.J., 2011a. *Homo sapiens* is as *Homo sapiens* was: behavioural variability versus "behavioral modernity" in Paleolithic archaeology. *Current Anthropology* 52: 1-35.

Shea, J.J., 2011b. Refuting a myth about human origins: *Homo sapiens* emerged once, not as modern-looking people first and as modern-behaving people later. *American Scientist* 99: 128-135.

Shea, J.J., 2009. The impact of projectile weaponry on Late Pleistocene hominin evolution. In: Hublin, J-J., Richards, M.P. (Eds.), *The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence.* Springer, New York, pp. 189-199.

Shea, J.J., 2006. The origins of lithic projectile point technology: evidence from Africa, the Levant, and Europe. *Journal of Archaeological Science* 33: 823-846.

Sheehan, M.S., 2004. Ethnographic models, archaeological data and the applicability of modern foraging theory. In: Barnard, A. (Ed.), *Hunter-gatherers in History, Archaeology and Anthropology.* Berg, New York, pp. 163-173.

Shennan, S., 2001. Demography and cultural innovation: a model and its implications for the emergence of modern human culture. *Cambridge Archaeological Journal* 11(1): 5-16.

Shipman, P., 1986. Scavenging or hunting in early hominids: theoretical framework and tests. *American Anthropologist* 88: 27-43.

Shipman, P., 1981. *Life History of a Fossil: An Introduction to Taphonomy and Paleoecology.* Harvard University Press, Cambridge.

Shipman, P., Rose, J., 1983. Early hominid hunting, butchering, and carcass processing behaviors: approaches to the fossil record. *Journal of Anthropological Archaeology* 2: 57-98.

Sikes, N., 1994. Early hominid habitat preferences in East Africa: paleosol carbon isotope evidence. *Journal of Human Evolution* 27: 25-25.

Sinclair, A.R.E., 1995. Serengeti past and present. In: Sinclair, A.R.E., Arcese, P. (Eds.), *Serengeti II: Dynamics, Management and Conservation of an Ecosystem.* Chicago University Press, Chicago, pp. 3-30.

Sinclair, A.R.E., 1979a. Dynamics of the Serengeti National Park. In: Sinclair, A.R.E., Norton-Griffiths., M. (Eds.), *Serengeti I: Dynamics of an Ecosystem.* Chicago University Press, Chicago, pp. 1-30.

Sinclair, A.R.E., 1979b. The Serengeti environment. In: Sinclair, A.R.E., Norton-Griffiths., M. (Eds.), *Serengeti I: Dynamics of an Ecosystem.* Chicago University Press, Chicago, pp. 31-45.

Sinclair, A.R.E., Norton-Griffiths., M. (Eds.), 1979. *Serengeti I: Dynamics of an Ecosystem.* Chicago University Press, Chicago.

Sinclair, A.R.E., Arcese, P., 1995a. Serengeti in the context of worldwide conservation efforts. In: *Serengeti II: Dynamics Management and Conservation of an Ecosystem.* Chicago University Press, Chicago, pp. 31-46.

Sinclair, A.R.E., Arcese, P. (Eds.), 1995b. *Serengeti II: Dynamics Management and Conservation of an Ecosystem.* Chicago University Press, Chicago.

Sinclair, A. R. E., Packer, C., Mduma, S.A.R., Fryxell, J.M. (Eds.), 2008. *Serengeti III: Human Impacts on Ecosystem Dynamics*. Chicago University Press, Chicago.

Singer, R., Wymer, J., 1982. *The Middle Stone Age at Klasies River Mouth in South Africa.* University of Chicago Press, Chicago.

Skinner, A.R., Hay, R.L., Masao, F., Blackwell, B.A.B., 2003. Dating the Naisiusiu Beds, Olduvai Gorge, by electron spin resonance. *Quaternary Science Reviews* 22: 1361-1366.

Smith, E.A., 1983. Anthropological applications of optimal foraging theory: a critical review. *Current Anthropology* 24: 625-651.

Smith, E.A., Winterhalder, B., 2003. Human behavioural ecology. In: *Encyclopaedia of Cognitive Science* Vol. 2, pp. 375-385.

Smith, E.A., Winterhalder, B., 1985. On logic and application of optimal foraging theory: a brief reply to Martin. *American Anthropologist* 87: 647-648.

Smith, F.H., 1992. The role of continuity in modern human origin. In: Bräuer, G., Smith, F. (Eds.), *Continuity or Replacement? Controversies in Homo sapiens Evolution.* Balkema, Rotterdam, pp. 145-156.

Smith, F.H., Janković, I., Karavanić, I., 2005. The assimilation model, modern human in Europe and the extinction of Neanderthals. *Quaternary International* 137(1): 7-19.

Smith, F.H., Falsetti, A.B., Donnelly, S.M., 1989. Modern human origins. *Yearbook of Physical Anthropology* 32: 35-68.

Smith, T.M., Tafforeau, P., Reid, D.J., Grün, R., Eggins, S., Boutakiout, M., 2007. Earliest evidence of modern human life history in North African early *Homo sapiens*. *Proceedings of the National Academy of Sciences* 104: 6128-6133.

Smolla, G., 1962. Steingeraete vom Tendaguru. *Actes du IVe Congress Pan-Afrieain de Prd- histoire et de l'dtude du Quaternaire, Section lII. Pret Proto-histoire,* Tervuren, Musée royal de t'Afrique centrale, pp. 243-249.

Soper, R.C., Golden, B., 1969. An archaeological survey of Mwanza Region, Tanzania. *Azania* 4: 15-79.

Speth, J.D., 1989. Early hominid hunting and scavenging: the role of meat as an energy source. *Journal of Human Evolution* 18: 329-343.

Speth, J.D., Tchernov, E., 2007. The Middle Palaeolithic occupations at Kebara cave: a faunal perspective. In: Bar-Yosef, O., Meignen, L. (Eds.), *Kebara Cave, Mt. Carmel, Israel: The Middle and Upper Palaeolithic Archaeology*. Peabody Museum of Archaeology and Ethnology, Cambridge, pp. 165-260.

Speth, J.D., Tchernov, E., 2002. Middle Paleolithic tortoise use at Kebara Cave (Israel). *Journal of Archaeological Science* 29: 471-483.

Speth, J.D., Tchernov, E., 2001. Neanderthals hunting and meet processing in Near East: evidence from Kebara Cave (Israel). In: Stanford, C.B., Bunn, H.T. (Eds.), *Meat-eating and Human Evolution.* Oxford University Press, Oxford, pp. 52-72.

Speth, J.D., Tchernov, E., 1998. The role of hunting and scavenging in neaderthals procurement strategies: new evidence from Kebara Cave (Israel). In: Akazawa, T., Aoki, K., Bar-Yosef, O. (Eds.), *Neanderthals and Modern Human in Western Asia.* Plenum Press, New York, pp. 223-239.

Spiller, K., Skinner, A., Willoughby, P.R., T. Colbert, T., 2014. Electron spin resonance (ESR) dating and human evolution. Paper presented at the 2014 Meeting of the Palaeoanthropology Society, Calgary, Alberta.

Stanford, C.B., Bunn, H.T. (Eds.), 2001. *Meat-eating and Human Evolution.* Oxford University Press, Oxford.

Steele, T.E., 2005. Comparing methods for analyzing mortality profiles in zooarchaeological and palaeontological samples. *International Journal of Osteoarchaeology* 15: 404-420.

Steele, T.E., Klein, R.G., 2009. Late Pleistocene subsistence strategies and resource intensification in Africa. In: Hublin, J-J., Richards, M.P. (Eds.), *The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence.* Springer, New York, pp. 113-126.

Steele, T.E., Weaver, T.D., 2002. The modified triangular graph: a refined method for comparing mortality profiles in archaeological samples. *Journal of Archaeological Science* 29: 317-322.

Steffen, M., Mackie, Q., 2005. An experimental approach to understanding burnt fish bone assemblages within archaeological hearth contexts. *Canadian Zooarchaeology* 23: 11-38.

Stephens, D.W., Krebs, J., 1986. *Foraging Theory.* Princeton University Press, Princeton.

Stiner, M.C., 2005. *The Faunas of Hayonim Cave, Israel: A 200,000-Year Record of Paleolithic Diet, Demography, and Society***.** Peabody Museum of Archaeology and Ethnology, Cambridge.

Stiner, M.C., 2002. On *in situ* attrition and vertebrate body part profiles. *Journal of Archaeological Science* 29: 979-991.

Stiner, M.C., 1994. *Honour among thieves: A Zooarchaeological Study of Neanderthal Ecology.* Princeton University Press, Princeton.

Stiner, M.C., 1991a. Food procurement and transport by human and non-human predators. *Journal of Archaeological Science* 18: 455-482.

Stiner, M.C. (Ed.), 1991b. *Human Predators and Prey Mortality.* Westview Press, Colorado.

Stiner, M.C., 1990. The use of mortality patterns in archaeological studies of hominid predatory adaptations. *Journal of Anthropological Archaeology* 9: 305-351.

Stiner, M.C., Munro, N.D., 2002. Approaches to prehistoric diet breadth, demography and prey ranking systems in time and space. *Journal of Archaeological Method and Theory* 9: 181-214.

Stiner, M.C., Barkai, R., Gopher, A., 2009. Cooperative hunting and meat sharing 400-200 kya at Qesem Cave, Israel. *Proceedings of the National Academy of Sciences* 106 (32): 13207-13212.

Stiner, M.C., Munro, N.D., Surovell, T.A., 2000. The tortoise and the hare small-game use, the broad-spectrum revolution, and palaeolithic demography. *Current Anthropology* 41(1): 39-73.

Stiner, M.C., Kuhn, S.L., Weiner, S., Bar-Yosef, O., 1995. Differential burning, re-crystallization, and fragmentation of archaeological bone. *Journal of Archaeological Science* 22: 223-237.

Stiner, M.C., Munro, N.D., Surovell, T.A., Tchernov, E., Bar-Yosef, O., 1999. Paleolithic population growth pulses evidenced by small animal exploitation. *Science* 283: 190-194.

Stoneking, M., Cann, R.L., 1989. African origin of human Mitochondrial DNA. In: Mellars, P., Stringer, C.B. (Eds.), *The Human Revolution: Behavioural and Biological Perspectives on the Origins of Modern Humans.* Princeton University Press, Princeton, pp. 17-30.

Stringer, C.B., 2002. Modern human origins: progress and prospects. *Philosophical Transactions of the Royal Society of London Series* 357B(1420): 563-579.

Stringer, C.B., 2001. Modern human origins-distinguishing the models. *African Archaeological Review* 18(2): 67-75.

Stringer, C.B., 1990. The emergence of modern humans. *Science American* 263(6): 98-104.

Stringer, C.B., Andrews, P., 1988. Genetic and fossil evidence for the origin of modern humans. *Science* 239: 1265-1268.

Sutcliffe, A. J., 1970. Spotted hyena: crusher, gnawer, digester, and collector of bones. *Nature* 227: 1110-1113.

Taçon, P., 2010. Neanderthals and us: conflicting new interpretations on our relationship to each other. *Before Famining* 3: 1-10.

TANAPA, 2012. TANAPA Today. TANAPA, Arusha.

TANAPA, 2006. Serengeti National Park General Management Plan 2006-2016. TANAPA, Arusha.

Templeton, A.R., 2002. Out of Africa again and again. *Nature* 416: 45-51.

Templeton, A.R., 1997. Advocacy for the multiregional hypothesis. *Current Anthropology* 38(5): 921-922.

Templeton, A.R., 1993. The “Eve” hypotheses: a genetic critique and reanalysis. *American Anthropologist* 95(1): 51-72.

Templeton, A.R., 1992. Human origins and analysis of mitochondrial DNA sequences. *Science* 255: 737-739.

Thompson, J.C., 2010. Taphonomic analysis of the Middle Stone Age faunal assemblage from Pinnacle Point Cave 13B, Western Cape, South Africa. *Journal of Human Evolution* 59: 321-339.

Thompson, J.C., 2008. Zooarchaeological tests for modern human behavior at Blombos Cave and Pinnacle Point Cave 13B, Southwestern Cape, South Africa. PhD dissertation, Arizona State University.

Thompson, J.C., 2005. The impact of post-depositional processes on bone surface modification frequencies: a corrective strategy and its application to the Loiyangalani site, Serengeti Plain, Tanzania. *Journal of Taphonomy* 3(2): 57-80.

Thompson, J.C., Henshilwood, S.C., 2014a. Nutritional values of tortoises relative to ungulates from the Middle Stone Age levels at Blombos Cave, South Africa: implications for foraging and social behaviour. *Journal of Human Evolution* 67: 33-47.

Thompson, J.C., Henshilwood, S.C., 2014b. Tortoise taphonomy and tortoise butchery patterns at Blombos Cave, South Africa. *Journal of Archaeological Science* 41: 214-229.

Thompson, J.C., Henshilwood, C.S., 2011. Taphonomic analysis of the Middle Stone Age larger mammal faunal assemblage from Blombos Cave, Southern Cape, South Africa. *Journal of Human Evolution* 60: 746-767.

Thompson, J.C., Faith, J.T., Cleghorn, N., Hodgkins, J., 2017. Identifying the accumulator: making the most of bone surface modification data. *Journal of Archaeolgical Science* 85: 105-113.

Thompson, J.C., Bower, J.R.F., Mabulla, A.Z.P., Marean, C.W., Stewart, K., Vondler, C.F., Fischer, E.C., 2004. Loiyangalani: behavior and taphonomic aspects of Middle Stone Age site in Serengeti plain, Tanzania. Abstracts of the Paleoanthropology Society Annual Meeting, Montreal, March 29-30. *Paleoanthropology* (http://www.paleoanthro.org).

Thorne, A.G., Wolpoff, M.H., 1992. The multiregional evolution of humans. *Scientific American* 266(4): 76-83.

Thorne, A.G., Wolpoff, M.H., 1981. Regional continuity in Australasian Pleistocene hominid evolution. *American Journal of Physical Anthropology* 55: 337-349.

Trigger, B., 2008. *A History of Archaeological Thought.* 2nd edition. Cambridge University Press, Cambridge.

Trigger, B., 1984. Alternative archaeologies: nationalist, colonialist and imperialism. *Man* 19: 763-787.

Tryon, C.A., Faith, T.J., 2013. Variability in the Middle Stone Age of Eastern Africa. *Current Anthropology* 54: S234-254.

Tryon, C.A., McBrearty, S., 2006. Tephrostratigraphy of the Bedded Tuff Member (Kapthurin Formation, Kenya) and the nature of archaeological change in the later Middle Pleistocene. *Journal of Human Evolution* 65: 492-507.

Turner, A., 1989. Sample selection, schlep effects and scavenging: the implications of partial recovery for interpretations of the terrestrial mammal assemblage from Klasies River Mouth. *Journal of Archaeological Science* 16: 1-11.

Ugan, A., 2005a. Climate, bone density, and resource depression: what is driving variation in large and small game in Fremont archaeofaunas? *Journal of Anthropological Archaeology* 24: 227-251.

Ugan, A., 2005b. Does size matter? body size, mass collecting, and their implications for understanding prehistoric foraging behaviour. *American Antiquity* 70: 75-89.

Ugan, A., Bright, J., 2001. Measuring foraging efficiency with archaeological faunas: the relationship between relative abundance indices and foraging returns. *Journal of Archaeological Science* 28: 1309-1321.

Ugan, A., Bright, J., Rogers, A., 2003. When is technology worth the trouble? *Journal of Archaeological Science* 30: 1315-1329.

Underhill, P.A., Kivisild, T., 2007. Use of Y-chromosome and mitochondrial DNA population structure in tracing human migrations. *Annual Review Genetics* 41: 539-64.

Underhill, P.A., Passarino, G., Lin, A.A., Shen, P., Mirazon, L.M., Foley, R.A., Oefner, P.J., Cavalli-Sforza, L.L., 2001. The phylogeography of Y-chromosome binary haplotypes and the origins of modern human populations. *Annals of Human Genetics* 65: 43-62.

Ungar, P. (Ed.), 2007. *Evolution of the Human Diet: The Known, the Unknown, and the Unknowable.* Oxford University Press, Oxford.

Ungar, P.S., Teaford, M.F. (Eds.), 2002. *Human Diet: Its Origin and Evolution*. Bergin and Garvey, Westport.

URT, 2010. Eastern Arc Mountains Forests of Tanzania: Nomination of the Properties for the Inclusion on the World Heritage List Serial Nomination. Ministry of Natural Resources and Tourism, Dar es Salaam.

Valladas, H., Mercier, N., Joron, J-L., Reyss, J-L., 1998. GIF laboratory dates for the Middle Paleolithic Levant. In: Akazawa, T., Aoki, K., Bar-Yosef, O. (Eds.), *Neaderthals and Modern Human in Western Asia.* Plenum Press, New York, pp, pp. 69-76.

Vesey-Fitzgerald, D., 1973. *East African Grasslands.* East African Publishing House, Nairobi.

Vigilant, L., Stoneking, M., Harpending, H., Hawkes, K., Wilson, A.C., 1991. African populations and the evolution of mitochondria DNA. *Science* 253: 1503-1507.

Villa, P., Lenoir, M., 2009. Hunting and hunting weapons of the Lower and Middle Paleolithic of Europe. In: Hublin, J.-J., Richards, M.P. (Eds.), *The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence.* Springer, Dordrecht, pp. 59-86.

Villa, P., Mahieu, E., 1991. Breakage patterns of human long bones. *Journal of Human Evolution* 21: 27-48.

Villa, P., Castel, J-C., Beauval, C., Bourdillat, V., Goldberg, P., 2004. Human and carnivore sites in the European Middle and Upper Palaeolithic: similarities and differences in bone modification and fragmentation. *Revue de Paleobiologie* 23: 705-730.

Voorhies M.R., 1969. *Taphonomy and Population Dynamics of the Early Pliocene Vertebrate Fauna Knox County Nebraska*. University of Wyoming Contributions to Geology Special Paper no 1. Laramie.

Vrba, E.S., 1980. The significance of bovid remains as an indicator of environment and predation patterns. In: Behrensmeyer, A.K., Hill, A.P. (Eds.), *Fossils in the Making*. University of Chicago Press, Chicago, pp. 247-272.

Wadley, L., 2010. Were snares and traps used in the Middle Stone Age and does it matter? A review and a case study from Sibudu, South Africa. *Journal of Human Evolution* 58: 179-192.

Wadley, L., 2001. What is cultural modernity? a general view and a South African perspective from Rose Cottage Cave. *Cambridge Archaeological Journal* 11(2): 201-21.

Wadley, L., 1997. Rose Cottage Cave: archaeological work 1987 to 1997. *South African Journal of Science* 93: 439-444.

Wakibara, J., 2012. Importance of wildebeests for Serengeti Ecology. TANAPA Newsletter 013: 26-27.

Walker, R., 1985. *A Guide to Post-Cranial Bones of East African Mammals.* Hylochoerus Press, Norwich.

Walker, R.C., Manega, P.C., Hay, R.L., Drake, R.E., Curtis, G.H., 1991. Laser-fusion ^{40}Ar/^{39}Ar dating of Bed I, Olduvai Gorge, Tanzania. *Nature* 354: 145-149.

Washburn, S.L., Lancaster, C.S., 1968. The evolution of hunting. In: Lee, R., DeVore, I. (Eds.), *Man the Hunter.* Aldine, Chicago, pp. 293-303.

Wayland, E.J., 1929. African pluvial periods and prehistoric man. *Man* 29: 118-121.

Wayland, E.J., 1924. The Stone-Age in Uganda. *Man* 24: 169-170.

Wendorf, F., Laury, R.L., Albritton, C.C., Schild, R., Haynes, C.V., Damon, P.E., Shafiqullah, M., Scarborough, R., 1975. Dates for the Middle Stone Age of East Africa. *Science* 187: 740-742.

Werner, J.J. 2014. The evolution of technological behaviour: an analysis of lithic artefacts from the Magubike archaeological site, Tanzania. MA thesis, University of Alberta.

Werner, J.J., Willoughby, P.R., 2017. Middle Stone Age technology and cultural evolution at Magubike rockshelter, southern Tanzania. *African Archaeological Review* 34(2): 249-273.

Wheeler, A., Jones, A.K.G., 1989. *Fishes*. Cambridge University Press, Cambridge.

White, T.D., Asfaw, B., DeGusta, D., Gilbert, H., Richards, G.D., Suwa, G., Howell, F.C. 2003. Pleistocene *Homo sapiens* from Middle Awash, Ethiopia. *Nature* 423: 742-747.

White, T.E., 1953. A method of calculating the dietary percentage of various food animals utilized by aboriginal peoples. *American Antiquity* 18: 396-398.

White, T.E., 1952. Observations on the butchering technique of some Aboriginal peoples. *American Antiquity* 19(3): 254-264.

Willoughby, P.R., 2016. Field Notes from Iringa, Tanzania. Unpublished Report.

Willoughby, P.R., 2012a. Inventory of artifacts collected from Magubike rockshelter (HxJf-1), Iringa Region, Tanzania. Unpublished Report Submitted to Department of Antiquities, Dar es Salaam, Tanzania.

Willoughby, P.R., 2012b. The Middle and Later Stone Age in the Iringa Region of Southern Tanzania. *Quaternary International* 270: 103-118.

Willoughby, P.R., 2007. *The Evolution of Modern Humans in Africa: A Comprehensive Guide.* AltaMira Press, Lanham.

Willoughby, P.R., 2005. Field Notes from Iringa, Tanzania. Unpublished Report.

Willoughby, P.R., 1996. The Middle Stone Age in Southwestern Tanzania. *Kaupia* 6: 57-69.

Willoughby, P.R., 1992. An archaeological survey of the Songwe River Basin, Southwestern Tanzania. *Nyame Akuma* 37: 28-35.

Willoughby, P.R., 1990. Stone age archaeology in Mbeya and Rukwa Regions, Southwestern Tanzania. *Nyame Akuma* 34: 30-37.

Wilson, A.C., Cann, R.L., 1992. The recent African genesis of humans. *Scientific American* 266(4): 68-73.

Winterhalder, B., 2002. Behavioural and other human ecologies: critique, response and progress through criticism. *Journal of Ecological Anthropology* 6: 4-22.

Winterhalder, B., 1997. Given, gifts taken: the behavioural ecology of nonmarket, intragroup exchange. *Journal of Archaeological Research* 5: 121-168.

Winterhalder, B., 1981a. Foraging strategies in the boreal forest: an analysis of Cree hunting and gathering. In: Winterhalder, B., Smith, E.A. (Ed.), *Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses*. University of Chicago Press, Chicago, pp. 66-98.

Winterhalder, B. 1981b. Optimal foraging strategies and hunter-gatherer research in anthropology: theory and models. In: Winterhalder, B., Smith, E.A. (Ed.), *Hunter-Gatherer Foraging Strategies: Ethnographic and Archaeological Analyses*. University of Chicago Press, Chicago, pp. 13-35.

Winterhalder, B., Smith, E.A., 2000. Analyzing adaptive strategies: human behavioural ecology at twenty-five. *Evolutionary Anthropology* 9: 51-72.

Wintle, A., 1996. Archaeologically-relevant dating techniques for the next century: small, hot and identified by acronyms. *Journal of Archaeological Science* 25(1): 123-138.

Wolanski, E., Gereta, E., 2001. Water quantity and quality as the factors driving the Serengeti ecosystem, Tanzania. *Hydrobiologia* 458: 169-180.

Wolpoff, M.H., 1992. Theories of modern human origins. In: Bräuer, G., Smith, F.H. (Eds.), *Continuity or Replacement*. Balkema, Rotterdam, pp. 25-63.

Wolpoff, M.H., 1989. Multiregional evolution: the fossil alternative to Eden. In: Mellars, P., Stringer, C.B. (Eds.), *The Human Revolution: Behavioral and Biological Perspectives on the Origins of Modern Humans.* Princeton University Press, Princeton, pp. 62-108.

Wolpoff, M.H., Caspari, R., 1997. What does it mean to be modern? In: Clark, G.A., Willermet, C.M. (Eds.), *Conceptual Issues in Modern Human Origins Research.* Aldine De Gruyer, New York, pp. 28-44.

Wolverton, S., 2002. NISP: MNE and %whole in analysis of prehistoric carcass exploitation. *North American Archaeologist* 23(2): 85-100.

Woodborne, S., 2004. Report on Radiocarbon Analysis, Loiyangalani Sample 3770, Laboratory Analysis No. GrA26016 (CSIR Environmentek), Pretoria.

Wynn, T., Chadderdon, T., 1982. The Kiwira Industry and the Later Stone Age of the Nyakyusa Basin. *Azania* 17: 127-143.

Yellen, J.E., 1991. Small mammals: !Kung San utilization and the production of faunal assemblages. *Journal of Anthropological Archaeology* 10: 1-26.

Yellen, J.E., 1977. *Archaeological Approaches to the Present: Models for Reconstructing the Past.* Academic Press, New York.

Yellen, J., Brooks, A.S., Helgren, D.M., Tappen, M., Ambrose, S.H., Bonnefille, R., Feathers, J., Goodfriend, G., Ludwig, K., Renne, P., Stewart, K.M., 2005. The archaeology of Aduma Middle Stone Age Sites in the Awash Valley, Ethiopia. *PaleoAnthropology* 10: 25-100.

Yeshurun, R., Bar-Oz, G., Weinstein-Evron, M., 2007. Modern hunting behavior in the early Middle Paleolithic: faunal remains from Misliya cave, Mount Carmel, Israel. *Journal of Human Evolution* 53: 656-677.

Yravedra, J., Domínguez-Rodrigo, M., 2009. The shaft-based methodological approach to the quantification of long limb bones and its relevance to understanding hominid subsistence in the Pleistocene: application to four Paleolithic sites. *Journal of Quaternary Science* 24(1): 85-96.

Appendix 1

MSA Sites in Tanzania Mentioned in this Dissertation

Site Name	Site Type	Nature of the Finds	Faunal Reported	References
Mumba	Rockshelter	Excavation	Yes	Mehlman 1989
Skull site/Near Mumba	Open-air	Surface	Yes	Kohl-Larsen 1943; Leakey 1936b
Sonai	Rockshelter	Excavation	No	Prendergast 2008
Lake Eyasi Lakebed	Open-air	Surface/Excavation	Yes	Domínguez-Rodrigo et al. 2008
Kisese II	Rockshelter	Excavation	No	Inskeep 1962
Haubi	Open-air	Surface	No	Masao 1992
DKB 11 and 12	Open-air	Surface	No	Masao 1992
Nasera	Rockshelter	Excavation	Yes	Mehlman 1977, 1989
Ngaloba Beds	Open-air	Excavation	Yes	Day et al, 1980
Ndutu Beds sites	Open-air	Surface/ Excavation	Yes	Leakey et al. 1972; Mabulla 1990a, b; Eren et al. 2013
Seronera	Open-air	Surface	No	Bower, 1973
Ichumbe Kopje	Open-air	Surface	No	TANAPA 2006
Pololeti Kirawira	Open-air	Surface	No	Masao et al. 2003
Loiyangalani	Open-air	Surface/Excavation	Yes	Bower 1977; Bower et al. 1985
Makundusi	Open-air	Surface	No	Lyaya 2016
Mbono River	Open-air	Surface	Yes	Kihwele pers. com 2016
Sonjo Buri	Open-air	Surface/Excavation	No	Seitsonen 2005, 2007
Lolchoro 1	Open-air	Surface	No	Seitsonen 2005, 2007
Engaruka Basin	Open-air	Surface	No	Keller et al. 1975
Unoto Resort 1a, 1c & 1c	Open-air	Surface	No	Seitsonen 2006
Edonyo Emwalimui Hill	Open-air	Surface	No	Seitsonen 2005
Tarangire River	Open-air	Surface	No	ACM
Olasiti Village	Open-air	Surface	No	ACM
Kibaoni Village	Open-air	Surface/Exavation	No	Zane 2009
Nyara River	Open-air	Surface	No	Clark 1988
Galula	Open-air	Surface	No	Clark 1988
Songwe River Valley sites	Open	Surface/Excavation	No	McBrearty et al. 1982, 1984
Ilima	Open-air	Surface	No	Clark 1988

Chamoto Hill	Open-air	Surface	Yes	Willoughby 1992; Biittner 2011
Isimila	Open-air	Surface	No	Willoughby 2007
Magubike	Rockshelter	Excavation	Yes	Collins 2009,
Mlambalasi	Rockshelter	Excavation	Yes	Collins 2009
Kigwabimbi	Open-air	Surface	No	Bushozi 2011
Kessakilolo	Rockshelter	Surface	No	Bushozi 2011
Nyamihuu	Open-air	Surface	No	Itambu 2013
Tendaguru	Open-air	Surface	No	Smolla 1962
Mbwemkuru Valley	Open-air	Surface	No	Kwekason 2011
Kimbilimu Hill*	Open-air	Surface	No	Kwekason 2011
Kipili*	Open-air	Surface	No	Kwekason 2011
Mandawa Village*	Open-air	Surface	No	Kwekason 2011
Chikotwa*	Open-air	Surface	No	Kwekason 2011
Kiliamanda Hill*	Open-air	Surface	No	Kwekason 2011
Mikadi (Newala)*	Open-air	Surface	No	Kwekason 2011
Nguruni	Open-air	Surface	No	Isaac 1974
Masakasa	Open-air	Surface	No	Isaac 1974
Kizimbani	Open-air	Surface	No	Karoma 1982
Kagera Basin	Open-air	Surface	No	O'Brien 1939
Ruhanga	Rockshelter	Excavation	No	Kwekason and Chami 2003
Rwambaizi	Open-air	Surface	No	Reid and Njau 1994
Kibwera	Open-air	Surface	No	Reid and Njau 1994
Buzwagi	Open-air	Surface	No	Masao 2009
Matongo	Open-air	Surface	No	Masao 1992

*Unpublished MSA assemblages preserved in the National Museum of Tanzania in Dar es Salaam