Transitions to animal domestication in Southeast Asia:

Zooarchaeological analysis of Cồn Cổ Ngựa and Mán Bạc, Vietnam

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To the best of my knowledge, the research presented in this thesis is my own except in cases where I acknowledge the work of other researchers. This thesis has not been submitted in any other form at this or any university.

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Abstract

The domestication of plants and animals was a pivotal process that significantly affected and shaped the trajectory of human history. However, this transition is still poorly understood in many parts of the world. For Mainland Southeast Asia (MSEA), most researchers believe this transition was initialised by a migration of agricultural groups that spread from the Yangtze into MSEA following rivers and the coastline (Bellwood and Oxenham 2008; Matsumura et al. 2008; 2011). This hypothesis posits that these migrant populations brought domesticated crops and animals into the region and lived alongside indigenous hunter-gatherer groups.

This thesis analyses the transition from hunting and gathering to domestication by comparing the taphonomic and taxonomic characteristics of the faunal assemblages of Cồn Cổ Ngựa (CCN) and Mán Bạc (MB) in northern Vietnam. Both sites were selected as they sit on either side of the presumed hunter-gatherer (CCN) and agricultural (MB) subsistence transition in Vietnam and have the potential to show crucial societal changes. Since CCN and MB are burial sites, human-animal interactions at the sites have the potential to portray the belief systems and ontology of the people. The ultimate aim was to contextualise CCN and MB within the framework of subsistence change in Southeast Asia (SEA) and determine how and whether human behaviour and human-animal relationships developed during this purported transitional phase in the Mid Holocene.

A clear and perceivable shift in the faunal composition between CCN and MB was found, and this transition can be confidently attributed to the introduction of domesticated animals around 4,000 cal. BP to northern Vietnam. Further, results from the principal component analysis of sites throughout SEA showed that the relative proportions of certain taxa can be useful in separating hunter-gatherer and agricultural based sites across the region, as well as revealing outliers based on localised environments and/or choice. It was emphasised that this transition from ‘hunting to farming’ was by no means clear-cut. MB still had a strong emphasis on hunting wild taxa and fishing, and these permeable cultural-economic boundaries are also perceivable in other SEA sites. However, this thesis suggests that domestic and wild animals probably imbued different meanings and significance. Further, both CCN and MB were not ‘simply middens’ reflecting what people ate, rather they pose intriguing insights into human-animal interactions. At both sites there is a perceivable change in the engagement with animals and the landscape that, this thesis argues, involved a reconceptualising of this relationship.

Chuyển đổi sang thuần dưỡng động vật ở Đông Nam Á: Những phân tích về khảo cổ học động vật ở Cồn Cổ Ngựa và Mán Bạc, Việt Nam.

Abstract translated from English into Vietnamese by Nguyễn Thị Hảo.

Tóm tắt

Thuần dưỡng thực vật và động vật là một quá trình quan trọng có ảnh hưởng lớn và định hình quỹ đạo của lịch sử nhân loại. Tuy nhiên, quá trình chuyển đổi này vẫn chưa được hiểu rõ ở nhiều nơi trên thế giới. Đối với khu vực Đông Nam Á lục địa (MSEA), phần lớn các nhà nghiên cứu tin rằng, sự chuyển đổi này được khởi nguồn từ sự di cư của các nhóm nông nghiệp trải dài từ sông Dương Tử tới khu vực Đông Nam Á lục địa dọc theo các con sông và đường bờ biển (Bellwood and Oxenham 2008; Matsumura et al. 2008; 2011). Giả thuyết này cho rằng những cư dân di cư ấy đã đưa những cây trồng và vật nuôi đã được thuần dưỡng vào khu vực này và sinh sống cùng với những nhóm người săn bắt – hái lượm bản địa.

Luận án này phân tích quá trình chuyển đổi từ săn bắt – hái lượm sang thuần dưỡng ở miền Bắc Việt Nam bằng cách so sánh các đặc trưng về hóa thạch và sinh học của các sưu tập động vật tại địa điểm Cồn Cổ Ngựa và Mán Bạc ở miền Bắc Việt Nam. Hai địa điểm này được chọn vì chúng nằm ở hai đầu của sự chuyển đổi tương đối về sinh kế từ săn bắt – hái lượm (CCN) sang nông nghiệp (MB) ở Việt Nam và có tiềm năng thể hiện những thay đổi xã hội quan trọng. Vì CCN và MB là các di tích mộ táng, nên những tương tác giữa người và động vật ở các di tích này có khả năng mô tả hệ thống tín ngưỡng và bản thể của con người. Mục đích cơ bản của Luận án là làm rõ bối cảnh CCN và MB trong cơ cấu thay đổi về sinh kế ở Đông Nam Á và xác định xem liệu có hay không hành vi của con người và mối quan hệ giữa con người- động vật phát triển trong suốt giai đoạn chuyển đổi có chủ định này ở thời kỳ Holocene giữa và nếu có thì sẽ như thế nào.

Một sự chuyển đổi rõ ràng và có thể hiểu được trong thành phần động vật giữa CCN và MB đã được tìm thấy và quá trình chuyển đổi này có thể được cho là việc đưa các động vật đã thuần dưỡng vào miền Bắc Việt Nam theo một cách thức riêng. Hơn nữa, những kết quả từ việc phân tích thành phần chính của các địa điểm trong khu vực Đông Nam Á cho thấy tỷ lệ tương đối của một số taxon nhất định có thể hữu ích trong việc phân tách các địa điểm săn bắt – hái lượm và nông nghiệp trải khắp khu vực, đồng thời tiết lộ những điểm khác biệt dựa trên môi trường địa phương và/hoặc khả năng lựa chọn. Cũng cần nhấn mạnh rằng sự chuyển đổi từ "săn bắt sang trồng trọt" này không được rõ ràng lắm. MB vẫn tồn tại rõ nét phương thức săn bắt động vật hoang dã và đánh bắt cá, và các

ranh giới đan xen này cũng có thể được tìm thấy ở các di tích khác ở Đông Nam Á. Tuy nhiên, Luận án này cũng gợi ra rằng những loài động vật được thuần dưỡng và hoang dã có thể có ý nghĩa và vai trò khác nhau. Hơn nữa, cả động vật ở CCN và MB không chỉ đơn thuần phản ánh những gì con người ăn, mà chúng còn đưa đến những hiểu biết sâu sắc và thú vị về sự tương tác giữa con người với động vật, và có thể thay đổi nhận thức về cảnh quan và các mối quan hệ giữa con người và động vật trong bối cảnh rộng hơn.

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Glossary and abbreviations

SEA: Southeast Asia
MSEA: Mainland Southeast Asia
ISEA: Island Southeast Asia
CCN: Cồn Cổ Ngựa
MB: Mán Bạc

Late Pleistocene: c. 40,000–19,000 BP
Terminal Pleistocene: c. 22,000–11,700 BP
LGM: Last glacial maximum, c. 19,000 BP
Holocene: c. 11,700–present
Mid Holocene: c. 7,500–4,500

BP: before present (1950), uncalibrated date
cal. BP: calibrated, before present
kya: thousand years ago

TNF: total number of (bone) fragments
NISP: number of identifiable specimens
MNI: minimum number of individuals
MNE: minimum number of elements
BPR: body part representation

PCA: principal component analysis
NCT: niche construction theory
OFT: optimal foraging theory

CHAPTER ONE
Introduction: setting the scene

1.1. Introduction

The domestication of plants and animals was a pivotal process that immensely affected and shaped the trajectory of human history. The profound impacts of the transition in subsistence and lifeways during the Early–Mid to later Holocene (c. 11,700–3,000 BP), is of transdisciplinary interest, spanning and connecting the humanities and sciences. Understanding this crucial process is considered to be one of the 'grand challenges' for archaeology (Kintigh et al. 2014; Zeder 2015a). Despite the acknowledged importance, this transition is still poorly understood in many parts of the world. The basic questions of 'when' and 'where' are no longer sufficient, instead, more nuanced and regionally specific queries are required.

The Southeast Asian (SEA) archaeological record is one that continually subverts simplistic 'progressive' narratives of human evolution (Figure 1-1). Many archaeologists working in the region have been unsatisfied with the current discourse surrounding agriculture and domestication, as there are increasingly numerous examples that do not fit 'push models' of environmental stress or climatic change as casual factors (Cohen 2011; Crawford 2011; Denham 2011; Aikens and Lee 2014; Hunt and Rabett 2014). In SEA, and increasingly worldwide, there is evidence of ecological management long before the development of agriculture or domestication and these activities developed alongside traditional hunter-gatherer economies rather than replacing them (Cohen 2011; Crawford 2011; Smith 2011; Amundsen-Meyer 2013; Hunt and Rabett 2014, 30–1). The increasing amount of archaeological data from SEA suggests a long process of development that was pocketed between regions (Hunt and Rabett 2014; Piper and Rabett 2014; Oxenham 2015; Oxenham et al. 2015).

China is generally agreed to have been one of the earliest regional centres of domestication in the world, with evidence of domesticated dog from c. 10,000–8,000 cal. BP and pig from c. 9,000-8,000 cal. BP (see Chapter three, section 3.5.3.; Flad et al. 2007; Yuan 2010). The introduction of domesticated crops and animals into the rest of SEA has been argued to have been at least partially stimulated by migrations of people from these regional centres (Bellwood 2005; Higham et al. 2014). For northern Vietnam, most researchers believe this transition was initialised by a migration of agricultural groups that spread from the Yangtze into Mainland Southeast Asia (MSEA) following rivers and the coastline (Bellwood and Oxenham 2008; Matsumura et al. 2008; 2011). This 'two-layer' or 'farming dispersal' hypothesis posits that these migrant populations brought domesticated crops and animals into the region and lived alongside indigenous hunter-gatherer groups.

Figure 1-1 Map of Southeast Asia showing modern day political boundaries. Map adapted from base map provided by CartoGIS, ANU.

In Vietnam and other parts of SEA these hypotheses have yet to be directly addressed using zooarchaeology or archaeobotany, as these sub-disciplines are relatively new to the region. Zooarchaeology has the potential to examine and test these hypotheses on a case-by-case and regional basis, as zooarchaeology enables broad characterisation of sites and periods, pin pointing when and how major transitions took place. It is also a powerful tool for emphasising individuality of sites by focusing on how particular circumstances have affected the choices people made.

1.2. Research aims and objectives

This thesis analyses the transition from hunting and gathering to domestication by comparing the taphonomic and taxonomic characteristics of the faunal assemblages of Cồn Cổ Ngựa (CCN) and Mán Bạc (MB) in northern Vietnam (Figure 1-2). Both sites were specifically selected as they sit on either side of the presumed hunter-gatherer (CCN) and agricultural (MB) subsistence transition in northern Vietnam and have the potential to show changes in human subsistence economies and display crucial social changes that took place.

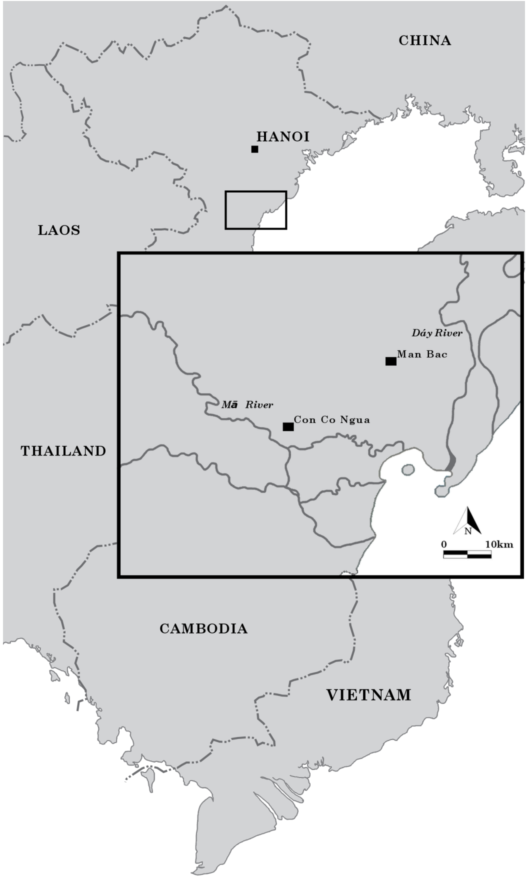

Figure 1-2 Map of Mainland Southeast highlighting the location of CCN and MB. Map adapted from base map provided by CartoGIS, ANU.

CCN is situated in the Đa Bút period (c. 6,000–5,000 BP), which scholars have argued represents a significant change from primarily terrestrial subsistence to a complex diet that exploited resources from a variety of environments with a particular emphasis towards coastal resources (Bui Vinh 1991; Nguyen Viet 2005; Oxenham et al. 2005). This subsistence shift is mirrored by social changes in the appearance of large burial sites, which also hints at an increase in sedentism. The site has yet to be scientifically dated, and the estimated dates are based on ceramic and lithic typologies. Thus, one of the main aims of this project is to radiocarbon date (^{14}C) a select range of faunal and human skeletal material from the site.

MB is dated to the later Phùng Nguyên period (c. 3,800–3,400 BP), which likewise sees major changes from the previous Đa Bút period in material culture, number and size of settlements, and skeletal morphology of the inhabitants (Matsumura et al. 2011; Oxenham et al. 2011). These changes are argued to represent the transition to agriculture and domestication stimulated by an external migration of farming communities from southern China (Matsumura et al. 2011; Oxenham et al. 2011). MB has previously been dated using charcoal excavated within the midden layer (Dung et al. 2011, 169; Matsumura and Oxenham 2011, 4). However, if the pigs and dogs are determined to represent domesticated taxa, additional direct ^{14}C dates from these skeletal elements will provide a minimum date for the introduction of domesticated animals into northern Vietnam.

These proposed social and economic developments within northern Vietnam have yet to be addressed in detail from a zooarchaeological perspective, despite its huge potential to contribute significantly to these inquiries. This thesis aims to contribute to research on these important sites by analysing directly the fauna people chose to exploit and the potential significance of their decisions and use this data to compare within the broader SEA framework. The ultimate goal of this project is to determine how and whether human behaviour and practices changed or developed during this purported transitory phase in the Mid Holocene of Vietnam. Zooarchaeology has the unique ability to be able to directly answer whether the animals at CCN and MB were wild or domesticated taxa. Two main traditional zooarchaeological approaches will be used: taphonomic and taxonomic analyses.

Taphonomic analyses allow for detailed reconstruction of pre- and post-depositional processes that have influenced site formation. Taphonomy fundamentally addresses agents of accumulation and attempts to distinguish between human and natural modifications (Lyman 1994b). This distinction is essential as one of the key modes of determining human behavioural practices through faunal remains is through butchery practices or selective culling of animals.

Taxonomic analysis of vertebrate remains is the second fundamental aspect of zooarchaeological research. It is aimed at determining which taxa humans were exploiting and reconstructing palaeoenvironmental conditions. The identification of domesticated fauna and distinction from wild animals is a crucial aspect of exploring the transition from hunting wild animals to domestication; methodical and theoretical aspects of this are covered in detail in Chapter four. Since zooarchaeology is still a relatively young sub-discipline within the context of SEA, it is hoped that both the taphonomic and taxonomic approaches presented in this thesis will provide a baseline of data that later studies in Vietnam and SEA can draw upon.

In summary, the main objectives and related questions are:

1. To undertake a taphonomic analysis of the vertebrate remains from CCN and MB to: a) provide information on pre and post depositional processes that have affected site formation, and b) distinguish between human and natural modification.

   ○ What can the taphonomy of faunal remains reveal about the past environmental conditions and the way humans have used the site?

   ○ Can human behavioural practices be identified through the faunal remains? For example, can butchery practices or selective culling of animals be inferred?

   ○ Can spatial analysis of the concentration of faunal remains reveal something about site use?

2. To undertake a taxonomic analysis of vertebrate remains from CCN and MB to: a) determine which taxa humans were exploiting, b) reconstruct palaeoenvironmental conditions, c) provide a baseline of data for later studies.

   ○ Can domesticated fauna be distinguished from wild fauna in an assemblage? If so, is it possible to identify CCN as a hunter-gatherer site and MB as an early agricultural site based on the faunal remains?

3. To conduct radiocarbon (^{14}C) analysis of selected faunal material from CCN and MB for two primary reasons: a) to provide the first radiocarbon dates for CCN and secure dates for the Đa Bút period, b) to securely pin a minimum date for potentially early domesticated fauna into northern Vietnam.

   ○ Does the radiocarbon dating support the previous ideas on the chronology of CCN being Mid Holocene? Does it fit the farming dispersal hypothesis for MB?

   ○ Is it possible to see diachronic / temporal changes in site use? Were the sites used for relatively short or long time periods?

4. To conduct a regional meta-analysis of faunal assemblages from SEA to address wider regional patterns and contextualise how CCN and MB relate to other sites within SEA.

1.2.1. Meeting theory and practice: research questions relating to theoretical concepts

To parallel the specific aims and objectives outlined above are three overarching theoretical and methodological approaches that frame this thesis. These frameworks can be summarised into three specific inquiries:

1. **Is there a perceivable shift in faunal composition between Cồn Cổ Ngựa and Mán Bạc, and if so, does this relate to the introduction of domestic animals?**

The faunal assemblages will be compared using traditional zooarchaeological methods to address whether CCN can be defined as a hunter-gatherer subsistence economy, and MB as an agricultural/domesticated economy. This will involve attempting to determine whether the pigs, dogs, and bovids from both sites are within the early phases of domestication or management using biometrics and age at death profiles. This rests on a multitude of scholarship on domestication of animals showing a correlation between domestication and size reduction, but also acknowledging the difficulty in determining the difference between early domesticated and wild animals, from both a theoretical and methodological perspective (Zeder 2006a; Russell 2007; Sykes 2014). In light of post-humanist scholarship by Haraway (1990; 2008b) and Latour (1993; 2005), dualisms between wild and domestic potentially overly simplify the relationship and the actual processes that are occurring. This project will therefore attempt to find a balance between attempting to characterise the domesticated/wild taxa, whilst acknowledging the complexities of the process. With these nuances in mind, one of the queries related to this question is how does the introduction of domesticates affect the faunal assemblages? Does this influence human economic, social, and cultural behaviour? For instance, does this impact hunting and other taxa humans are exploiting? These questions are discussed in detail in Chapter eleven section 11.4., and are based on a synthesis of results from Chapters six– nine.

2. **How can the transition from 'foraging to farming' be characterised in Vietnam and Southeast Asia?**

The purpose of this question is to place CCN and MB within their wider regional SEA context. The faunal comparison of CCN and MB will be expanded to encompass contemporary sites in SEA to query whether: a) these sites are typical for their time period; and b) there are perceivable temporal patterns (diachronic change) in SEA related to the introduction of domesticates.

The concept of Niche Construction Theory (NCT) provides a useful framework for these questions (see Chapter four, section 4.4). NCT sees the organism and the environment as intrinsically tied, rather than people constantly being forced to react to whatever the environment throws at them. Evolution is seen as a continuously developing dialogue between organism-environment-genes (Lewontin 1983; Odling-Smee et al. 2003; Laland and O'Brien 2010; O'Brien and Laland 2012). Within the framework of NCT both hunting and gathering and agricultural lifeways are not separated into a dualistic oppositional choice of one or the other (Rowley-Conwy and Layton 2011; Smith 2011; Amundsen-Meyer 2013; Smith 2015). Rather, they can be characterised as a subtle shift in the modes of engagement with the environment.

With these concepts in mind, this thesis will address whether it is possible to distinguish between hunter-gatherer sites and agricultural sites based on the faunal composition. Further, how big of a role does the environment, or group and individual choice play in faunal assemblages? This is specifically discussed in Chapter eleven section 11.5., and is based on a regional meta-data analysis of faunal composition in SEA sites in Chapter nine, section 9.4.

3. What can be inferred about human-animal relationships in Cồn Cổ Ngựa and Mán Bạc? How can domestication be reframed into a less anthropocentric perspective?

This question is aimed at querying whether human-animal relationships at CCN and MB can be understood as more than hunting wild animals or controlling domesticated ones. Since both CCN and MB are burial sites, human-animal interactions have the potential to display something about the belief systems and ontology of the people. Additionally, following the arguments outlined above that CCN reveals an increase in sedentism and MB provides evidence supporting the two-layer hypothesis, what can be said regarding societal and ideological changes in this period? How did people perceive and relate to their surrounding environment?

These questions are discussed in greater detail in Chapter eleven section 11.6., drawing from theoretical frameworks introduced in Chapter four. My approach to these queries is greatly influenced by developing conceptions around agency and interspecies studies in post-humanist scholarship (Haraway 2008a; 2008b; Hayward 2012; Overton and Hamilakis 2013). The aim is to understand domestication from a less anthropocentric perspective by emphasising animal agency and an asymmetric approach to human-animal relationships (see Chapter four, section 4.5). Asymmetrical relationships oppose automatically assuming that human-animal relationships are essentially governed by domination or control. Asymmetry has been applied to other fields, especially gender studies, where scholars have argued that human-human relationships are almost always asymmetrical (Haraway 2008b; Armstrong Oma 2010). Thus, the asymmetry of human-animal relationships becomes less about human exceptionalism and interspecies difference, and more about looking at what else is at play. The goal is to show how zooarchaeology can be a useful tool in highlighting not only human agency, but also agency of non-human animals.

1.3. Relevance and contribution of study

As mentioned previously, CCN and MB have been selected to address these outstanding research problems as they sit on either side of the period that is presumed to represent the transition from foraging to farming and the beginnings of modern agricultural practices and domestication of animals in Vietnam. The faunal assemblages from CCN and MB have yet to be studied in detail. This study aims to address these questions directly and in greater depth in order to better understand the transition from hunting and gathering to the beginnings of agriculture, animal domestication, and sedentism in northern Vietnam. Improving our understanding of how and when human populations adopted a sedentary pattern of existence and integrated domestic animals into their subsistence strategies will not only improve our understanding of the Neolithic in Vietnam, it will also provide a baseline of data for the origins of human and animal populations that migrated south and east across MSEA. This will have wider implications for the timing of this transition within the context of MSEA. In particular, this thesis will hold implications related to previous scholarship on migrations of people within the later Neolithic and the two-layer/farming dispersal hypotheses.

Although there has been a handful of faunal analyses published on Vietnam (Vu The Long et al. 1996; Bacon et al. 2004; Piper et al. 2012; Oxenham et al. 2015) and preliminary faunal analyses of CCN (Vu The Long 1980) and MB (Sawada et al. 2011; Toizumi et al. 2011), as yet, no significant zooarchaeology research has been undertaken/published comparing assemblages across the wider region. Further afield, zooarchaeology has been gaining attention in Thailand, China, Indonesia, Malaysia, and the Philippines, which will be useful comparisons to this study (Higham 1975b; 2004; Grant and Higham 1991; Ma 2004; Flad et al. 2007; Piper et al. 2008b; Jin and Shipman 2010; Kijngam 2010; Yuan

2010; Amano et al. 2013; Piper and Rabett 2016). Additionally, most zooarchaeological research in SEA has been characterised by relatively limited theoretical development. This partly mirrors a reluctance to engage in social theory in the sub-discipline itself due to its ancestral links with taxonomy (Overton and Hamilakis 2013). This thesis attempts not only to bring a valuable data set of zooarchaeological information into an understudied region, but to also add theoretical development by providing new frameworks for conceptualising the zooarchaeological record in SEA.

1.4. Terminology

While it is important to continually evaluate the definition and usage of the Neolithic, it is a term that remains popular within literature due to its convenience as a general descriptor and widespread applicability. Although the term 'Neolithic' is commonly used within Vietnamese archaeology, it is not wholly satisfactory in that is does not directly equate with the Neolithic of Europe or the Middle East. In Vietnam it is used to indicate the use of grinding-stone technology and ceramic production (Nguyen Khac Su et al. 2004, 177). However, strong evidence for agriculture or domestication of animals is limited to the later stage of the Neolithic. Further, Oxenham and Matsumura (2011, 128) point out that ceramic production is absent prior to the Đa Bút period. The term 'Mesolithic', a phase between the Neolithic and Palaeolithic in other parts of the world, is not used in Vietnam (Nguyen Khac Su et al. 2004, 177).

In China, pottery production begins with foraging populations from c. 20,000 BP and sedentary villages appear from c. 9,000 BP (Cohen 2011; Zhang and Hung 2012). However, domestication of plants and animals arrive at different times in different places and domesticates did not make a significant contribution to the diet until several millennia later (Cohen 2011; Zhang and Hung 2012). Zhang and Hung (2012, 11) note that the 'Neolithic' in China denotes the manufacturing of pottery but does not imply agriculture. Similarly, Cohen (2011, 288) definition of the 'Early Neolithic' in China is linked with several crucial developments: sedentism, social and ideological changes, new concepts of territoriality, ownership, and an increase in niche construction. Thus, this definition of 'Neolithic' does not involve farming or domestication as essential ingredients from the onset.

Following these definitions, the Đa Bút period in Vietnam could be argued to represent a similar 'Early Neolithic' with widespread use of pottery, increased sedentism, a complex subsistence economy and – this thesis argues – ideological and social changes as evidenced from increases in niche construction. However, it is important to note the term ‘Neolithic’ is a loaded concept originating from Near Eastern and European archaeology and the ways in which the Neolithic is expressed varies around the world.

Chronological terminology follows Rabett and Piper (2012, 38). Dates are either referred to as ‘BP’, years before present, or ‘cal. BP’ if calibrated radiocarbon dates are available. The Late Pleistocene is informally defined as a period from c. 40,000 BP until the end of the of the glacial period. The Last Glacial Maximum (LGM) spans the period from 26,500–19,000 BP. The Last Termination covers the period from the height of the LGM to the Pleistocene/Holocene boundary c. 22,000–11,700 BP. Finally, the Holocene is generally divided into Early, Mid and Late periods, with the Mid Holocene here defined as c. 7,500–4,500 BP. Since this thesis concentrates on two Mid Holocene sites and the transition from foraging and hunting to domestication, the bulk of the literature review covers the Terminal Pleistocene to Mid Holocene period.

1.5. Structure of thesis

This thesis is comprised of 12 chapters. The first chapter introduces the aims, objectives, and questions driving the thesis and provides the reader with an understanding of the main concepts and debates within the research topic. Chapter two provides the environmental and archaeological background to the sites. Previous research specifically on CCN and MB is addressed to build the local and regional context. Overall, Chapters one and two highlight the relevant gaps in scholarship and how this thesis aims to contribute to SEA archaeology.

Chapter three offers a wider perspective on zooarchaeological research within MSEA and southern China from the Late Pleistocene to the Mid Holocene. This situates CCN and MB within their temporal, regional, and historical contexts as well as within the wider framework of academic research within SEA. It is argued that while there is a perceivable transition to domesticated animals through the introduction of pigs and dogs in the Mid-Late Holocene, there is considerable inter-site variability.

Chapter four provides the theoretical frameworks this thesis rests on: a post-humanist ‘social zooarchaeology’ and niche construction theory. The aim is to integrate theoretical approaches that have developed independently in science and social sciences into the way zooarchaeology conceptualises domestication. These developing approaches have great potential in understanding human-animal relationships and the SEA record without the necessity of fitting into reductionist models.

Chapter five specifies the methodology used throughout the thesis, the rationale behind the techniques employed, and main issues surrounding these methods. The main areas addressed are: excavation and post-excavation techniques, taphonomy, quantification, ageing and sexing of faunal remains, statistical methods, and radiocarbon dating.

The results chapters are split into five chapters. Chapter six covers the taphonomic and taxonomic faunal analysis of CCN, and Chapter seven provides the same information for MB. Areas that are addressed specifically include the quantification and spatial distribution of skeletal elements, a taphonomic analysis of the faunal remains, and a taxonomic identification and description of the species excavated from both sites.

Chapter eight gives a biometric analysis of the pigs, dogs, and bovids from CCN and MB compared to published data. The primary purpose of collecting biometric data for pigs and dogs was to assess whether they were domesticated or in the early phases of domestication. For bovids it was also to attempt to distinguish between different genera and species of Bovinae. For the pigs, cluster analyses and significance testing were performed to determine whether there were perceivable groups or clusters within the data. The results are interpreted with ANOVA post-hoc testing.

Chapter nine provides a taxonomic comparison of CCN and MB and a regional meta-analysis. The specific comparison between CCN and MB is largely based on taxonomic indices outlined in Lyman (2008). The purpose of this is to understand and account for any perceivable similarities or differences between the assemblages. The multivariate meta-analysis is aimed at addressing wider regional patterns within SEA faunal assemblages, which contextualises both sites within the broader ‘big picture’. The final results section, Chapter ten, summarises the radiocarbon dating (^{14}C) results for CCN and MB. The aim of ^{14}C for CCN was to provide a scientific series of dates to test whether relative dates based on ceramic and lithic typologies were robust. The aim of obtaining ^{14}C dates for MB was to securely pin a minimum age for the introduction of domesticated animals into northern Vietnam.

Chapter eleven is the discussion chapter which summarises the main findings of the thesis, addresses each aim and objective, and attempts to understand this in relation to theoretical frameworks described above (section 1.2.1.). Finally, Chapter twelve concludes the thesis with a summary of the major findings and suggestions for future research.

CHAPTER TWO
Environmental and archaeological background

2.1. Introduction

This chapter provides the environmental and archaeological backgrounds of CCN and MB. The environmental section briefly details the geography and environment of SEA, in particular on northern Vietnam, and provides a summary of paleoenvironmental conditions during the Holocene. The rest of the chapter is dedicated to providing the archaeological background of CCN and MB, specifically addressing previous excavations and research. Particular attention is paid to palaeoenvironmental and faunal analyses.

2.2. Environmental background

2.2.1. Geography of Southeast Asia

The recognition of SEA as a separate political and geographical entity is very recent. SEA is not a natural biogeographical unit as it is sharply divided into two zoogeographical boundaries by the Wallace and Lydekkar Lines, which mark the boundary between Oriental and Australian fauna (Corlett 2005, 105). The boundary between these lines is known as Wallacea, a biogeograhical transitional zone with its own distinct fauna. However, SEA is distinguished from most other areas in the tropics by its forest climates and its native fauna largely adapted to and dependent on forests (Corlett 2005, 114).

As defined by Gupta (2005, 38): “Southeast Asia is a corner of the continent of Asia which ends in an assemblage of peninsulas, archipelagos, and partially enclosed seas.” To the north is the eastern Tibetan plateau, the Himalayan Mountains, the plateau of Assam in India, and the Yunnan Province of China (Figure 2-1). A number of large rivers run from this mountainous region in a north-south and northwest-southeast direction. To the south and east are coastal plains, rocky peninsulas, and deltas. On the outer margins of SEA are the islands of Indonesia and the Philippines. The northern edge of SEA is characterised by mountain ranges and steep gorges with large rivers. The northern mountainous region across Myanmar, Laos, and Vietnam is essentially a continuation of the Assam Himalayas in India and the Yunnan in China, although very few mountain peaks rise above 3000 m (Gupta 2005, 42).

Figure 2-1 Map of MSEA showing modern political boundaries, major rivers, and elevation of land. 1, location of CCN, 2, MB. Map adapted from base map provided by CartoGIS, ANU.

2.2.2. Northern Vietnam

Vietnam covers approximately 330,363 km^2 and borders China to the north, and Laos and Cambodia to the west (Nguyen 1995, 7). Climatically, Vietnam can be characterised as humid with tropical monsoons but there is a stark difference in the climate between the north and the south. Northern Vietnam has a seasonal climate with high levels of humidity, while the South has a tropical hot and humid climate (Oxenham 2006, 212–3). Tectonic movement has resulted in mountain chains in three-quarters of the country, although 85% is still below 1000 m in elevation (Nguyen 1995, 13).

Approximately 20% (60,000 km^2) of Vietnam is covered by exposed carbonate karst and this is mainly distributed in the north (Gillieson 2005, 170). Karst lands are formed on limestone bedrock and are subjected to solutional erosion above and below ground, which are ideal conditions for creating cave systems. Karst mountains cover an area of 400,000 km^2 in SEA and range in age from the Cambrian to the Quaternary; they are found in Malaysia, the Philippines, Thailand, Brunei, Indonesia, Cambodia, Vietnam, Laos, and Papa New Guinea (Gillieson 2005, 157).

CCN and MB are situated within the karst limestone region of the Bac Bo plain in North Vietnam, which forms the edge of the southern Chinese plateau (Nguyen 1995, 22, 64). This area is comprised of the mountains and hills on the west bank of the Red River (Song Hong), the Bac Bo plain, and the coast of the Bac Bo (Nguyen 1995, 64). The area has widespread karst mountains with subtropical vegetation covered with dense bamboo and evergreen forests on the plains, and mangroves on the coast (Li et al. 2006b, 7; Oxenham 2006, 213). The Gulf of Bac Bo is a shallow sea with an average depth of about 40m, ranging up to 200 m (Nguyen 1995, 28). A series of major rivers divides the Bac Bo into sections. The greater part of the Bac Bo region is watered by the Red-River-Thai Binh system linked by the Duong and Luoc Rivers (Nguyen 1995, 43).

The Red River is one of the largest deltas in Southeast Asia at around 1,200 km (Li et al. 2006b, 5). It begins in the Yunnan Province in China and enters Vietnam in Lao Cai Province before draining into the Gulf of Bac Bo (Tonkin) in the South China Sea (Nguyen 1995, 43; Li et al. 2006b, 5). On average the total volume of water carried by the Red River is 25% of the Mekong's volume (120 km^3), but the amount of alluvial deposit the river carries surpasses the Mekong at more than 100–130 million tons per year, which gives the river a red tinge (Nguyen 1995, 43; Li et al. 2006b, 5).

2.2.3. Paleoenvironment during the LGM and Holocene

The Sunda shelf is an extension of the continental shelf of SEA, connecting a vast area between Vietnam, Indonesia and the Philippines (Hanebuth et al. 2000). During the Last Glacial Maximum (LGM) the shelf was widely exposed, and the sea level was c. 120 m below present level (Figure 2-2; Tanabe et al. 2003; 2006; Hanebuth et al. 2009). Between c. 19,000–14,000 BP the sea level rose and inundated this land mass (Hanebuth et al. 2000). These changes in sea level had a profound impact on biogeography as vast areas of land were inundated or exposed over the course of the Late Pleistocene and Early Holocene. The exact timing and dynamics of this sea level rise is somewhat controversial and debated for a number of reasons. As summarised by Hanebuth et al. (2009, 76–7), there is a complex relationship between glacio- and hydro-isostatic effects and how they are locally expressed, there are problems in dating precisions, there are poor and often contradictory field records, and attempting to match field observations with models is difficult. For the Sunda Shelf, Hanebuth et al. (2009, 83) have recently argued the LGM lowstand was slightly lower at -123 m below present level, and there was a rapid rise of 10m between 19,600–18,800 cal. BP.

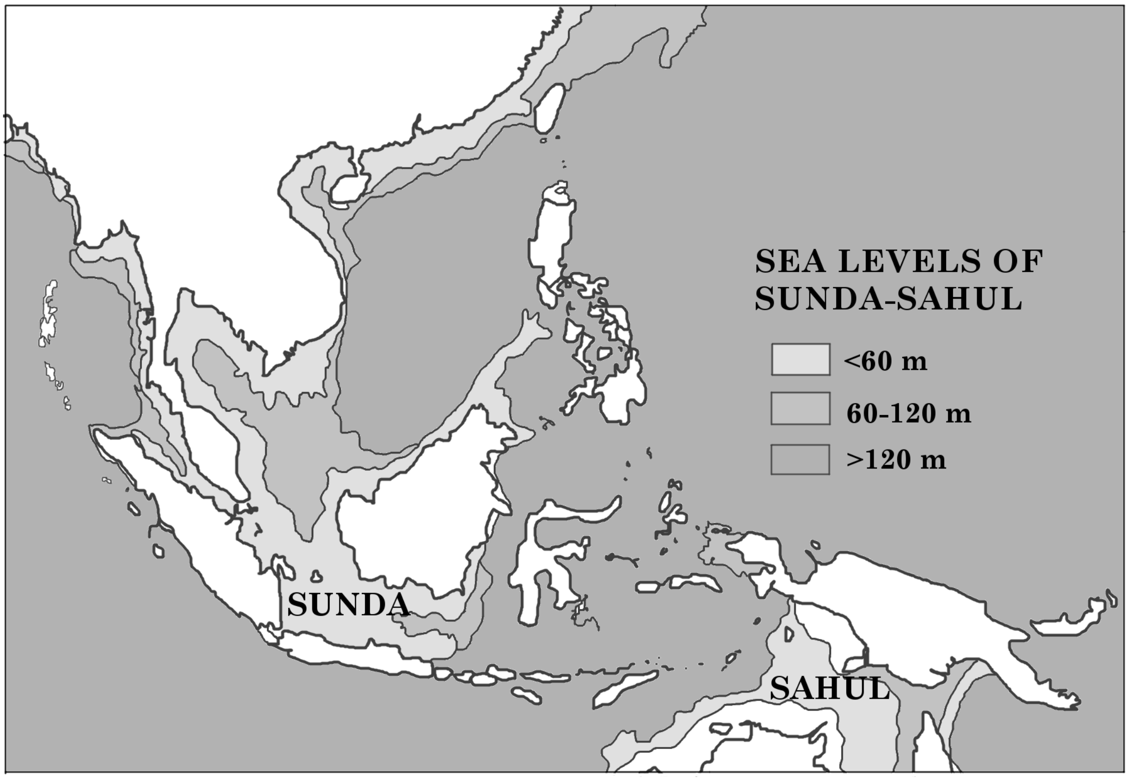

Figure 2-2 The extent of dry land in Southeast Asia during the LGM (-120 m) and average (-60 m) sea levels. Map based on Hope (2005, 27).

During the Early–Mid Holocene the sea level continued to rise, at first rapidly c. 9,000–8,200 BP until it stabilised and gradually dropped at to the present level (Tanabe et al. 2003). Tanabe et al. (2003, 2355) summarised the Holocene sea level changes in the Red River delta into three main phases: 1) between 9,000–6,000 cal. BP the sea level rose from 15m below present level to 3m below present level; 2) 6,000–4,000 cal. BP after reaching a high of +2 to 3 m, the sea level stabilised; 3) 4,000 cal. BP–present, at first rapid then gradual drop to present sea level.

There is some variability in sea level changes globally, and differences in timing and magnitude of the Mid Holocene highstand in various regions can be attributed to differences in mantle rheology or in hydro-isostatic effects (Stattegger et al. 2013). These variations mean the highstand might have started earlier near the equator (Long 2001). In general, the Mid Holocene highstand is agreed to be have been between 7,900–4,500 BP in most equatorial coastlines (Long 2001; Stattegger et al. 2013, 214). In Southeast Vietnam, beachrocks reveal that the Mid Holocene sea level highstand was reached between 6,700 and 5,000 cal. BP, with a peak value close to +1.5m around 6,000 cal. BP. After 5,000 cal. BP, the sea level dropped below +1.4 m and fell at an almost linear rate (Stattegger et al. 2013, 214). In North Vietnam geological studies clearly show that the coastline during this period was located near modern day Hanoi (Masanari 2005, 99). Hope (2005, 27) argues the rise in sea level during the Early–Mid Holocene would have massively impacted human settlement patterns. Masanari's (2005) and Funabiki et al.'s (2012) study of Neolithic settlement along the Red River delta clearly shows a settlement pattern

Figure 2-3 Map adapted from Masanari (2005) showing the location of Early to Late Neolithic sites in the Bac Bo region and the elevation. The position of CCN and MB have been indicated.

reflective of these sea level changes. Early Neolithic sites are generally located on higher land while later Neolithic sites are closer to the current shoreline (Figure 2-3).

During the LGM on the Sunda Shelf pollen records show lowland and montane rainforests indicative of humid vegetation on the exposed shelf, this suggests that climate during the LGM was cooler than present conditions (Wang et al. 2009). During the Early Holocene, pollen studies by Li et al. (2006a, 428; 2006b) show an increase in fern and mangrove species between 9,000–6,500 cal. BP, which indicates moist and warm weather conditions. This was followed by a short cooling period between 6,500–5,200 cal. BP, as indicated by an increase in temperate pollen species such as conifers, birches, oaks, and chestnut trees (Li et al. 2006a, 423, 428). The overall environmental picture from the Holocene is one of a great diversity in pollen taxa (Li et al. 2006a; 2006b) and this is reflected in faunal diversity.

2.2.4. Terrestrial vertebrate fauna in Vietnam

Terrestrial and aquatic fauna in Vietnam are characteristic of subtropical zones. The diversity of the animals in Vietnam is reflective of its diverse environment and vegetation (Sterling et al. 2006, 97). Mammals and birds are the best documented fauna in Vietnam, Sterling et al. (2006, 128) detail more than 270 mammalian species and 850 bird species. Birds are the best recorded vertebrate species in Vietnam because they are generally easier to observe and record than mammals and many surveys have largely focused on avifauna (Sterling et al. 2006, 128). Evergreen forests are the most significant habitat in terms of species richness. Lowland forests are critical habitats of pheasants, pittas, magpies. Grasslands and wetlands are home to numerous large water birds, including: storks, ibises, herons, cormorants, and birds of prey. Estuaries and beaches are important habitats for ducks, gulls, plovers, and spoonbills.

Reptiles make up a significant proportion of Vietnam's vertebrates, including: snakes (172 species), lizards (110 species), turtles (34 species), and crocodiles (two species; Sterling et al. 2006, 147). Snake and lizards are evenly distributed across the lowlands and highlands, whereas turtles are primarily a lowland species (Sterling et al. 2006, 148). Several large species of monitor lizard (*Varanus* spp.) are found in Vietnam, including the widespread Water Monitor (*V. salvator*) (Bennett et al. 2010) and Clouded Monitor (*V. bengalsensis*) (Papenfuss et al. 2010).

The most species-rich mammalian orders in Vietnam include bats (91 species), rodents

(64 species), carnivore (40 species), primates (19 species), and ungulates (18 species; Sterling et al. 2006, 99). Vietnam has three non-human primate families, including: gibbons (Hylobatidae), leaf monkeys and macaques (Cercopithecidae), and lorises (Lorisidae). Tarsiers (Tarsiidae) and orangutans (Ponginae subfamily) once occurred in MSEA but are now restricted to evergreen forests in the Sunda Islands (Sterling et al. 2006, 106). Although Vietnam's primates are diverse and rich in species, many are now endangered or vulnerable, including: Delacour's Leaf Monkey (*Trachypithecus delacouri*) (Nadler et al. 2008), Cat Ba Leaf Monkey (*T. poliocephalus poliocephalus*) (Bleisch et al. 2008), Gray-shanked, Red-shanked, and Black-shanked Douc (*Pygathrix* spp.) (Ngoc Thanh et al. 2008a; 2008b; Rawson et al. 2008), and Tonkin Snub-nosed Monkey (*Rhinopithecus avunculus*) (Xuan Canh et al. 2008a).

Second to primates, carnivores are among Vietnam's most threatened orders, often coming into conflict with humans and vulnerable to exploitation for consumption and use in traditional medicines (Sterling et al. 2006, 114). Canidae species include: Golden Jackal (*Canis aureus*) (Jhala and Moehlman 2008), Dhole (*Cuon alpinus*) (Kamler et al. 2015), Red Fox (*Vulpes vulpes*) (Hoffmann and Sillero-Zubiri 2016), and Raccoon Dog (*Nyctereutes procyonoides*) (Kauhala and Saeki 2016). There are two bear species: the larger Asian Black Bear (*Ursus thibetanus*) (Garshelis and Steinmetz 2008), and Sun Bear (*Helarctos malayanus*) (Scotson et al. 2017). Mustelidae is the largest of the carnivore family with 65 recognised species, including: weasels and martens, badgers, and otters (Sterling et al. 2006, 115). Ten species of Viverridae are distributed in Vietnam, including: civets, linsangs, and genets (Sterling et al. 2006, 117). Felids historically ranged across most of the country but are now restricted to remote areas, such as large species: Indochinese tiger (*Panthera tigris corbetti*) (Goodrich et al. 2015), Leopard (*P. pardus delacouri*) (Stein et al. 2016), and intermediate species: Clouded Leopard (*Neofelis nebulosa*) (Grassman et al. 2016), Asian Golden Cat (*Catopuma temminckii*) (McCarthy et al. 2016), Fishing Cat (*Prionailurus viverrinus*) (Mukherjee et al. 2016), and smaller species: Marbled Cat (*Pardofelis marmorata*) (Ross et al. 2016), Leopard Cat (*P. bengalensis*) (Ross et al. 2015).

There are a number of ungulate species in Vietnam and some are among the country's most threatened animals. Large ungulates include: Eurasian Wild Boar (*Sus scrofa*) (Oliver and Leus 2008), Wild Water Buffalo (*Bubalus arnee*) (Hedges et al. 2008), Gaur (*Bos gaurus*) (Duckworth et al. 2016), Banteng (*B. javanicus*) (Gardner et al. 2016), Kouprey (*B. sauveli*) (Timmins et al. 2016a), Eld's deer (*Cervus eldii*) (Gray et al. 2015), Sambar

(*C. unicolor*) (Timmins et al. 2015b), Chinese Goral (*Naemorhedus griseus*) (Duckworth et al. 2008), Hog Deer (*Axis porcinus*) (Timmins et al. 2015a), and several species of Muntjacs (*Muntiacus* spp.) (Groves and Grubb 2011; Timmins et al. 2016c, 86–91). Particularly large and rare herbivores include the Asian Elephant (*Elephas maximus*) (Choudhury et al. 2008), and Javan Rhinoceros (*Rhinoceros sondaicus annamiticus*) (van Strien et al. 2008b).

Another unique and extremely vulnerable animal worth mentioning are pangolins (Order Pholidota). Two species are found in Vietnam, with currently non-overlapping geographic ranges: the Chinese Pangolin (*Manis pentadactyla*) (Challender et al. 2014a) in the north of the country, and the Sunda Pangolin (*M. javanica*) (Challender et al. 2014b) to the centre and south. Based on historic records, both species were once widespread throughout SEA, however, their numbers have sharply declined in modern times due to habitat loss and the international wildlife black market, as there is a high monetary value for this species (Challender et al. 2014a; 2014b).

During the Middle and Late Pleistocene several large species of fauna in Vietnam became extinct including, the orangutan (*Pongo* sp.), the panda (*Ailuropoda melanoleuca*), the stegodon (*Stegodon orientalis*), the Asian straight-tusked elephant (*Palaeoloxodon namadicus*), the giant tapir (*Megatapirus augustus*), and the giant ape (*Gigantopithecus blacki*) (Louys 2007, 26). In comparison to Australia, the Americas, or Madagascar, these extinctions occurred gradually over a longer period of time, which makes it easier to attribute them to natural environmental changes, as opposed to human exploitation (Corlett 2007, 292; Louys 2007). Despite many major extinctions in SEA over the Pleistocene, Corlett (2007, 299) concluded that over the last 30–50 years there has been an exponentially accelerating decline of fauna as a result of recent widespread destruction of habitat and the black market. In particular, the Chinese and Vietnamese black market has created a huge demand for ‘traditional’ medicines and exotic pets (Corlett 2007, 299).

2.3. Archaeological background

2.3.1. Cồn Cổ Ngựa: the physical environment

CCN is located in Ha Tinh village, Ha Trun district of Thanh Hoa province and is situated around 30km from the present coastline and about 3 km north of the Ma River

(Figure 2-4). The site sits in a modern rice paddy field in an open plain surrounded by uplifted limestone mountains, which range from 50–350 m above sea level (asl; Oxenham 2006, 213). These mountains have steep edges and look similar in appearance to Ha Long Bay. The name 'Cồn Cổ Ngựa' means 'The neck of the horse hill' after the shape of a hill that lies to the south of the valley which has now been heavily destroyed due to modern construction (Bui Vinh 1980, 8). The site is situated within a transitional plains-upland region, but it is still low enough to be inundated every rainy season (June-September). The natural vegetation has dramatically changed since occupation due to agricultural practices. Rice, cassava, tea, and tobacco are currently grown in the region (Bui Vinh 1980).

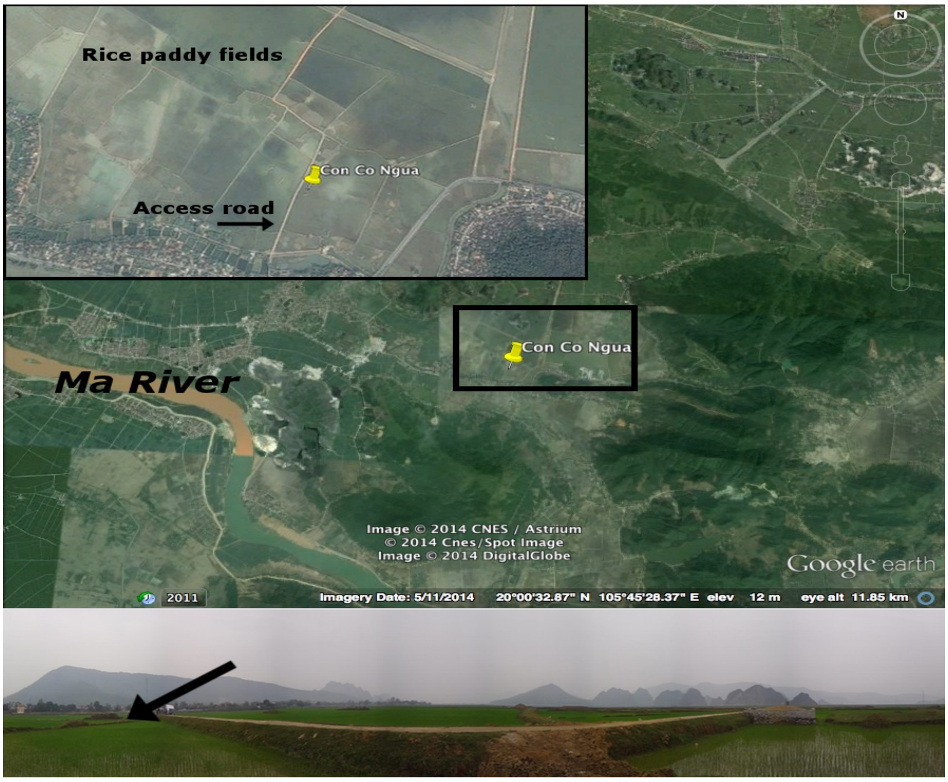

Figure 2-4 Above; composite Google Earth map of CCN showing the Ma River. Below; panorama of CCN looking south-west-north, arrow points to location of excavation. Photo taken from near the modern building (see Figure 2-5).

2.3.2. History of excavations at Cồn Cổ Ngựa

CCN was originally excavated in 1980 by the Institute of Archaeology of Hanoi and was recently re-excavated in March 2013 by a joint team from the Australian National University and the Institute at Hanoi (Figure 2-5). The site is believed to represent the initial and intermediate phases of the Đa Bút period, c. 6,000–5,000 BP, based on the material culture (Bui Vinh 1991; Nguyen Viet 2005). Further, a couple of enamel dates on human teeth produced a date of c. 3000±30 BC (Zhang and Hung 2012, 21). CCN is the largest burial site from this period with well over 200 individuals excavated from the two excavations.

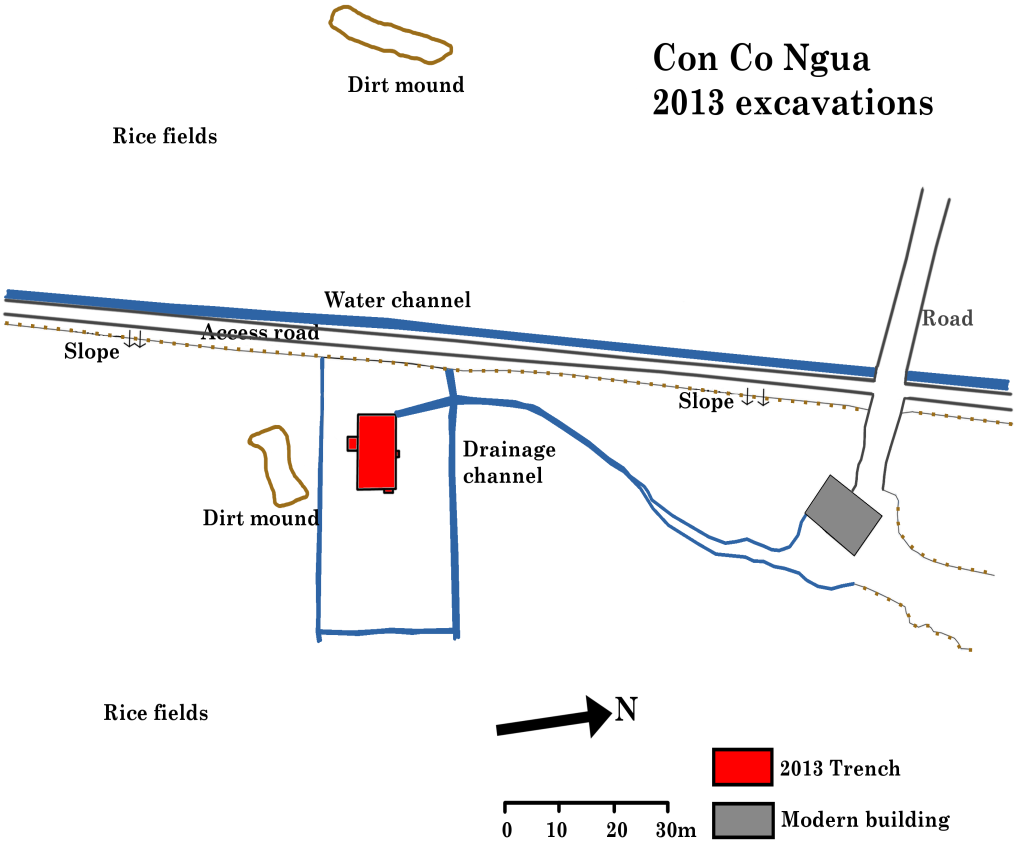

Figure 2-5 Site map of CCN showing the excavation square and immediate surroundings. Based on original drawing by Dao Xuan Ngoc.

2.3.4. Summary of the 1979–80 excavation

The original 1980 excavation was reported by Bui Vinh (1980). The original translated report is summarised as follows:

> In July of 1979 an investigation into [the] Cổ Ngựa river islet was carried out on the basis of some material culture that had been discovered and collected by two separate museums. From 15th of January – 15th April 1980 an excavation of Cổ Ngựa was undertaken by the Institute of Archaeology in Hanoi. No pumping was conducted, which meant the pit was constantly flooded, and no sieving of any kind was attempted. Two pits were opened; pit 1 measured 10x10 m^2 and pit 2 measured 128.5 m^2.

The archaeological Layers 2 and 3 were capped with a sterile bluish-grey clay (Layer 1) that Bui Vinh (1980) suggested was probably the result of a major flood. This flood may have happened at the end of the Holocene when there was a rise in sea level.

The total number of burials recorded was 101 but due to the constant inundation of water, visibility was low and the exact number may be different. Burials 17, 42, and 81 were reported to have stag horns alongside the burials in near complete, intact condition. Patte (1932) also recorded the presence of stag horns at Đa Bút in grave XII.

The shellfish that were excavated were made up of fresh water molluscs as well as salt-water oysters and mussels.

2.3.5. Summary of 2013 excavation

In March 2013 a joint Vietnamese and Australian excavation was carried out. In total, 146 human burials were excavated. The burials were arranged in a tightly flexed, squatting, or fetal position. Combining the two excavations together gives a total of 252 burials. For particular details on method of excavation and recovery see the methodology Chapter five section 5.2.

Four main stratigraphic layers were identified (Figure 2-6). Layer one consisted of a c. 20 cm thick sterile clay associated with the modern rice paddy. Layers two and three comprised thick grey-brown clay midden containing shell, bone and lithic artefacts as well as human burials. Layer four consisted of a sterile yellow-grey silty-clay.

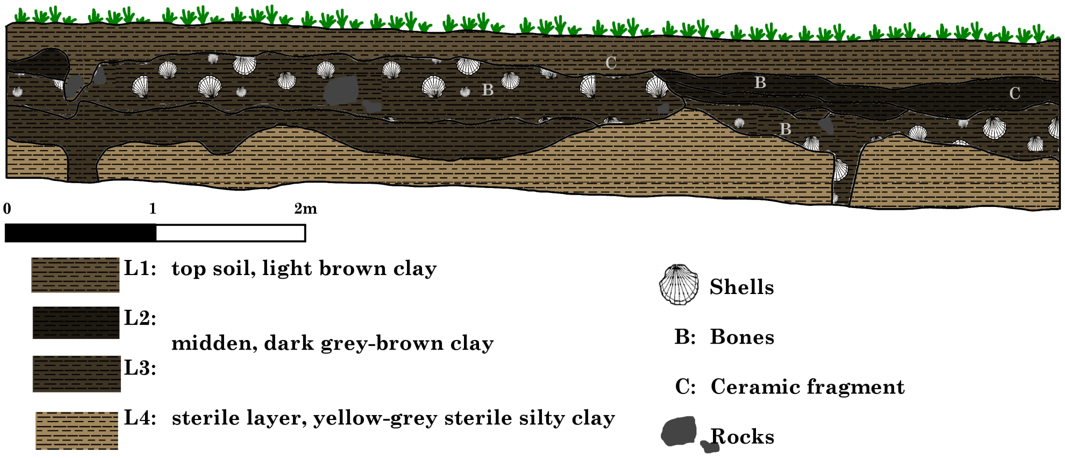

Figure 2-6 Section of the west wall at CCN showing the four stratigraphic layers identified. Based on original section drawing by Dao Xuan Ngoc.

2.3.6. Paleoenvironment

Based on paleoenvironmental reconstruction discussed above (section 2.2.3.), during the time of occupation of CCN, people had access to riverine, estuarine, costal, and dense sub-tropical forest resources within close proximity to the site (Oxenham 2006, 213). Nguyen Viet (2005, 91) describes the environment as a swamp system that exhibits a change in strategy from collecting marine and freshwater molluscs in the lower stratigraphic layer to marine fishing with weighted nets from c. 6,000 BP. By 5,500 BP the sea level appears to retreat and freshwater shellfish become common again (Nguyen Viet 2005). Oxenham (2006, 215) interprets the stratigraphy of CCN as a basal layer in which the burials are located within a midden matrix of fresh and salt-water molluscs, which is capped by a sterile clay layer. This clay layer has been interpreted as the result of a major flood. Layer two contains the majority of artefacts including fishing net sinkers, spinning whorls, bone awls, and chisels, and an absence of marine shells and plants (Oxenham 2006, 215).

2.3.7. The human skeletal evidence and lifestyle of inhabitants

The large size of the cemetery led Nguyen Viet (2005, 89–90) to suggest that the lifestyle was relatively sedentary, and he proposed that this may be the first time in Vietnam that the deceased were collectively buried in or near the village where they were living. In contrast, Oxenham (2016, pers. comm.) believes the site shows no obvious evidence of housing, although, it is possible the inhabitants were using the nearby caves for shelter.

Given the homogeneous nature of the matrix the burials were dug into and the lack of visible grave cuts, developing an idea of the sequence of timing for the burials is difficult. From M120 onward the graves were visibly cut into sterile soil, which means these burials must represent the first activity at the site (Anna Willis 2016, pers. comm.). Further, a whale radius seems to have been deliberately vertically dug into the sterile soil, which could represent early site use (see Chapter eleven section 11.6.5.). Alternatively, people could have cut through layers to position the whale radius.

In an analysis of the human skeletal material, Oxenham (2006, 233) found that CCN has the largest percentage of serious healed trauma than any other Southeast Asian assemblage. The lack of obvious weaponry or signs of warfare and the inclusion of stag horns in some graves led to the suggestion that hunting large animals may have been an important part of the culture (Oxenham 2006, 233). Overall, the skeletons were healthier than the average South Asian population during the period and suffered less skeletally sensitive diseases than people from the later Metal periods (Oxenham et al. 2005; Bower et al. 2006). An isotopic study on four individuals from both CCN and the Metal Age site of Nui Nap[1] concluded that the barium to strontium ratio and zinc levels were significantly lower for CCN, while the copper levels were higher, which indicates they had a greater marine component in their diet than Nui Nap (Bower et al. 2006, 82). Due to the small sample size it is difficult to determine the extent to which rice or other C3 plants may have played a role in the diet.

Work by Anna Willis and Ainslie Kells have revealed insights into the cultural and ritual aspects of burial at CCN (2015, pers. comm.). Willis has used 'anthropologie de terrain', which is a method that reconstructs the conditions of burial by examining the in-situ position of the skeletal remains. Willis suggests that some people were probably wrapped in perishable materials, such as baskets, prior to burial. Kells has analysed the post-mortem cutmarks on human remains, which shows people were heavily butchered after their initial burial.

2.3.8. Faunal analysis

The vertebrate assemblage from the 1979–80 excavation was analysed by Vu The Long (1980). The list of species is small and unfortunately raw data counts (NISP, or MNI) are not provided (Table 2-1). It is unclear what methodology was used to determine the percentage of fauna, although it was probably percentage of total NISP. No carnivores or primates were identified and Bovinae make up the majority of the recorded fauna. The clear dominance of large mammalian species and the limited number of taxa identified was likely influenced by the lack of sieving and use of appropriate drainage during excavation.

Table 2-1 Original species list for the 1980 excavation (Vu The Long 1980). *This species identification may be a mistake as according to the IUCN red list website its range is from Indonesia to Papa New Guinea.

Taxa recorded	% (%NISP?)	Common name
Bubalus bubalis	29	Water buffalo
Bovinae spp.	22	Cattle, buffalo
Rusa unicolor	25	Sambar deer
Sus scrofa	12	Wild boar
Pelochelys bibroni	9	Giant soft-shelled turtle*
Pisces	4	Fish

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[1] Like CCN, Nui Nap is located on the Ma River in Thanh Hoa Province, but it is closer to the coast, see Oxenham et al. (2002; 2005) for more details.

Vu The Long (1980) concluded that the water buffalo and pig bones were of similar size to domesticated animals. However, he does not mention what methods or comparative samples he used to determine this. In fairness, Vu The Long (1980) cautions not to jump to conclusions about the domestic status of *Bubalus* as in many parts of Vietnam, buffalo are in a 'semi-domesticated form', which makes it hard to distinguish wild from domesticated. Nonetheless, Bui Vinh (1991) and Nguyen Viet (2005) have argued that CCN represents the first evidence for domestication of pigs (*Sus scrofa*), water buffalo (*Bubalus bubalis*), and possibly dogs (*Canis familiaris*). This has been contested and has yet to be validated, as it is unclear what these conclusions were based on (Oxenham and Matsumura 2011; Sawada et al. 2011). Neither was there solid evidence for agriculture, despite the arguments by Bui Vinh (1991) and Nguyen Viet (2005) that stone axes were used for rice agriculture.

Bui Vinh (1980, 26–27) in the original report mentioned stag horns alongside three burials (nos. 17, 42, 81) in near complete condition and suggested they represented burial objects linked to worshipping sacred animals or ancestors. Bui Vinh (1980) also hints that faunal remains were commonly found within the graves. Unfortunately, the lack of records makes validating these claims difficult. In the 2013 excavation a large concentration of calcined deer antlers were found close to a grave (M133) cut into the sterile soil. This could potentially strengthen the original claims about the association between stag horns and burials.

The faunal analysis of this study will dramatically increase our understanding of the paleoenvironment by providing a detailed list of the species that were exploited and their habitats. The domestic status of bovines, pigs, and canids will be critically assessed. Further, contextual artefactual, and human skeletal information will help to lend more insight into social and cultural practices and the relationship between animals and humans during this period.

2.3.9. Mán Bạc: the physical environment

Mán Bạc is located in the Yen Mo district of the Ninh Binh province and sits approximately 25 km from the present coastline (Matsumura and Oxenham 2011, Figure 2-7). It lies on the southern margin of the Red River delta. The site is believed to be associated with the later Phùng Nguyên period dated to c. 4,000–3,500 BP (Matsumura and Oxenham 2011, 4). The area is now being used for modern agricultural purposes and a modern Catholic cemetery was built directly to the east. MB is closely nestled into the adjacent limestone mountain shaped like an amphitheatre surrounding the site (Figure 2-7). MB is approximately 200–300 m^2 with a 2 m deep deposit (Oxenham et al. 2008, 191).

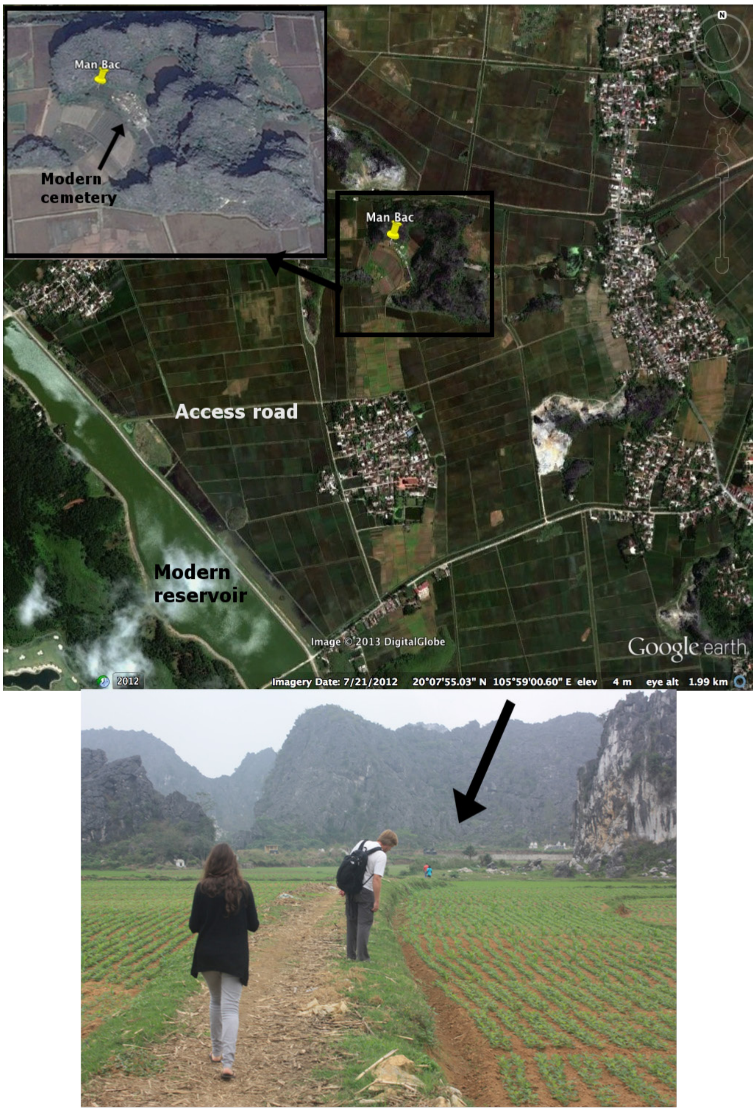

Figure 2-7 Above; composite Google Earth map of MB and surroundings. Below; walking north towards the site. Arrow points to location of excavation.

2.3.10. History of excavations and site summary

Oxenham et al.'s (2008, 191) preliminary analysis indicated that there were two distinct cultural phases with three stratigraphic layers: the two upper units were interpreted as occupation phases and the lower unit was almost exclusively burials in sterile silt. The similarity in material culture between the upper and lower phases suggests the burials are associated with the occupation layer(s).

Throughout the six years of excavations at MB, 99 burials were found making it the largest Phùng Nguyên burial site excavated so far (Matsumura and Oxenham 2011, 2). Again, the large number of burials indicated a degree of sedentism and throughout the excavation evidence for postholes and compacted floors were widespread (Tilley and Oxenham 2016). This suggests there was some form of structural foundations at the site and could indicate people were living within close proximity to the site. Oxenham et al. (2008, 196) tentatively suggested that people were buried underneath the floors of their houses or other structures. This was due to the clustering of burials with at least one adult and a range of younger ages, suggesting family groupings (Oxenham et al. 2008, 202). This has also been suggested for the roughly contemporaneous site Khok Phanom Di in Thailand (Higham et al. 1992). Similar practices of burying deceased family members underneath housing floors was widespread in prehistoric Near East, with well-known examples from Pre-Pottery Neolithic sites in the Levant, Jericho in Palestine, and 'Ain Ghazal in Jordan (Steadman 2016, 273). Further, Carr's (1995, 165) study of 31 'non-state' societies across Africa, Asia, the Pacific, and the Americas found that cross-culturally grave location within a cemetery often reflects kin relations.

Although burial groupings related to family is plausible it is perhaps less likely people were buried directly under the floors of houses, as presumably there would be more midden material within the burial matrix (Philip Piper 2017, pers. comm.). Another scenario would be a pattern similar to An Son (southern Vietnam), where burials were originally outside of the settlement area, but as the settlement expanded the midden eventually covered the burials (Bellwood et al. 2011, see Chapter ten section 10.1.5. for further discussion).

The excavators presume that horticulture or agriculture was practiced to some extent, as substantial amounts long grain rice phytoliths were found during the excavation, although this has yet to be published (Peter Bellwood 2013, pers. comm.). Throughout the excavated layers a wide variety of material culture was discovered that displayed attestable skill in jewellery and ceramic manufacture (Oxenham et al. 2008, 192). The style of ceramics and jewellery represent a significant departure from the previous Đa Bút period, and shares similarities to sites in Guangxi and Guangdong provinces in southern China (Bellwood et al. 2011, 2015; Sarjeant 2014, see Chapter three, section 3.6.1. for more details).

2.3.11. Human skeletal evidence and the 'two-layer' hypothesis

The mortuary practices at MB show little distinction between individuals on the basis of age, sex, or physical disability (Oxenham et al. 2008; Tilley and Oxenham 2011). Tilley and Oxenham (2011) demonstrated that the survival of M9, who was an individual with quadriplegia, till at least 10 years old would have necessitated daily care. His inclusion within the burial ground, and yet the different posture and positioning of the body, is indicative of community acceptance whilst acknowledging a difference (Tilley and Oxenham 2011, 40). They suggest the survival of M9 may reflect the high value of individual life within the community.

Perhaps the most potentially important aspect of MB as argued by the excavators is that the site captures a unique and significant transition (Matsumura et al. 2008; Oxenham and Matsumura 2011). Using metrical and qualitative analyses, Matsumura et al. (2008) have shown the majority of the population were markedly different from the previous Hoabinhian and Dabutian cultures and shared close affinities to later Dong Son cultures as well as ancient and modern southern Chinese individuals. Only one male individual (C29) showed a close affinity to previous cultures, including the skeletal population from CCN. These factors led Oxenham and Matsumura (2011) to argue MB represented a population undergoing major changes following the migration of agricultural groups of people from southern China into northern Vietnam.

This is consistent with an established theory sometimes referred to as the 'Two-Layer' hypothesis, which argues that SEA was originally inhabited by an 'Austro-Melanesian' population (the First Layer) that subsequently underwent significant genetic admixture with migration of North and/or East Asian populations (the Second Layer) that spread agriculture into SEA (Von Koenigswald 1952; Brace 1976; Howells 1976; Bulbeck 1982; Brace et al. 1991). This process was described by Bellwood (1987, 187) as long-term, geographically complex, and not the result of a rapid north-south flow of a uniform population from central China. More recently and specifically, scholars have argued that rice farming cultures (the Second Layer) spread from the Yangtze Basin into MSEA and ISEA from c. 4,000 BP where they intermixed with the indigenous populations, based on craniometric and genetic data from numerous sites (Bellwood and Glover 2004; Higham 2004b; Bellwood 2005; 2011; Matsumura et al. 2008; 2011, 153). Further, a recent genetic study supports a migration from southern Chinese agriculturalists with significant genetic admixture with hunter-gatherer populations at MB and other SEA sites (Lipson et al. 2018). Regardless of their origin, there is significant evidence to attest that the population of MB was undergoing a major transition. The paleopathology of MB also suggested that the population was undergoing a decline in health, and the high infant mortality rate suggests an increase in fertility (Oxenham et al. 2008; Domett and Oxenham 2011; Oxenham and Domett 2011).

2.3.12. The paleoenvironment and faunal analyses

Aside from the paleoenvironmental studies previously mentioned, faunal analyses by Sawada et al. (2011) and Toizumi et al. (2011) give insight into the environment surrounding MB. Sawada et al. (2011, 110) concluded that the mammals being exploited were from diverse environmental niches, including; forests, grasslands, watered lowlands, and marine sources. The analysis of the fish remains also pointed to access to marine, estuarine and freshwater species (Toizumi et al. 2011). Toizumi et al. (2011, 123) suggest the area was likely to have been similar to present day Ha Long Bay with the downstream basins of the rivers flowing into the bay. Based on these faunal analyses, the people living at MB would have access to numerous environment niches.

Table 2-2 Summary of the taxonomic list present in Sawada et al. (2011, Table 9.1, 108).

		Layer 1		**Layer 2**		**Layer 3**	
Taxon	**Common name**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**
Muridae	Rats, mice			1	1		
Canis sp.	Dogs, wolves	3	1	4	2		
Aonyx cinerea	Oriental small-clawed otter	1	1				
Viverra sp.	Civet cats	1	1				
Small carnivore		1					
Medium carnivore		5		1			
Rhinoceros	Rhino	1	1			1	1
Sus scrofa	Eurasian wild boar/domestic pig	86	10	43	8	15	2
Muntiacus muntjak	Muntjac	1	1	1	1		
Cervus sp.	Deer	6	1	6	2		
Bovinae	Cattle, water buffalo	1	1	1	1		
Medium artiodactyla		1					
Cetacea	Whale, dolphin			1	1	1	1
Subtotal **Total NISP = 182** **Total MNI = 37**		**107**	**17**	**58**	**16**	**17**	**4**

Table 2-3 Summary of taxonomic list of fish, sharks and rays in Toizmui et al. (2011, Table 10.1, 118).

		Layer 1		Layer 2		Layer 3		Total
Taxon	**Common name**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**	**MNI**	**NISP**
Lamnidae	Mackerel, white sharks	4	1			1	1	5
Lamniformes?	Mackerel sharks	36	1	10	1	2	1	48
Rajiformes	Rays	52	5	21	1	4	1	77
Elasmobranchi	Sharks, rays	20		3				23
Clupeidae	Sardines or shads	1	1					1
Siluriformes	Catfish	17	9	4	2	1	1	22
Siluriformes?		2						2
Mugilidae	Mullets	1						1
Mugilidae?		2	1	1	1			3
Lates calcarifer	Barramundi	59	6	10	2	6	1	75
Serranidae	Groupers	16	2	5	4	1		22
Lates calcarifer or Serranidae		11		1				12
Carrangidae	Jacks	1	1					1
Sciaenidae?	Croackers	3	1					3
Acanthopagus	Black seabream	138	31	32	9	18	13	188
Sparidae?	Seabreams	11						11
Platycephalida	Flatheads	1	1			1	1	2
Fish		28		2				30
Subtotal		**403**	**60**	**89**	**20**	**34**	**19**	**526**
Total NISP = 526								
Total MNI = 99								

The species recorded during Sawada et al.'s (2011) analysis can be seen in Table 2-2. Although the sample size is very small (NISP 182), *Sus scrofa* clearly dominate the taxa, followed by Cervidae and Canidae (presumed domestic dog).

Analysis of the pig molars led Sawada et al. (2011) to tentatively conclude that it was 'not improbable' the MB pigs were in the early stage of domestication. Although metrical measurements of pig molars showed a similar average length to wild pigs, the age composition portrayed an early kill-off pattern, which is often indicative of a managed herd where optimising the meat yield is a priority (Sawada et al. 2011, 106–7). Further, the proportion of pigs within the assemblage was far greater than other animals, indicating they were more important to the diet (Sawada et al. 2011, 107–9). This pattern of a disproportionate amount of pig bones compared to other taxa and young ages-at-death profiles is markedly different from the faunal composition at Đa Bút sites. Sawada et al. (2011, 109–10) also found a diverse range of wild animals within the assemblage, suggesting that hunting was still an important part of the diet and culture.

The analysis of fish remains by Toizumi et al. (2011) revealed a dominance of large fish such as *Acanthopagrus* (black seabream), *Lates calcarifer* (barramundi), and Serranidae (groupers) (Table 2-3). Elasmobranchii such as Myliobatiformes (rays) and Lamniformes (mackerel sharks) were also identified. Most of the identified taxa inhabit marine or brackish waters. Black seabreams mainly occupy waters with low levels of salinity such as estuaries, mangroves and lagoons. Barramundi and catfish can occupy a variety of habitats including marine waters to fresh water. The Elasmobranchii identified point to a marine origin, although exact species are unknown and many species of sharks or rays can be found in estuarine environments. Based on the relative frequencies of the various taxa, Toizmui et al. (2011, 123) suggest that marine and estuarine fishing were more important than freshwater.

Toizmui et al. (2011) also suggest that Serranidae may have been imported or traded due to their different habitat and extremely large size. Further, the large size of many of the fish suggest that angling technology existed. No fish hooks were found but the authors suggest that pointed bone artefacts may have been used as fishing gorges (Toizumi et al. 2011, 124). Likewise, the exploitation of a range of mammalian taxa attests to considerable and diverse hunting skill (Sawada et al. 2011, 110). The evidence for substantial skill in hunting and complex knowledge of local and regional ecological systems was a factor adding to the argument that MB attests to interaction between indigenous and migrant populations:

> Man Bac is clearly representative of interaction, possibly at many levels, of in-coming food producing migrants and an indigenous population. The new migrants brought domesticated plants and pigs to the table, while the indigenous populations with whom they were integrating likely brought a sophisticated and intimate knowledge of the local environment, including an ancient tradition of hunting and fishing. Man Bac is one of those rare archaeological instances of a community in transition, both in terms of its human genetic makeup, and with respect to major behavioural shifts in subsistence life-ways.
> Oxenham and Matsumura 2011, 131.

2.4. Summary of sites

Overall, these paleoenvironmental studies are a confirmation of what is seen in the archaeological record at CCN and MB. Faunal analysis by Sawada et al. (2011) and Toizumi et al. (2011) indicate that inhabitants at MB had access to resources from numerous environmental niches. The report by Vu The Long (1980) for CCN also suggested an economy based on a variety of aquatic and terrestrial resources. The general picture that emerges during the Mid Holocene is one of diversity and plenitude of resources.

CHAPTER THREE
Zooarchaeological Research in Southeast Asia

3.1. Introduction

Southeast Asia (SEA) is one of the most culturally and environmentally diverse regions in the world. The archaeological record of SEA challenges traditional Eurocentric narratives of how we define our species and understand the material record (Habgood and Franklin 2008; Denham 2011; Haidle and Pawlik 2011; Rabett and Piper 2012; Dennell 2014; Hunt and Rabett 2014; Piper and Rabett 2014). Research into this diverse landscape has increased in recent years but remains largely restricted to particular areas. Within archaeology, specialisations such as zooarchaeology are relatively limited to large, internationally funded projects (Higham 1975a; Grant and Higham 1991; Kijngam 2010; Rabett et al. 2011; Piper et al. 2012; Oxenham et al. 2015; Samper Carro et al. 2015; Conrad et al. 2016). Though there are basic site reports listing fauna excavated from archaeological sites by Vietnamese zooarchaeologists, such as Vu The Long (1979; 1980), this thesis represents the first PhD in Vietnamese zooarchaeology in English and thus adds vital information to this crucial area.

This chapter sets the geographic and temporal context for CCN and MB by providing a chronological review of zooarchaeological research from the Terminal Pleistocene to the Mid Holocene (c. 22,000–4,500 BP). It aims to contextualise the sites by drawing together northern Vietnamese and Southeast Asian zooarchaeological scholarship. Particular attention is paid to the Đa Bút (c. 6,500–5,000 BP) and Phùng Nguyên (c. 3,800–3,400 BP) periods to place CCN and MB within their regional and historical contexts. Major faunal patterns between sites and periods are discussed, including the greater variety of fauna from a diverse range of environmental niches during the Đa Bút period, as well as the introduction of domesticates during the Phùng Nguyên period.

The following section compares CCN and MB to contemporary sites in Thailand and Southern China. These two regions hold the most archaeological similarity and relevance to Vietnam, especially Northern Vietnam and Southern China due to the geographical proximity. The regional inter-site comparison between Vietnam, Thailand, and China attempts to coalesce patterns and transitions that take place between the Early to Mid Holocene. It is argued here that while there is a perceivable transition to domesticated animals through the introduction of pigs and dogs, there is considerable inter-site variability. This indicates that local environmental conditions as well as human and animal agentic decision-making played an important role in shaping the outcomes and trajectories across SEA.

3.1.1. Primary regions of study and time periods

Figure 3-1 displays the main regions that will be discussed in this chapter, and used in Chapter nine for regional meta-analysis. Table 3-1 provides a breakdown of the major dates and cultural time periods between each region in MSEA and China.

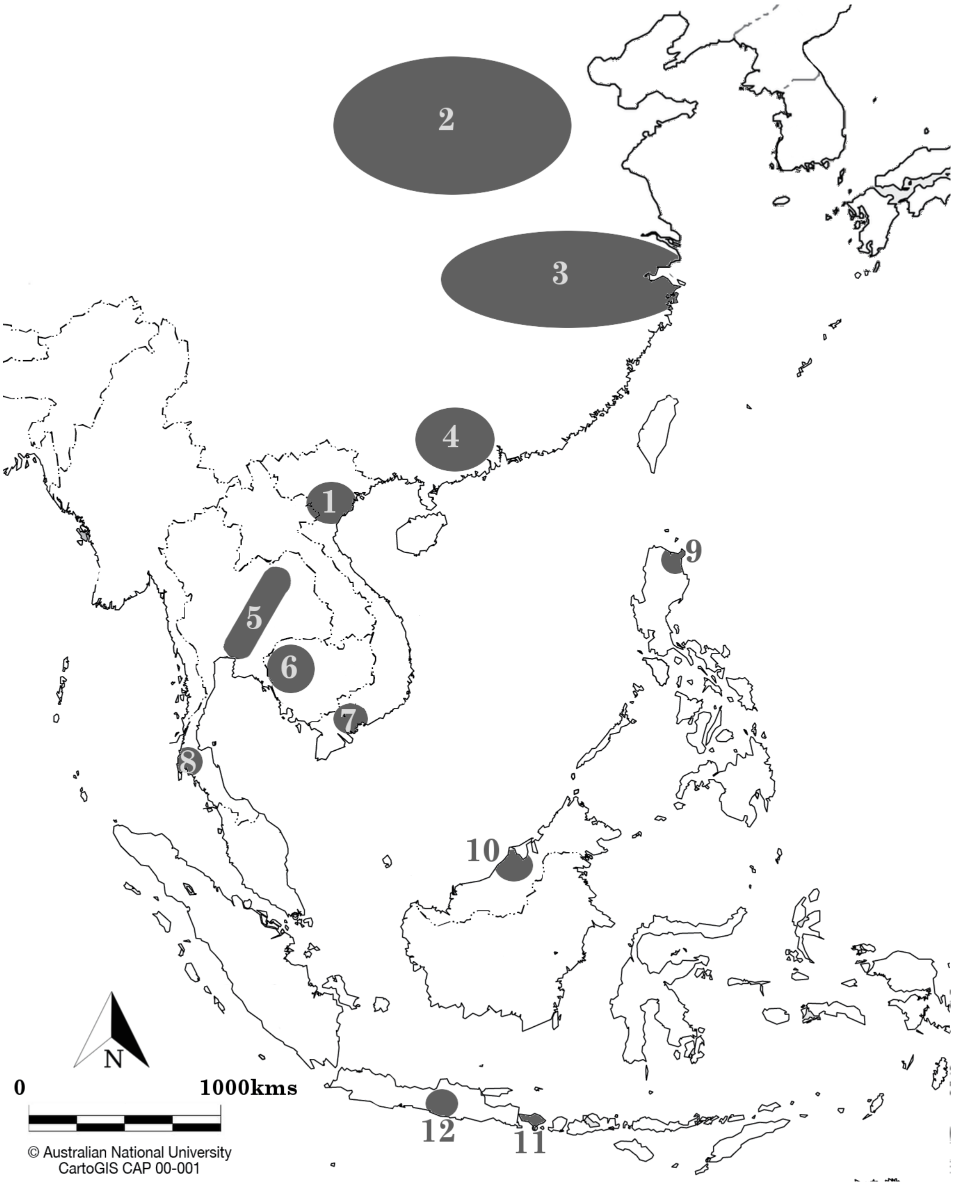

Figure 3-1 Map of SEA highlighting regions that will be discussed in detail in this chapter. 1: study area (Da But and Phung Nguyen sites), 2: Yellow River sites, 3: Yangtze River sites, 4: Dingsishan culture sites, 5: Mainland Thai sites, 6: Cambodian sites; 7: Southern Vietnam sites, 8: Thai peninsula sites, 9: Nagsabaran, 10: Niah Cave sites, 11: Pacung & Sembiran, 12: Indonesian peninsula sites.

Table 3-1 List of main periods and sites from the Terminal Pleistocene to Late Holocene mentioned in text.

Date BP	Geological phase	Archaeological period	Yellow River	Yangtze River	South China	Vietnam	Thailand	Cambodia	ISEA
22,000-11,700	Terminal Pleistocene				Zengpiyan	Ma U'Oi	Spirit Cave		Niah Cave
		Hoabinhian				Hang Boi	Lang Rongrien	Laang Spean	Song Gupuh, Terus, Keplek, Goa Braholo
			Cishan	Pengtoushan sites	Tangzigou				
8,000	Early Holocene	Chinese "Neolithic"			Dingsishan				
7,000									
6,000		Viet "Neolithic"	Yangshao period	Hemudu		Da But sites			
			Xipo	Daxi culture		**CCN**			
5,000	Mid Holocene								
			Majiayou	Qujialing culture					
			Linhia	Shijiahe culture					
		Thai "Neolithic"	Banshan	Liangzhu					
4,000					Dingsishan phase 4	Phung Nguyen sites	KPD		Nagsabaran
		Chinese "Bronze Age"	Xia dynasty			**MB,** An Son, Rach Nui	BNW, BC		
3,000			Shang dynasty			Lo Gac, Loc Giang	NNT		
			Zhou dynasty						
2,000	Late Holocene	Chinese "Iron Age" Viet and Thai "Bronze Age"		Springs and autums		Dong Dau			
				Warring states		Go Mun	BNW, NNT		
1,000		"Iron Age"							
			Han dynasty			Dong Son		Phum Snay	Sembiran/ Pacung

3.2. Early evidence for human occupation in SEA and Vietnam

Since this thesis is investigating the transition from hunter-gathering to domestication, the focus of this chapter is the Pleistocene-Holocene transition to the Mid Holocene (Table 3-1). To contextualise the lead up to this transition, the Pleistocene is briefly discussed below, however, for more detailed discussions on the Pleistocene in SEA see (Dennell 2009; Boivin et al. 2013; Dennell and Porr 2014). As detailed in Chapter one (section 1.4.), the chronology follows Rabett and Piper (2012).

The earliest evidence for hominin occupation in SEA comes from Java in Indonesia during the Early Pleistocene with *Homo erectus* dating to about 1.2–0.75 Ma (Reynolds 1993; Hope 2005, 33) or possibly as early as 1.8–1.74 Ma (Higham 2014, 25). The evidence for *H. erectus* on the mainland is more problematic. In Vietnam, the evidence consists of isolated teeth found at Tham Kuyen and Tham Hai (Figure 3-2, Table 3-2), which is controversial because distinguishing between orang-utan and *H. erectus* teeth when they are worn is difficult (Bacon et al. 2004, 306). However, there is increasing evidence that hominins were relatively widespread throughout SEA during the Upper Pleistocene. A recent find of a third metacarpal U-series dated to 67 ±1 kya from Callao Cave in northern Philippines has been tentatively ascribed to modern *Homo sapiens* (MHS; Pawlik et al. 2015). Regardless of the final taxonomic attribute of the hominin, the cutmarks on fauna excavated in association with the metacarpal shows this hominin was tool-using (Pawlik et al. 2015).

Opinions vary greatly over when MHS first spread across Asia. A large part of the problem is a lack of human skeletal evidence. Most researchers suggest an eastward expansion from Africa between c. 80–70 kya (Dennell and Porr 2014, 4). Although new research also suggests multiple exits from Africa from c. 120 kya, with an initial rapid expansion into southern Asia c. 90 kya (Timmermann and Friedrich 2016, 1–2). The earliest date for MHS in the Asia-Pacific comes from Lake Mungo in Australia, although the dating is controversial. Initial direct dating on the 'Lake Mungo 3' human skeleton using U-series and ESR produced a date of 62±6 kya (Thorne et al. 1999). Bowler et al.'s (2003, 839) direct OSL on two human burials produced a date of 40±2 kya, and OSL on sand beneath the burials containing 11 silcrete flakes gave bracketed ages of 50.1±2.4 kya and 45.7±2.3 kya. This led Bowler et al. (2003) to suggest a date of human occupation at Mungo from 50–60 kya, which Hiscock (2013) approves, although Dennell and Petraglia

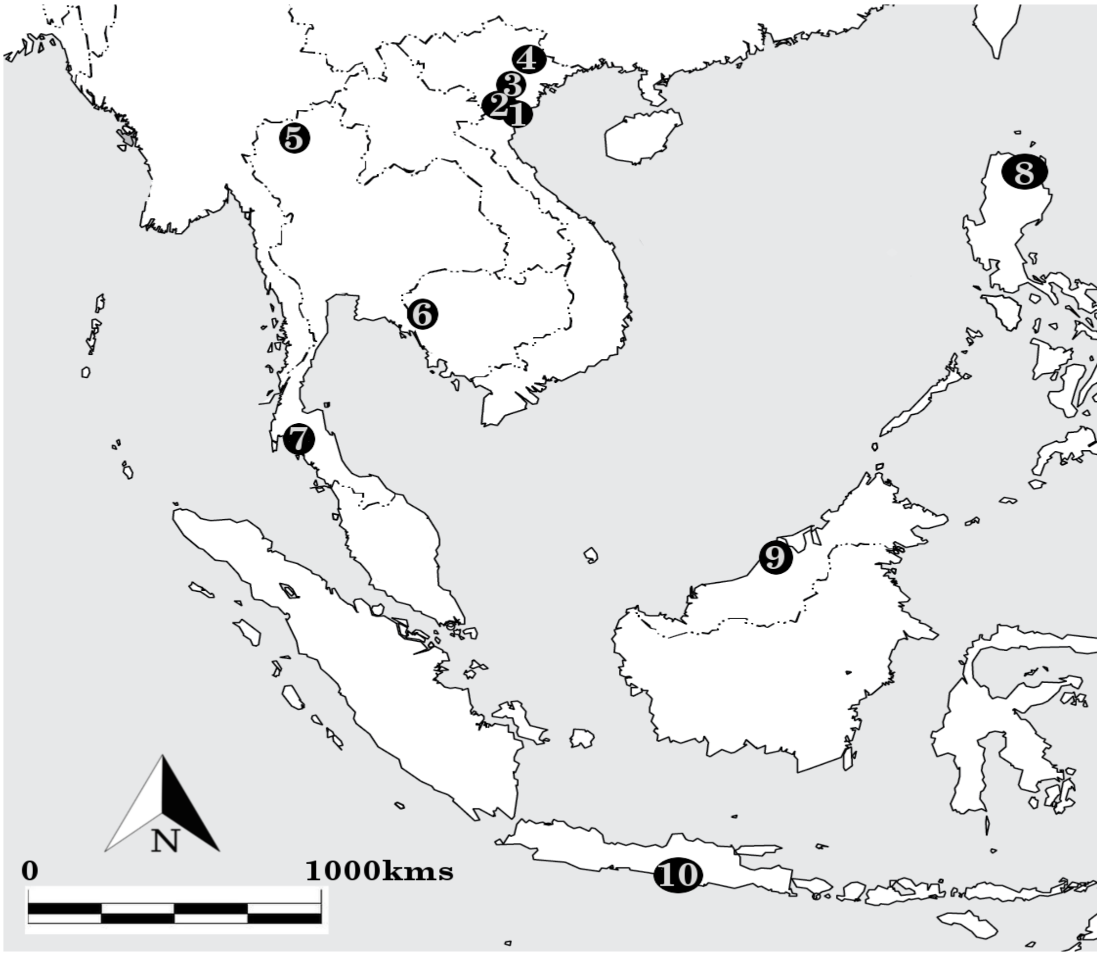

Figure 3-2 Late Pleistocene and Early Holocene sites in MSEA and ISEA mentioned in text and used in PCA analysis in Chapter nine. 1: CCN and Dabutian sites, 2: Hang Boi, Lang Trang, 3: Ma U'Oi 4, Tham Khuyen, 5: Spirit Cave, 6: Laang Spean, 7: Long Rongrien, 8: Callao Cave, 9: Niah Cave 10: Song Gupuh, Song Terus, Song Kepet, Goa Braholo.

(2012, 17) prefer a more conservative 40 kya. A recent study suggests human occupation of northern Australia by c. 65 kya based on OSL dates of deposits with lithics and ochre at Madjedbebe rock shelter (Clarkson et al. 2017). Although the timing of the colonisation of Australia is heavily debated, it provides a minimum date for the spread of MHS into SEA.

The most securely dated MHS in the SEA region is from Niah Cave in Borneo c. 45–39 kya cal. BP based on U-series dating of bone fragments from a MHS skull ('Deep Skull') and associated charcoal radiocarbon dates (Barker et al. 2007, 258). In Vietnam, only three Pleistocene sites have been recently excavated; Tham Kuyen (475 ±125 kya), Tham Hai (300–200 kya), and Lang Trang (80–60 kya; Bacon et al. 2004, 306). The fauna associated with these deposits is typical of the Middle Pleistocene, known as the Ailuropoda-Stegodon complex, and is accompanied by the arrival and migration of *H. erectus* and later *H. sapiens* (Bacon et al. 2004, 306). Scholarship on the arrival and spread of MHS into Asia is very much a work in progress and more archaeological and skeletal evidence is sorely needed.

The Pleistocene in SEA has long suffered from European narratives on human evolution used as a universal rule upon which to measure levels of 'modernity' (Habgood and Franklin 2008; Haidle and Pawlik 2011; Rabett and Piper 2012; Dennell 2014). Against the backdrop of the European and African Palaeolithic tool assemblage, SEA suffers from the notion of an unchanging and stagnate culture (Rabett 2011; Dennell 2014). The emergence of modernity was bound up in the expansion of *H. sapiens* out of Africa during the Upper Pleistocene. All MHS were, and often still are, treated as though they were as unified behaviourally as they are genetically (Habgood and Franklin 2008; Haidle and Pawlik 2011; Rabett and Piper 2012, 38). However, the concept of behavioural modernity has been heavily critiqued and the increasing amounts of data from across the globe are portraying a diverse and complex picture. As Rabett and Piper (2012, 38) note, how our species developed and adapted looks increasingly diverse and locally contingent.

Table 3-2 Main sites in Vietnam mentioned in text.

Site Name	Country	Province / Region	Type	Period	Uncal. BP	^{14}C date BP	Date reference
Hang Boi	Vietnam	Ninh Binh	Cave	Hoabinhian		c. 13,600–10,620	(Rabett 2012, 241, Appendix 1)
Hang Hum, Phai Ve, Keo Leng	Vietnam	Hoang Lien Son, Lang Son	Cave	Upper Pleistocene			(Hoáng Xuân Chinh 1991)
Lang Trang	Vietnam	Thanh Hoa	Cave	Upper Pleistocene			(Vu The Long et al. 1996)
Ma U'Oi	Vietnam	Hoa Binh	Cave	Upper Pleistocene			(Bacon et al. 2004)
Da But	Vietnam	Thanh Hoa	Rockshelter/ shellmidden	Dabutian	6,460–5,710		(Bui Vinh 1991, 128) and (Nguyen Viet 2005, 91); based on dates from 1971 and 1986
Con Co Ngua	Vietnam	Thanh Hoa	Cemetery/ midden	Dabutian		6,636–5,947	This study
Go Trung	Vietnam	Thanh Hoa	Midden	Dabutian	4,700 ±50 / 4,790 ±70		(Bui Vinh 1991; Nguyen Viet 2005)
Ban Thuy	Vietnam	Thanh Hoa		Dabutian	5,655–4,905		(Nguyen Viet 2005)
Lang Cong	Vietnam	Thanh Hoa		Dabutian	4,985–4,780	4,460–3,710	(Nguyen Viet 2005)
Hang Sao	Vietnam	Ninh Binh		Dabutian			
Dong Vuon	Vietnam	Ninh Binh		Dabutian			
Hang Co	Vietnam	Ninh Binh		Dabutian			
Man Bac	Vietnam	Ninh Binh	Cemetery/ midden	Phung Nguyen		3,836–3,083	This study
Phung Nguyen	Vietnam			Phung Nguyen			
An Son	Vietnam	Long An	Residence/ cemetery			4,410–3,010	(Bellwood et al. 2011)
Rach Nui	Vietnam	Long An	Residence			3,555–3,265	(Oxenham et al. 2015)

3.3. Subsistence during the Pleistocene/Holocene boundary in SEA

Diversity or a 'broad spectrum' diet is a common feature within faunal assemblages during the Terminal Pleistocene and a wide variety of habitats are often exploited. Gorman (1970) was the first to argue that SEA did not show a transition between the Pleistocene and Holocene, like the broad spectrum revolution in European assemblages. This was based on his excavation of Spirit Cave in Thailand (Figure 3-2), which was one of the first projects in MSEA to use sieving frequently and consequently enabled a diverse range of fauna to be collected and identified. Recent reanalysis of the faunal material by Conrad et al. (2016, 18) suggests human occupation of Spirit Cave was not continuous during the Pleistocene/Holocene transition. This was based on the abundance of Hipposiderid bat remains, as they do not roost in caves when humans are present. Further, the identification of a calcined Burmese hare calcaneus suggested landscape disturbance, possibly related to forest clearing from c. 8,000 BP stimulated by humans or natural agents (Conrad et al. 2016, 19). Similarly, at Niah Cave (c. 16,000–8,400 cal. BP, Figure 3-2) in northern Borneo people were exploiting a diverse range of fauna and adapting hunting strategies and technologies to different environmental conditions (Piper et al. 2008b; Piper and Rabett 2009; Rabett 2012; Rabett and Piper 2012). Rabett (2012, 209) posits that subsistence within the tropics is likely to have always followed a diverse pattern of exploitation as this directly reflects the environment itself. This pattern holds true for the Mid Holocene where diversity of fauna and a continued reliance on wild taxa persists, despite the introduction of domesticated animals (see section 3.6. below). Further, Medway demonstrated that for West Mouth (Niah Cave) domestic pigs only occur in the sub-surface layers while the majority of the deposit consists of the Bornean bearded pig (Sus barbatus) (Piper et al. 2013b, 128). Medway's methods were well in advance of their time and the comparative data-set he collected of bearded pig dental biometric remains the only such database for this species.

In a recent synthesis Piper (2016) traces the technological and cultural developments during the Late Pleistocene to Mid Holocene. At Niah Cave, Song Gupuh, Song Terus, Song Keplek and Goa Braholo (Figure 3-2) during the Terminal Pleistocene there is a shift to greater exploitation of arboreal taxa especially Cercopithecidae (monkeys), Viverridae (civet cats), and *Pongo* sp. (orangutan) (Rabett and Piper 2012; Piper 2016, 27). This shift in subsistence coincides with innovations in technology, especially bow and arrow implements produced from material such as string ray spines (Rabett and Piper 2012, 42). This is also mirrored in the assemblage of Braholo Cave, in which Amano et al. (2015) described a marked shift in faunal composition from the Late Pleistocene to Mid Holocene. The pre-LGM and LGM assemblages were dominated by bovids and deer, while the onset of the Holocene saw a marked increase in arboreal mammals and taxa highly dependent on rainforest environments. This suggests that regionally in SEA there was an expansion of rainforest environments from c. 12,000 BP (Piper and Rabett 2009; 2014). However, both Amano et al. (2015) and Piper and Rabett (2014) emphasise that certain species were specifically targeted, such as the Javan lutang in Braholo Cave, and the bearded pig throughout Niah Caves. This dramatic change from open to forested environments would have necessitated different hunting strategies and technologies.

This change in technology throughout the region is coupled with emergence of deliberate burial of human remains and the use of animal body parts in burials (Piper 2016, 33). Further, there is a paucity of pig and monkey skulls and mandibles in the Niah Cave assemblage for no perceivable taphonomic reason, which hints at potential trophy keeping of specific elements (Piper 2016, 27). These interesting developments imply a significant change in human perceptions of the environment and human-animal relationships. Piper (2016, 36) argues the increased evidence for ritual behaviour suggests a growing emphasis on social identity. There is an interesting correlation between the massive changes in sea level and environment during the Terminal Pleistocene and the developments of new technologies and ideologies. For an in-depth discussion on implications of this changing ideology see discussion section 11.6.7.

3.3.1. The Hoabinhian

The techno-complex that has the most relevance to the Pleistocene/Holocene boundary within North Vietnam is known as the Hoabinhian. The problem of how to understand the SEA tool assemblage is apparent through the Hoabinhian lithic industry as it is characterised by low-input pebble tools especially sumatraliths (unifacial pebble tools) and short axes, and hundreds of sites occur in Vietnam, Thailand, Burma, Cambodia, Malaysia, and northern Sumatra (Figure 3-3; Reynolds 1993, 9; 2007). Similar industries also appear in Southern China, Nepal, and Australia but these are generally considered to be outliers (Hà Ván Tân 1997), and Marwick (2008b, 1191) argues there has been limited work towards understanding assemblage variation at large scales and evaluating these claims. The low-input and ‘unchanging’ nature of the Hoabinhian lithic assemblage over such a widespread area is part of the reason why Late Pleistocene archaeology in SEA was treated as stagnate (Rabett 2011; Dennell 2014). Although Marwick (2008a, 190) argues this concept of an 'unchanging technology' is largely based on lithic typological classification systems, which inherently hide or compress variation into a small number of groups. Further, the idea of the Hoabinhian period itself is problematic. Since it extends over most of MSEA, designating the period as a single 'culture' with starting and terminating dates is dubious. With these reservations in mind, the term 'Hoabinhian' is still commonly used by archaeologists and is useful as a general classification for the sites.

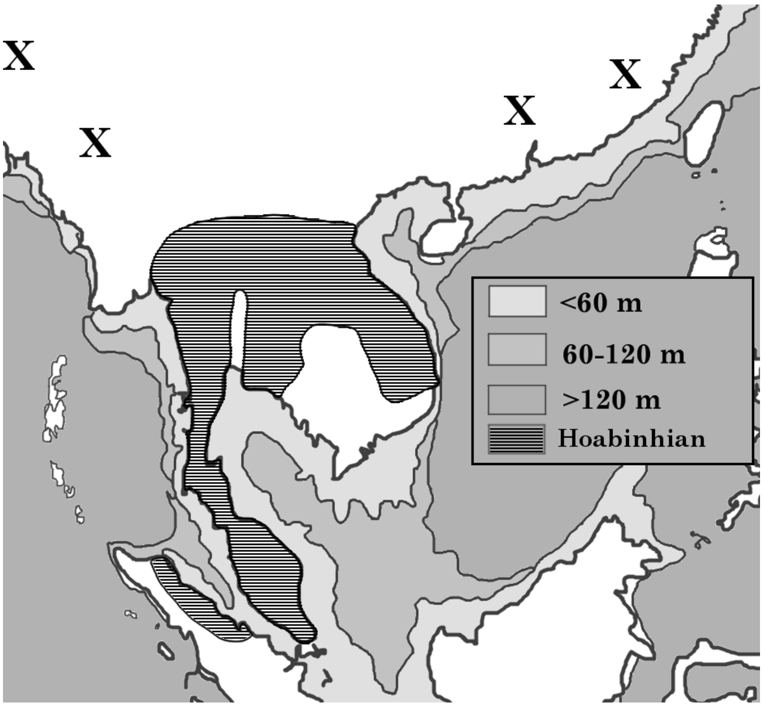

Figure 3-3 The main Hoabinhian range and potential outliers (X). Estimated sea level based on previous map (Chapter two, Figure 2-2), c. 15,000 BP would have been 100 m below present. Hoabinhian range based on White (2011, 19).

While generally thought to be a Holocene technocomplex, the Hoabinhian is particularly rich in Vietnam from the LGM to the end of the Pleistocene (Reynolds 1993, 8). Reynolds (1993, 8) classifies the Vietnamese techno-complexes during this period in four ways: Sonvian, Ngoum, Hoabinhian, and Bacsonian; while Rabett et al. (2008, 87) add Dabutian to this list. Marwick (2008a, 111) argues that although typological differences between lithic industries are relatively clear, their historical relationship is uncertain. For instance, it is unclear whether they are divergent industries from a common ancestor, or whether they represent adaptations to different ecological conditions within a single industry (Marwick 2008a, 111).

Northern Vietnam seems to have been a concentrated area of Hoabinhian sites with over 120 found, especially around Hoa Binh Province, from which the period derives its name (Nguyen Khac Su et al. 2004; White 2011, 25). In general, Hoabinhian sites are found in mountainous areas in caves, however, this may be a sampling bias and given the rise in sea levels, it is possible sites have been submerged underwater (White 2011, 25). The increasingly complex picture from Vietnam suggests an intensity in the use of cave and rock shelters by small groups of mobile hunter-gatherers during the Pleistocene/Holocene transition.

3.3.2. Fauna at Hoabinhian sites

Hoabinhian sites generally show a diversity of fauna from large ungulates to shellfish. The site of Laang Spean in Cambodia shows a dominance of large wild cattle (*Bos* sp.) and deer as well as riverine turtles and shellfish (Forestier et al. 2015). For Bovidae and Cervidae the majority of the body is represented but vertebrae and phalanges dominate %NISP, in particular the phalanges commonly show fracture patterns indicative of marrow extraction (Forestier et al. 2015, 205). The authors argue the majority of the taxa suggest exploitation of nearby rainforest and riverine environments supplemented by large ungulate hunting (Forestier et al. 2015).

Other Hoabinhian sites show a similar diversity but a greater reliance on inland aquatic resources. One such example from Vietnam is Hang Boi cave in Ninh Binh Province, dated around the Pleistocene/Holocene transition (12,000–10,000 cal. BP; Rabett 2012, 241–2). During this time the sea level was 60–50 m lower than it is now; Hang Boi was approximately 60 km from the coast and would have been surrounded by salt marshes and lagoon landscapes (Rabett 2012, 242, 246). The faunal assemblage is predominately an inland shell midden dominated by land snails. In particular, the deposit consists of whole shells of the genus *Cyclophorus*, despite there being a range and abundance of other land snail taxa beyond the cave (Rabett et al. 2011, 162; Rabett 2012, 236). This land snail is still commonly consumed by Vietnamese today for medicinal purposes, the preferred method is boiling with the dregs of rice wine to improve the flavour (Rabett et al. 2011, 162). Rabett et al. (2011, 162) believe the sheer volume of the shells indicates they were of subsistence value and that boiling may have been the method of cooking.

The diversity of vertebrate fauna with butchery marks (turtles, deer, felids, pigs, and monkeys) attest to human hunting abilities at Hang Boi (Rabett et al. 2011, 162). However, with the exception of monkeys, turtles, and fish, most of the vertebrates appear in low frequencies. Further, the taxa represented appears to reflect change over time, with the most intensive period of occupation towards the end of the sequence. Body part representation of small to intermediate sized mammals shows that whole carcasses were being brought to the site and consumed, whereas larger animals such as pigs and deer are mainly represented by their extremities and occasionally limb and cranial elements. The absence of meat-bearing bones from large animals suggests that carcasses were never brought up to the cave or that they were subsequently removed after being butchered.

Rabett et al. (2011, 163) conclude that the faunal assemblage from Hang Boi is consistent with small-scale community employing mostly opportunistic hunting and short term site occupation, which may have been governed by reliable and seasonal peaks in the availability of land snails. The faunal remains show a reliance on local marsh or lagoon habitats but there is some evidence of contact with the coast with pierced neritid shells and fragments of Đa Bút pottery in the upper layers (Rabett 2012, 250). The limited numbers of freshwater molluscs led Rabett and colleagues (Rabett et al. 2011, 162; Rabett 2012, 251) to argue that Hang Boi is only giving a partial reflection of the subsistence landscape and hints at inter-site variability within the Hoabinhian. The comparison of Hang Boi to the large ungulate dominated assemblage of Laang Spean in Cambodia shows a similar diversity of taxa but different emphasis on particular species (shellfish, monkeys, turtles, and fish). This confirms the suggestion of inter-site variability and how the local environment and human decision-making were important factors affecting the assemblage.

3.4. The Đa Bút period: Cồn Cổ Ngựa in context

The precise nature of the relationship between the Hoabinhian and the Dabutian (Đa Bút) is ambiguous. Bui Vinh (1991) has stipulated that Đa Bút, as well as other Neolithic cultures with a coastal focus, developed out of the Hoabinhian culture around 6,500–6,000 BP. Conversely, Higham and Thorsarat (2004b, 154–5) believe the origins lie further towards the coast and that these sites are probably now submerged underwater. What is clear is that there are a number of significant transitions between the Hoabinhian and the Đa Bút period, particularly an increase in settlement size and an increasingly complex faunal exploitation strategy.

Dabutian sites were originally named after the site of Đa Bút excavated by Etienne Patte (1932). They are characterised by coarse pottery that varies little in form or material with mat or cord-impressed designs (Bui Vinh 1991; Nguyen Viet 2005). Net sinkers and edge-ground axes commonly comprise the tool kit and the use of net sinkers at CCN and Go Trung represents the earliest evidence for fishing with nets in Vietnam (Nguyen Viet 2005, 90).

Table 3-3 Recorded Đa Bút sites according to Nguyen Viet (2005: 89).

Province	Site
Thanh Hoa	Da But CCN Ban Thuy Lang Cong
Ninh Binh	Hang Sao Dong Vuon Hang Co

Vietnamese archaeologists believe Dabutian sites are restricted to the coastal plains and banks of the Ma River in Thanh Hoa province (Bui Vinh 1991; Nguyen Viet 2005). According to Nguyen Viet (2005, 89) eight Đa Bút sites have been recorded in Thanh Hoa and Ninh Binh provinces (Table 3-3). In general, Vietnamese Hoabinhian sites are largely based in mountainous areas geared towards inland resources while Đa Bút sites shifted to coastal lowlands and display a greater diversity in location as well as habitat exploitation (Bui Vinh 1991; Nguyen Viet 2005; Rabett 2012, 248–9). A number of scholars have suggested this transition in site location and economic focus is an adaptation to the higher sea level of the Mid Holocene (Bui Vinh 1991; Nguyen Viet 2005; Rabett 2012, 249).

Bui Vinh (1991) and Nguyen Viet (2005) have attempted to characterise and summarise the chronology of the Đa Bút period (Table 3-4). Both suggest there is evidence for a decline in sea level during the period, which prompted development in fishing technologies.

Table 3-4 Summary of Bui Vinh 1991 and Nguyen Viet's 2005 chronology for the Đa Bút period.

Phase	Date	Exploitation strategy	Sites
1	c. 6000 BP	Exploitation of estuarine, lake, and swamp environments. Middens of molluscs (*Corbicula*) are common.	Da But, Ban Thuy, lower layers of CCN
2	c. 5500 BP	Decline in sea level resulted in seasonal exploitation of mountainous environments and development of fishing technologies.	Upper layer CCN, Lang Cong, Hang Sao, Hang Co
3	c. 5000 BP	Expansion along coastline, fishing with nets and stone weights.	Go Trung

One of the major debates is how to interpret the presence of edge-ground axes in Dabutian assemblages. Some Vietnamese archaeologists have argued the presence of edge-ground axes represents initial agriculture at CCN and Go Trung (Bui Vinh 1991; Nguyen Khac Su et al. 2004). Other scholars remain sceptical since there is no basis for this assumption and no evidence of rice cultivation (Higham 1996; Higham and Thosarat 2004b, 154–5; Nguyen Viet 2005; Matsumura et al. 2011). Matsumura et al. (2011, 157) regard Đa Bút communities as foragers with a degree of sedentism (as evidenced by large cemeteries), and marked marine resource dependency. Similarly, Nguyen Viet (2005, 89) argued Đa Bút communities were hunter-gatherers with a complex subsistence strategy drawing from a variety of environmental niches, such as, coastal, freshwater swamps, lakes, rivers, and mountainous habitats. Nguyen Viet (2005, 92) finds the sudden appearance of polished adzes in the Đa Bút period puzzling and suggests it may be related to housing construction or manufacturing of implements.

The argument for agriculture based on edge-ground axes is probably related to assumed 'progressive' cultural trajectories based upon European or Chinese models. Sedentism or the presence of ceramics is not necessarily an indicator of agriculture or domestication. Indeed, Higham and Thorsarat (2004b, 154–5) argue the Jōmon culture in Japan is analogous to the Dabutian. Jōmon sites are also located along the coast and developed ceramics, polished stone tools, and cemeteries without the presence of agriculture (Crawford 2011).

3.4.1. Fauna from Đa Bút sites

One of the commonalities between Đa Bút sites is that they are essentially middens with an emphasis on molluscs and large mammalian species. Apart from CCN, the two sites that have reports summarised in English or French are Đa Bút and Go Trung. The latter was excavated in 1977 and covered a 170 m^2 area (Bui Vinh 1991, 129). For this site there is only a basic summary available in English, which mentions the vast majority of faunal remains were from marine species of fish (80%) and almost 200 net sinkers were excavated in addition to a possible spindle whorl (Bui Vinh 1991; Nguyen Viet 2005, 90). The dominance of fish is probably related to the coastal location of the site.

The site of Đa Bút is in the same valley as CCN. It was excavated twice, the first time by the French scholar Étienne Patte in 1932 and secondly from the 1960s onwards by a Vietnamese team from the Museum of History. Patte (1932) noted that Đa Bút was a large shell midden measuring approximately 50 m long, 32 m wide, and 5 m high. The lithic artefacts were ground-edge axes similar to Bac Son (local Hoabinhian style), but unlike the Hoabinhian culture there was also coarse mat-impressed pottery (Patte 1932; Bui Vinh 1991, 127). The 12 burials that were excavated were found in a squatting position and Patte (1932) believed they were probably bound before burial.

The main shellfish species recorded were from an estuarine habitat (Table 3-5) and pollen indicated the presence of a salt marsh (Patte 1932, 49; Higham and Thosarat 2004b, 154). Although there were a number of species of shellfish recorded, Patte (1932, 50) emphasised Corbicula sp. were by far the most common. In terms of large mammalian fauna, *Muntiacus*, *Cervus*, *Sus* sp. and Bovidae were listed but without mention of NISP or MNI. Patte (1932, 48) also noted the presence of a dog ulna and that it was similar to a dingo. However, Patte did not compare the bone to *Cuon* or other canid species, which makes its domesticated status uncertain at best.

Table 3 5 Summary of taxa excavated from Đa Bút during the 1932 and 1960s excavations *indicates presence.

Taxa	Common name	1932	1960s
Gastropods			
Neritinia sp.	Mollusc	*	
Cyclophorus sp.	Mollusc	*	
Melanoides tuberculata	Red-rimmed melania	*	
Cypraea sp.	Cowries	*	
Melo melo	Indian volute	*	
Corbicula sp.	Mollusc	*	
Placuna placenta	Windowpane oyster	*	
Meretrix sp.	Mollusc	*	
Arca sp.	Mollusc	*	
Fish			
Siluriformes	Cat fish	*	
Myliobatiformes	Sting rays	*	
Barbus sp.	Common barbel	*	
Labridae	Wrasses	*	
Sparidae	Breams	*	
Mammals			
Hystricidae	Porcupine	*	
Viverra zibetha	Indian civet	*	
Paradoxurus hermaphroditus	Asian palm civet	*	*
Mustelidae	Otters, badgers, ferrets etc.		*
Arctonyx sp.	Hog badger		*
Sus sp.	Wild pig	*	
Muntiacus muntjak	Barking deer	*	*
Cervus sp.	Deer	*	*
Bovidae		*	*
Bubalus bubalis	Water buffalo		*
Bibos sp.	Gaur, banteng		*
Sea mammal			*

Since the 1932 excavation the site was unfortunately partly destroyed due to road construction and the faunal remains excavated by Patte have since been lost (Vu The Long 1979). During the 1960s Vietnamese teams excavated a 50 m^2 area and discovered bi-polished axes as well as coarse pottery, which convinced the archaeologists the site represented a separate culture to the Hoabinhian (Bui Vinh 1991, 128). Further, four shell dates were obtained from different layers ranging between c. 6,500–6,000 BP which is significantly later than the majority of Hoabinhian dates. The faunal remains were analysed by Vu The Long (1979) and summarised in a short report (Table 3-5). The faunal assemblage was extremely small (TNF = 60; NISP = 42) but apparently showed signs of burning and butchery marks. Vu The Long (1979) wrote that there were six cattle bones and teeth that were of comparable size to domesticated cattle and suggested that people may have practiced agriculture and initiated animal husbandry, but still exploited the local natural resources. Later Bui Vinh (1991, 128–9) exaggerated Vu The Long's suggestions by claiming Đa Bút had "6 teeth of domesticated bovid".

In summary, Đa Bút sites are characterised by large shell middens that display a focus on molluscs and mammals from a variety of environmental niches. Đa Bút itself and CCN are the two key sites from this period due to the quantity of human and faunal material excavated from both sites as well as the availability of published material.

3.5. Looking north: Connection to China

Archaeologically, the region that holds the most cultural similarity to northern Vietnam is southern China. Scholars have previously pointed out the parallels between the Đa Bút and contemporary sites in southern China (Zhang and Hung 2008; 2012; Oxenham and Matsumura 2011). Dingsishan (c. 7,000–3,000 BC Zhang and Hung 2012, 18) and associated cultural sites in Guangxi province share close similarities to CCN, as detailed below in section 3.5.2.2. This similarity with Đa Bút is not considered to be the result of a migration event, like the subsequent Phùng Nguyên period (section 3.6.1.). Rather, Zhang & Hung (2012, 21) suggest Dabutian and Dingsishan sites may have shared a cultural origin with the Hoabinhian.

This section summarises current scholarship on the Terminal Pleistocene and Early Holocene in China with a specific focus on the development of agriculture and domestication. This region is especially relevant to northern Vietnam due to shared cultural similarities and trajectories. It provides a wider regional context for the Đa Bút and sets the scene for the later introduction of domesticates into Vietnam and SEA (section 3.6.). The main sites and rivers discussed in the text below and used in PCA analysis in Chapter nine are displayed in Figure 3-4.

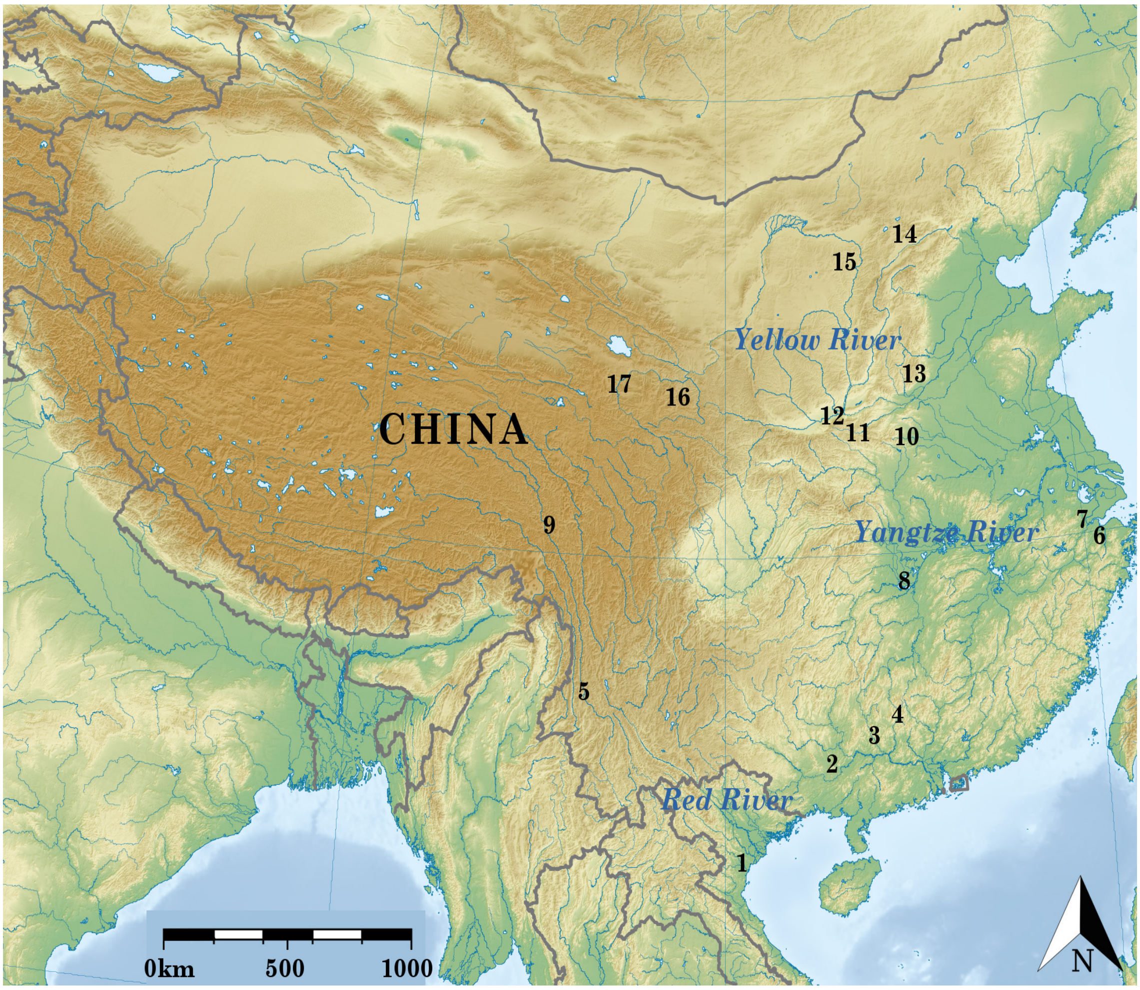

Figure 3-4 Topographic map of China showing sites mentioned in text and used for PCA analysis in chapter 7. 1: CCN and MB, 2: Dingsishan, 3: Zengpiyan, 4: Yuchanyan, 5: Tangzigou, 6: Hemudu, 7: Kuahuqiao, 8: 'Middle Yangtze sites' Pengtoushan, 9: Karuo, 10: Jiahu, 11: Xipo, 12: 'Wei River Valley sites' Wayougou, Jiangzhai, Baijiacun, Kangjia, 13: Cishan, 14: Miaozigou, Shihushan, Dabagou, 15: Zhukaigou, 16: Qinweijia, Dahehuang, 17: Zhongri. Base map adapted from image created by Ksiom under Creative Commons license.

3.5.1. Terminal Pleistocene and Early Holocene in China

The Terminal Pleistocene and Early Holocene in China have been argued to show intensification and a broader spectrum of diet leading up to the development of agriculture and domestication. This is largely based on the appearance of microlithic technology and archaeobotantical evidence suggesting a wider exploitation of plants (Bettinger et al. 2010; Bar-Yosef 2011; Liu et al. 2014; Yang et al. 2015). Bar-Yosef (2011) and Bettinger et al. (2010) draw parallels between the Levant and Mesoamerican models as useful analogies for the origin of millet cultivation in north China. Bar-Yosef (2011) suggests the climatic conditions of the Younger Dryas stimulated agricultural development in the Levant and northern China arguing it was a risk-minimising strategy to stay put and intensify exploitation.

To a lesser extent, similar attempts to draw parallels with the development of agriculture and domestication in the Levant have been made with faunal analyses (Prendergast et al. 2009; Jin 2010; Zhang et al. 2013). Here, the debate surrounds the nature of resource intensification as a proxy measure of abundance versus stress. Prendergast et al. (2009) gave a relatively inconclusive account for resource intensification at Yuchanyan (17,700–13,970 cal. BP), arguing long bone breakage suggested marrow exploitation which in turn implied scarcity of resources. However, other pieces of evidence contradicted this theory. Although there was evidence for a broad diet, the dominant focus on large cervids suggested the hunters could afford to be picky, contrary to resource stress expectations or optimal foraging theory models. The authors argued more work is needed before deciding whether this pattern is a departure from tradition or business as usual (Prendergast et al. 2009, 1035–6).

Jin's (2010) analysis of Tangzigou (9000±40 and 8800±40 cal. BP) in the Yunnan province also failed to produce convincing evidence of resource stress. Jin (2010) suggested Tangzigou was a butchery site based on the absence of pottery, or residential features such as hearths. Jin (2010, 9) argued the elevated position of the site would have served as an excellent vantage point to check for predators, and the presence of large boulders would have created useful food-processing platforms. Numerous stone artefacts were found including flaked tools and ground stone axes (Jin 2010, 11). Among mammals identified in the assemblage, large Cervidae were the most common followed by Bovinae (Jin 2010, 130). The faunal analysis suggested that people chose to process phalanges during the times when food resources were abundant, rather than a result of resource stress. Jin (2010, 93) suggested the behaviour was the result of a cultural decision or based on taste and texture, rather than one based on maximising the net caloric returns.

Zeder (2012a) and Crawford (2011) have argued that agriculture in the Near East, China and Japan did not arise from stress caused by population packing or environmental change, but instead as a response to increasingly favourable climatic conditions and an abundance and variety of resources. They argue that a broad-spectrum diet in China was the result of resource abundance rather than stress, which favoured the production of stable and sustainable subsistence strategies.

> In China, with its greater degree of habitat variation and its wider array of potentially domesticable resources, this broad spectrum resource strategy led relatively quickly to the adoption of agricultural economies based on millet in the north and rice in the south.
> Zeder, 2012a, 248–9.

Further, Cohen (2011) has argued the northern and southern centres of domestication do not emerge independently but rather through a series of interrelated relationships through variable forms of interaction and social exchange between regions. Cohen (2011) argues that sedentary villages emerge several millennia before cultivate plants or domesticated animals make a significant contribution to the diet. He emphasises that these parallel processes in different regions did not emerge from isolation.

3.5.2. Development of agriculture and domestication in China

The development of agriculture in China shows much diversity in the timing and nature of how people initiated this change in plant-animal-human relationships. It is generally agreed that there were at least two major centres of agricultural domestication in China; foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum miliaceum*) along the Yellow River in the north, and rice (*Oryza sativa japonica*) in the middle and lower Yangtze River (D'Alpoim Guedes and Butler 2014). Although Yuan et al. (2008, 359) also add tuber crop farming in the south as another distinct centre. Similarly, faunal subsistence traditions between the Yellow and Yangtze Rivers contrast, with an emphasis on domesticated animals along the Yellow River in the north and more of a continued reliance on hunting and fishing in the Yangtze and southern region (Yuan et al. 2008). The explanation for this divergence between regions is usually down to environmental and climatic differences, as China is an extensive country with numerous ecological niches. The north is generally drier with a continental climate, while the south is wetter and warmer with a monsoonal climate.

Yuan et al. (2008) argue that the desire for predictable access to meat through pressure from unstable habitats or social forces encouraged the rearing of pigs in the north. While in the south, the natural abundance of wild animals and aquatic resources downplayed the necessity or reliance on domesticated animals (Yuan et al. 2008). However, this situation was highly contextual and "highly contingent on the needs, desires and practices of individual communities within the environmental and social context in which they were situated" (Yuan et al. 2008, 362). Further, although the different environmental conditions (such as abundance and diversity taxa) did not determine the nature of the human-animal relationship, but it "would have had an important affect on the choices humans (made) about subsistence patterns" (Yuan et al. 2008, 362). However, Yuan et al. (2008, 362) also emphasise these choices were not conscious and the overall pattern is one of "passive development" through "situation-based decisions." If by 'conscious choice' Yuan et al. (2008, 362) imply an aware intention towards a certain goal (i.e. domestication), then this is probably accurate. However, see Chapter four section 4.3.1. for a detailed discussion on the concept of agency and intention and how they are not inherently the same, as this misconception has often confused discussions on domestication.

3.5.2.1. Southern China

Zhang and Hung (2010; 2012) argue the idea of a "Neolithic package" in China does not make sense for this part of the world where pottery, domestication, and agriculture arrive at different times with strong regional variations. Although rice agriculture began in the Yangtze around 9,000–8,000 BP it appears to have taken more than 3000 years to spread to the southwest (Zhang and Hung 2010; D'Alpoim Guedes et al. 2013, 759; D'Alpoim Guedes and Butler 2014). D'Alpoim Guedes and Butler (2014, 3) argue in the southwest of China, the mountainous environment and low temperatures would have presented a challenge to the adoption of rice. The Yunnan-Guizhou plateau and western Sichuan is surrounded by high mountains traversed by deep river valleys creating a highly vertical landscape. The foothills of these mountains taper south and this would have influenced the movement of people into MSEA.

When rice appears at sites in the southwest of China around 4,700–3,700 BP, it is sudden and intensive (D'Alpoim Guedes et al. 2013, 759; D'Alpoim Guedes and Butler 2014, 3). These sites, collectively known as the Baodun culture, are characterised by large walled settlements and they do not have an obvious indigenous hunter-gatherer origin (D'Alpoim Guedes et al. 2013, 759). This has led Zhang and Hung (2010) to suggest the Baodun culture represents a spread of agriculturalists into the region. D'Alpoim et al.'s (2013) analysis of the botanical remains of Baodun confirmed the presence of both millet and rice and the authors argued that both crops were of crucial importance in aiding expansion into new territories. Nonetheless, Zhang and Hung (2010; 2012) point out the distinction between foraging and farming is blurred in many areas, especially in the south where agricultural and hunter-gatherer groups coexisted alongside each other for millennia.

3.5.2.2. Southern China and Vietnam

Southern China is the region most archaeologically relevant to northern Vietnam and it is particularly notable for its diversity in subsistence practices. In particular, Dingsishan and related sites have been likened to Dabutian sites in North Vietnam (Zhang and Hung 2008; 2012). Dingsishan sites are located on river terraces from c. 9,000–4,000 BP in Guangxi province and appear to have coexisted with agricultural groups in the Middle and Lower Yangtze (Fu 2002; Zhang and Hung 2012).

The site of Dingsishan itself has parallels with CCN. The dating of the site is problematic but based on relative chronology the excavators argue phase I is probably Early Holocene, phases II-III between c. 8,000–7,000 BP, and phase IV c. 6,000–5,500 BP (Fu 2002). Dingsishan consists of a huge shell midden and cemetery of around 5000m^2 that contains clear separations between living, refuse, and burial areas (Zhang and Hung 2012, 18–21). The burials include flexed, crouched and dismembered individuals without grave goods. Artefacts made from bone and stone include axes, adzes, arrowheads, needles, awls, spears, and hooks. The pottery is coarse with ribbed or cord marking on the surface.

A faunal study of Dingsishan suggested that domestic dogs were present in the upper layers of the site but the pigs and Bovinae were considered to be wild based on size (Lu 2010). Looking at the relative proportions of taxa it is interesting to see high absolute NISP of *Bubalus* and *Sus scrofa* (Table 3-6). However, when converting this into a %NISP of medium-large mammals, Cervidae dominate at 91.9%NISP, which attests to the importance of hunting deer (see also Chapter nine). Although the methods for determining the domestic status of dogs are not detailed it is interesting that canid remains are only identified in the upper layer, which is where rice phytoliths make an appearance (Lu 2010, 98; Zhang and Hung 2012, 18).

Table 3-6 Summary of NISP and %NISP of medium-large mammalian taxa from Dingsishan. Data from Lu (2010, 98).

Taxa	**NISP**	**%NISP**
Bubalus sp.	1762	6
Sus sp.	584	2
Canis sp.	14	0
Total Cervidae	28071	92
Cervus sp.	21081	69
Muntiacus sp.	6990	23
Cercopithecidae	22	0
Viverridae	7	0
Mustelidae	76	0
Total	**30536**	**100**

Zhang and Hung (2012, 21) conclude that Dingsishan and Dabutian sites are archaeologically analogous and show little change throughout time:

> Agriculture began to appear in the Yangtze Valley after c. 7000 BC and domestic pigs and textiles c. 5500 BC; but all were absent in Dingsishan (phases 1 to 3) and Da But. In terms of residential locations, subsistence strategies, burial practices, and various aspects of material culture, these Dingsishan-related midden sites reveal little significant change through time, although artefact forms and styles show slight variation from site to site.

This 'lack' of change in Dingsishan sites is in spite of agricultural groups migrating into the region, which clearly portrays the diversity in cultural groups in the Mid Holocene.

3.5.3. Timing of domesticated animals in China

Ascertaining the timing of domesticated animals in China is hampered by the lack of secure dating and contexts for purported finds. Researchers are often quick to claim earliest domestication without proper consideration of multiple lines of evidence. A recently published high-profile example of this is Xiang et al.'s (2014) claim for domesticated chicken at c. 10,000 BP from Nanzhuangton and c. 8,000 BP from Cishan based on mtDNA. This paper has been subsequently criticised (Peters et al. 2015; Peng et al. 2015) for multiple reasons, ranging from poor methodological DNA analysis to lack of archaeological context from either site (see Chapter four, section 4.2.2. for more details). Based on studies that have used multiple lines of evidence, the timeline for the domestication of animals in China is summarised in Table 3-7.

3.5.3.1. Dogs (Canis familiaris)

Dogs are the earliest domesticated animal from at least 15,000 BP (favouring the short chronology) or c. 35,000 BP (favouring the long chronology) in Europe (Germonpré et al. 2009; Boudadi-Maligne et al. 2012; Morey 2014; Morey and Jeger 2015). The earliest potential evidence from China is currently from Nanzhuangtou, based on a reduction in mandible length. According to Yuan (2010) the average mandibular length for wolves in the Chinese Late Pleistocene was approximately 79.4 mm while the Nanzhuangtou canid is 72.68 mm. Clearer evidence of domestication comes from the slightly later sites of Jiahu (c. 9,000–8,000 cal. BP) and Cishan (c. 8,000 BP), where dogs not only show a size reduction but have also been carefully buried. Yuan (2010, 301) notes the dog from Jiahu was given special treatment and buried like a person. Consequently, Flad et al. (2007,

Table 3 7 Summary of timing for major domesticates in China following Yuan and Flad (2002); Flad et al. (2007); Yuan (2010).

Taxa	Sites	Evidence	Earliest Date
Dog	Nanzhuangtou?	Size reduction	c. 10,000 BP
	Jiahu, Henan Province	Burial and reduction in size	9,000–8,000 cal. BP
	Cishan, Heibei Province	Burial and reduction in size	c. 8,000 BP
Pig	Jiahu, Henan Province	LEH, age structure	9,000–8,000 cal. BP
	Cishan, Heibei Province	Size reduction, age structure, burials	c. 8,000 BP
	Kuahuqiao		c. 8,200 BP
Sheep	Tianshui City, Gansu Province, Hexi Corridor Sites	Introduction from northwest	c. 5,000–4,000 BP
Cattle (*Bos taurus*)	Zhecheng Mount Tai Temple Ruins, Henan Province (Longshan Culture)	Burials	c. 4,000 BP
Water buffalo (*Bubalus*)		More evidence needed	Unclear
Goat	Yanshi City, Henan Province	More evidence needed	c. 3,700 BP?
Horse	Yongjing County, Gansu Province	Burial, and textual?	c. 3,700 BP
Chicken	Chifeng City, Inner Mongolia		c. 3,600 BP

192) believe that domesticated dogs were probably present in China from the end of the Pleistocene in hunter-gatherer communities before the introduction of agriculture.

3.5.3.2. Pigs (Sus scrofa)

The earliest secure evidence for the domestication of pigs comes from the same sites, Jiahu (from at least 6,600 cal. BP) and Cishan (Flad et al. 2007; Yuan 2010; Cucchi et al. 2011). From Cishan, this is based on three factors: the reduction of the lower M3s, the age at death profile of 60% of pigs killed between 0.5–1 years of age, and burials of complete pig skeletons in pits with large amounts of millet. Further, the human and pig isotope analysis indicated the consumption of large amounts of C4 plants. This suggests people were growing millet not only for their own use but also for their pigs.

By the Middle Yangshao period (c. 6,000–5,500 BP) sites along the Yellow River portray heavy exploitation of domesticated pigs. This period coincides with a dramatic increase in the number and size of settlements around the Yellow River. Ma (2005,

73) suggests that land clearing for cultivation had a significant effect on populations of wild animals. At Xipo, pigs dominate the assemblage (84% NISP of all taxa, 85% NISP mammals, and 89.2% NISP of medium-large mammals) and the majority were slaughtered before reaching two years of age (Ma 2004; 2005, 1). Further, morphometric comparison shows a clear separation in molar size between pigs from Xipo and wild samples (Ma 2005, 63). Isotopic evidence suggests a diet of practically 100% reliance of C4 plants, most likely millet (Ma 2005, 71).

3.5.3.3. Cattle, sheep, goats (Bos, Bubalus, Ovis, Capra)

Cattle (*Bos taurus*) are considered to have been introduced into China via the south or west, but there are indigenous populations of *Bos* in China that could have been locally domesticated (Flad et al. 2007). The domestication of cattle is generally thought to have occurred between 5,000–4,000 BP but there is currently a lack of well-documented sites (Flad et al. 2007, 192). Similarly, evidence for the introduction of domesticated water buffalo in China is even more scant. Wild water buffalo (*Bubalus mephistopheles*) are indigenous to China but DNA analysis suggests it is unlikely they contributed to modern domesticated water buffalo (*B. bubalis*) (Flad et al. 2007, 192; Yuan 2010). *Bubalus* remains are relatively common in Chinese sites, but more work is needed to determine the relationship between indigenous populations and modern water buffalo.

Both goats and sheep are thought to have been introduced into China based on DNA evidence which shows the indigenous gazelle, goral, or serow were not the progenitors of domesticated caprines (Flad et al. 2007; Yuan 2010). This is supported by archaeological evidence that caprines were domesticated from c. 11,000–10,000 cal. BP in the Zagros mountains (Zeder 2008). Again, evidence is lacking as to how this introduction took place in China. According to Yuan (2010, 301) the earliest potential evidence for domesticated sheep is from 5,600–5,000 BP in Gansu and Qinghai Provinces. According to the reports from the 1970s excavation a sheep burial was found in Majiayao tombs (Yuan 2010, 301). However, the first well-documented evidence comes from around 4,000 BP from a number of sites including; Tianshui City in Gansu Province, and several Hexi Corridor sites (Flad et al. 2007, 173; Yuan 2010, 301). Thus, Flad et al. (2007, 173) suggest that domesticated sheep were probably introduced into north-western China between 5,000–4,000 BP.

According to Yuan (2010) the earliest documented evidence for goats comes slightly later at around 3,700 BP in Yanshi County, Henan Province. However Flad et al. (2007, 193) were more cautious and described goat identifications as “somewhat tenuous”.

3.5.4. Summary of domestication in China

The current evidence suggests that agriculture and domestication of animals was not a change that swept through China swiftly. Rather, it was a long process and regionally specific. In the north, pigs were in the early phase of domestication around 2000 years after agriculture had begun in the region and long after pottery manufacture. Although there is substantial evidence for domestication of pigs and dogs at Cishan c. 8,000 BP, by 4,000 BP there still appears to be a mixed display of subsistence practices, and sites geared towards hunter-gatherer economies were still common. Especially in the south along the Yangtze River there was an emphasis on wild taxa despite the development of rice agriculture. This suggests that models advocating a single main cause for agriculture and domestication as being the main impetus (such as climate change or population growth), are too simplistic. Although such factors no doubt played an important role, the process was probably more nuanced and related to regional environmental appropriateness as well as individual and group choices.

3.6. Mid Holocene in SEA and Vietnam

The development of agriculture and domestication in China leads naturally onto this subsequent transition in MSEA. Akin to the material culture and site similarities between Dabutian and Dingsishan-related sites, along the Yangtze and southern regions of China during the terminal Chinese Neolithic (c. 4,500–4,000 BP) sites share cultural similarities to MB. As discussed in Chapters one and two, this is purported to be related to a migration of agricultural groups from southern China into northern Vietnam (Bellwood and Oxenham 2008; Matsumura et al. 2011; Oxenham and Matsumura 2011).

The following sections detail the Mid Holocene period in SEA and Vietnam with specific focus on the nature of the transition to domestication. Vietnam and Thailand are given special attention, partly due to their related material culture but also because the majority of archaeological investigation from this time frame has concentrated on these countries. Within Vietnam, the Phùng Nguyên period is explored in more detail to provide contextual background to MB (section 3.6.1.). This is compared to sites in the south of Vietnam which display an analogous but different expression of the Neolithic. The second section (3.6.2.) details major sites in Thailand and compares the faunal data to Vietnam. Mid and Later Holocene sites are discussed in this section, and sites used for PCA analysis in Chapter nine are displayed in Figure 3-5.

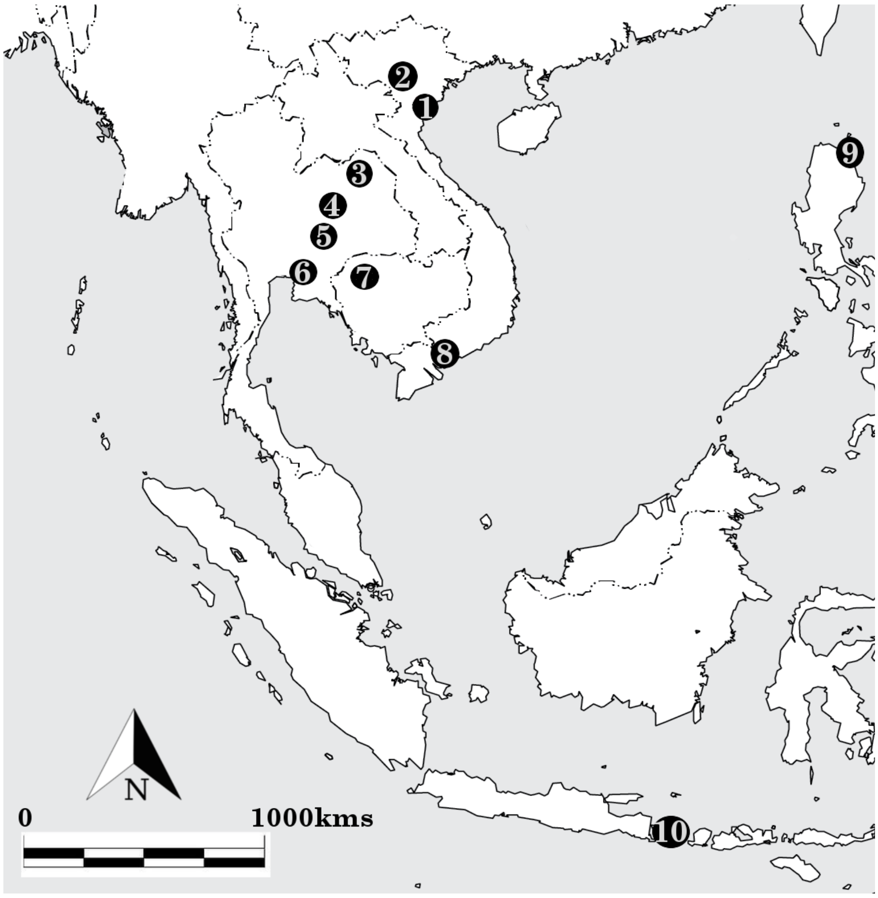

Figure 3-5 Later Holocene sites in MSEA and ISEA mentioned in text and used in PCA analysis in Chapter nine. 1: MB, 2: Phung Nguyen, 3: Ban Chiang, 4: Non Nok Tha, 5: Ban Non Wat, Ban Lum Khao, 6: Khoc Phanom Di, 7: Phum Snay, 8: An Son, Rach Nui, Lo Gach, Loc Giang, 9: Nagsabaran, 10: Pacung, Sembiran.

3.6.1. Phùng Nguyên: Mán Bạc in context

The terminal Neolithic in Vietnam is represented by a burgeoning of archaeological sites and cultures. In the north, the Ha Long and Phùng Nguyên cultures are particularly well known, and comprise significant quantities of human skeletal material. The Ha Long culture dates to approximately 4,500–3,000 BP and is situated along the coast of Ha Long Bay, northeast of Hanoi (Matsumura et al. 2011, 157). Phùng Nguyên sites spread along the edges of the Red River in the Bac Bo plain south of Hanoi from approximately 3,800–3,400 BP (Nguyen Khac Su et al. 2004; Oxenham et al. 2008; Matsumura et al.

2011, 157). These sites were approximately 1–3 ha in size and are thought to have been based on rice agriculture.[1]

There is some discrepancy in the terminology used to define the chronology of the Phùng Nguyên period, with some archaeologists using the term 'Early Bronze Age' and others preferring 'Late Neolithic' (Nguyen Khac Su et al. 2004; Matsumura and Oxenham 2011; Sarjeant 2014). Generally, there is very little evidence for bronze technology in the assemblages. For example, at the site of Phùng Nguyên, from which the period derives its name, only six pieces of bronze waste material were found (Nguyen Khac Su et al. 2004, 190). Thus, the term 'Early Bronze Age' has little relevance to the Phùng Nguyên period.

The material culture and biological traits of the people from Phùng Nguyên sites present a significant departure from the previous Đa Bút period. Phùng Nguyên sites are known for their wide variety of material culture including: adzes, axes, chisels, blades, grinding stones, net sinkers, nephrite beads, bangles, rings, and ceramics (Nguyen Khac Su et al. 2004, 190; Oxenham et al. 2008, 192). Most of the pottery is coarse but is typically decorated with horizontal and symmetrical straight lines and S-shaped curves, dots and triangles (Nguyen Khac Su et al. 2004; Sarjeant 2014, 368). Pottery anvils attest to local manufacturing of ceramics (Oxenham et al. 2008, 192). Similarly, waste products support evidence for stone jewellery manufacture (Oxenham et al. 2008, 192).

Bellwood and colleagues (Bellwood et al. 2011; Bellwood 2015b) have emphasised the similarities in material culture between Phùng Nguyên sites and the Guangxi and Guangdong provinces in China as well as north-eastern Thailand. For instance, MB has nephrite bracelets with T-shaped cross-sections and there are contemporary comparisons in Thailand, the Malay Peninsular and late Neolithic and Bronze Age sites in China, especially Sichuan (Bellwood 2015b, 60). Sarjeant's (2014, 371) analysis of the material culture from Phùng Nguyên sites found many similarities between MB and Xom Ren, in particular; the presence of nephrite jewellery, shell temper in ceramics, and geometric impression, scroll incisions and eye-shaped incisions for ceramic decoration. Bellwood (2015b, 60) believes the nephrite artefacts from Phùng Nguyên sites were probably imported from Late Neolithic or Bronze Age China.

Based on material culture similarities Phùng Nguyên is often defined as a culture with an implied assumption that this is linked to a shared identity, ethnicity, or language (Sarjeant 2014, 12). As Sarjeant (2014, 12) argues, in reality the identities of the people

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[1] Rice phytoliths of *Oryza sativa japonica* were found at Man Bac but this is yet to be published (Peter Bellwood 2013, pers. comm.).

from Phùng Nguyên sites are likely to have been fluid and complex.

3.6.1.1. A view to the south: An Son and Rach Nui

Until recently, southern Vietnam has received less archaeological attention than the north. Bellwood (2015b, 61–2) believes this is partly to do with the connection between southern China and northern Vietnam and their widely perceived role in Vietnamese origins. However, several internationally funded excavations have recently increased our understanding of the Neolithic along the Mekong Delta. The sites An Son and Rach Nui have shown some interesting affinities with the roughly contemporaneous Phùng Nguyên culture (Bellwood et al. 2011; Oxenham et al. 2015). Yet, the exact nature of the connection between southern Vietnamese sites and the Phùng Nguyên culture is unclear.

An Son lies close to the Cambodian border, northwest of Ho Chi Minh city. The site is a mound approximately 4m high and measures 90x65 m (Bellwood et al. 2011, 146). Based on radiocarbon dating of twelve human enamel and nine charcoal samples the excavators argued the site was occupied from c. 4,300–3,200 cal. BP.[2] This places An Son in roughly the same time frame as MB.

Two samples of rice husk found within pottery temper were analysed and were identified as *Oryza sativa japonica*, which is a subspecies of domesticated rice from China not native to SEA, also found at MB (Bellwood et al. 2011, 168). The ceramics had strong affinities with the ceramics of other sites within the Mekong Delta region as well as Khok Phanom Di in Thailand, but less so of the Phùng Nguyên sites (Bellwood et al. 2011; Piper et al. 2012). This led Bellwood et al. (2011, 160) to suggest the existence of a 'Greater Mekong cultural network' from around 4,500 BP onwards that involved migration and settlement by a Neolithic population that lacked obvious Hoabinhian attributes.

Analysis of the faunal remains suggested domesticated pigs were present from at least c. 3,800–3,600 cal. BP but interestingly, dogs were the most frequently occurring mammal (Piper et al. 2012). Intriguingly, Bovinae were absent from the assemblage, which is in contrast to sites in northern Vietnam or Thailand. Piper et al. (2012) argued that the pigs were in the early stages of domestication. Although the pigs did not show a size reduction of molars, the age profile portrayed a reliance on animals aged between 12–18 months (Piper et al. 2012, see Chapter four section 4.2.2. for details on identifying

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[2] Although it should be noted that enamel dates are often 'younger' see Chapter five section 5.10. on radiocarbon dating for details.

early domesticated animals). Thus, the most likely explanation was the pigs represented an early-managed population.

Mammals did not constitute the most frequently occurring taxa in the assemblage, which was instead dominated by Geoemydidae (hard shelled turtles) and riverine fish taxa such as catfish, eels, snakeheads, and carp. The lack of marine species suggest that the sea had retreated and lower riverine or upper estuarine conditions characterised the area at the time of the occupation (Piper et al. 2012, 145–6).

Rach Nui is situated closer to the coast and is dated to 3,390–3,850 cal. BP (Oxenham et al. 2015). The site consists of a mound that is approximately 5 m high and 75 m in diameter. Modelling of the paleoenvironment suggests that Rach Nui could not have been occupied before 4,500 cal. BP as it would have been under a shallow sea, whereas An Son would have been above sea level even during the Mid Holocene high stand at c. 6,000 BP (Oxenham et al. 2015, 22). By 2,500 cal. BP the area surrounding Rach Nui would have been a well-established mangrove forest (Oxenham et al. 2015, 22).

Rach Nui represents one of the few sites in SEA that has a solid record of building construction. The site was carefully planned since its inception with multiple processes of clearing, depositing of midden foundations, and raised lime mortar platforms (Oxenham et al. 2015, 22). Once the inhabitants needed a new house the old one was burnt and the foundations were replaced. This may be the first evidence of the use of shell lime for construction in SEA.

Flotation of sediments produced evidence of rice and foxtail millet, which is the earliest evidence for foxtail millet in Vietnam (Oxenham et al. 2015, 23). However, the faunal and botanical remains indicate that Rach Nui was more reliant on wild plants rather than cultivation. Domesticated pigs and dogs were present however, like An Son, Rach Nui occupants were more reliant on riverine and estuarine fish species and reptiles such as Geoemydidae, *Varanus* sp., and *Crocodylus* sp., than mammals (Oxenham et al. 2015, 18–9). Further, the age at death pattern for pigs indicated the presence of adult, sub-adult and juvenile pigs, which is in contrast to expectations of a managed population (Oxenham et al. 2015, 21). Attempted differentiation using dental biometry was also inconclusive. s on some canid bones indicates they were occasionally consumed and do not seem to be have been given special status.

3.6.1.2. Summary on Late Neolithic sites in Vietnam

When viewing the Late Neolithic sites in Vietnam collectively there are a number of similarities in material culture and subsistence. One of the clearest commonalities is the presence of rice, domesticated dogs, and potentially early-domesticated pigs. However, there seems to be a striking amount of variability in the taxa exploited and relative proportions of species. Again, this is likely to be partly a reflection of the surrounding environment and the adaptations people make to fit varying situations.

3.6.2. Neolithic and Bronze Age sites of Thailand

Thailand has received the most archaeological attention within SEA due to large projects headed by archaeologists such as Rasmi Shoocongdej, Surin Pookajorn, Charles Higham, and Joyce White. Both Shoocongdej (1996; 2000; 2006; 2007) and Pookajorn (1985; 1996) have been instrumental in shaping research in Thailand, especially in analysing Late Pleistocene and hunter-gatherer populations. Shoocongdej (1996; 2007) has also offered interesting critiques regarding the use of traditional European chronological frameworks and the lasting impacts of colonialism in SEA. In terms of the chronology and origins of the Neolithic and Bronze Age in Thailand, Higham and White have been significant investigators, and this topic continues to be controversial as a result of these two competing researchers. Although it is out of the scope of this thesis to detail this debate, the basic situation is as follows. Higham and colleagues (Higham 1996; Higham and Thosarat 2004b, 153–5) favour an external impetus for the introduction of agriculture and domesticated animals into Thailand (the so-called ‘short chronology’), linking the two-layer hypothesis for Vietnam to Thailand (see Chapter two, section 2.3.11.). White and colleagues (White and Hamilton 2009; White 2011; 2015) see agriculture as a local development, and argue for connections to the north Ural Mountains during the Bronze Age, favouring the so-called ‘long chronology’. This second view does not hold as much support with other researchers, especially with those working in Vietnam where the migration of agricultural groups appears suddenly in the record (Bellwood and Oxenham 2008; Bellwood 2015a; Oxenham 2015; Oxenham et al. 2015; Pryce 2015).

Within Thailand, there are several key Neolithic and Bronze Age sites that are useful comparisons to MB and CCN (Table 3-8). Ban Non Wat (NBW), Ban Chiang (BC), and Non Nok Tha (NNT) are located in the Khorat Plateau in northern-central Thailand and are relatively close to one another. Khok Phanom Di (KPD) is located on the eastern coast of the Gulf of Thailand. Since KPD and BNW were more recently and thoroughly analysed, discussion will focus on these two sites.

Table 3-8 Main Thai sites mentioned in text. Where calibrated BP dates were not provided by the authors dates were calibrated using Oxcal version 4.2 (Bronk Ramsey 2009), IntCal 13 (Reimer et al. 2013).

Site Name	Region	Type	Period	Uncal. BP	^{14}C date BP	Reference
Spirit Cave		Burial site / Rockshelter	Terminal Pleistocene–Mid Holocene?			Gorman (1970; 1971)
Lang Rongrien	Krabi, Malay Peninsula	Rockshelter	Late Pleistocene-Early Holocene	*c.* 43,000–8,300		Mudar & Anderson (2007, 300–302)
Bun Lum Khao (BLK)	Khorat Plateau	Burial site	Bronze Age		3,120 ±50 to 3,080 ±50	Higham & Thosarat (2004a, 5)
Khok Phanom Di (KPD)	Coast/Gulf of Siam	Residence/ Burial site	Neolithic & Bronze Age	*c.* 4,000–2,500		Higham & Thosarat (2004b)
Non Nok Tha (NNT)	Khorat Plateau	Settlement / burial site	Neolithic & Bronze Age		3,448–3,258 to 2,684–2,352	Higham et al. (2014, 64)
Ban Non Wat (BNW)	Khorat Plateau	Burial site	Neolithic to Iron Age	1,800–1,200 BC		Higham (2015) & (Higham et al. 2015)
Ban Chiang (BC)	Khorat Plateau		Neolithic to Iron Age		4,238–3,928 to 2,741–2,490	Higham et al. (2015, 10)

Higham and Thosarat (2004b) argue that KPD is essentially an indigenous group of hunter-gatherers that increasingly interacted with rice agriculturalists as they migrated into the area. A large part of this argument is based on the strontium isotopic difference on tooth enamel between some of the women at KPD who display different marine enrichment, which suggests they were raised elsewhere (Higham and Thosarat 2004b, 156–8).

For BNW, Higham (2015, 1213) has argued the initial occupation “involved a coalescence of indigenous hunter-gatherers and intrusive Neolithic farmers” akin to MB. Currently, this interpretation is mainly based on the presence of both flexed and extended burials and Higham (2015) argues flexed burials are characteristic of indigenous hunter-gatherer groups. Bellwood (2015a, 1225) is sceptical on this particular assumption as he “has difficulty in accepting that flexed burial is a necessary indicator of an indigenous hunter-gatherer origin” and points out craniometric analysis is needed.

3.6.2.1. The fauna

The presence of domesticated dogs, cattle, and pigs has been argued at a number of sites on the Khorat Plateau (BNW, NNT, BC, and Ban Na Di). For BNW, the size disparity of the first fore phalanges of Bovinae led Kijngam (2010) to argue that people were hunting wild *Bos gaurus* whilst maintaining a domestic herd. *Bubalus* are present but in lesser numbers than *Bos* and are argued to represent wild populations (Kijngam 2010). Kijngam (2010) argued that pigs and dogs were domesticated but noted Cervidae of various sizes were the most common taxa exploited along with turtles. Further, several species of catfish were abundant as were *Filopaludina* sp. and *Pila* sp. shellfish, which points to the importance of freshwater resources in the diet (Thosarat 2010).

At KPD the domesticated status of animals is less clear. Based on the large size of the phalanges Grant and Higham (1991, 148–9) concluded *Bubalus bubalis* probably represented wild species, while the domestic status of Bovidae (*Bos* spp.) were uncertain. Neither genera made up a significant proportion of the taxa in the assemblage with only a NISP of 10 *Bubalus* and 13 Bovidae. Canids were not found in the lowest layer at KPD but make an appearance in Layer 10:16 (Grant and Higham 1991, 154). Their remains were also relatively rare with an MNI of nine and age ranging from very young to adult based on dentition (Grant and Higham 1991, 152–3). Grant and Higham (1991, 152–3) were cautious regarding the domestic status of the canids, arguing that wolves could be ruled out based on biogeography and *Cuon alpinus* (dhole) based on the absence of two cusps on lower M1. However, the authors conceded *Canis aureus* (Asiatic jackal) could potentially be present in the assemblage.

When the NISP of taxa is compared between sites it is clear that wild taxa such as Cervidae and Geoemydidae remain important despite the introduction of domesticates (Higham 1975b; Higham and Kijngam 1979; Grant and Higham 1991; West 1991; Kijngam 2010). It is difficult to properly compare the BC and NNT fauna; as although the methods were decent for the time the faunal analyses are out-dated.[3] A quick comparison of the %NISP of medium to large mammals from KPD and BNW shows there are some individual site differences (Table 3-9). For instance, KPD has a high NISP of Cercopithecidae remains while none are reported at BNW. BNW has a comparably higher %NISP of Bovinae and canids but fewer pigs than KPD. Both sites have a comparable proportion of total Cervidae but BNW has a greater proportion of muntjacs.

This is likely to be partly reflective of the different environments surrounding the sites, KPD being on the Gulf of Thailand while BNW is situated in the Khorat Plateau. Paleoenvironmental evidence from KPD suggests estuary conditions during the Early-

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[3] A reanalysis of the material is currently underway by Cyler Conrad.

Table 3-9 Comparison of %NISP of medium-large mammalian fauna from KPD and BNW, data for KDP from (Grant and Higham 1991; West 1991) and data for BNW from (Kijngam 2010). Using only these taxa below, KPD total NISP = 2052; BNW total NISP = 1520.

Potential domesticates						
Site Name	***Bubalus* sp.**	***Bos* sp.**	**Bovinae spp.**	**Total Bovinae**	***Sus* sp.**	**Canidae**
KPD	1	0	2	3	29	1
BNW	2	11	13	26	23	7

Wild taxa								
Site Name	***Cervus* sp.**	***Muntiacus***	**Total Cervidae**	**Cercopithecidae**	**Felidae spp.**	***Panthera tigris***	**Viverridae**	**Mustelidae**
KPD	39	2	41	20	2	0	2	2
BNW	34	9	44	0	0	1	0	0

Mid Holocene (Higham and Thosarat 2004b, 156–8). Analysis of clay shows the area was covered in marine sediment which indicates mangrove swamps and saline flats may have surrounded the site (Higham 1990, 2). Conversely, BNW is significantly further inland and the faunal remains indicate woodlands, forest fringes, and fresh water within close vicinity (Kijngam 2010, 197). The faunal remains from the nearby site of BC also indicate the presence of lakes, swamps, and woodlands (Higham and Kijngam 1979). The general picture from the sites in Thailand is a similar one to other SEA sites. Diversity in taxa is a common factor and the hunting and gathering of wild species continued to be an important aspect of the diet even after the introduction of domesticated animals.

3.6.2.2. Comparison of Vietnamese and Thai sites

The wealth of burial goods and skill in creating various bone, lithic, and ceramic artefacts is one of the main characteristics of KPD along with differences in the treatment of males and females and associated artefacts. Higham (2014, 97) argues KPD is "a society that grew to be wealthy and socially graded, on the basis of controlling and participating in long distance exchange." The implied difference in levels of individual wealth and status within the KDP population is in stark contrast to CCN or MB, which display limited social differentiation. There is also considerable variation between other Neolithic and Bronze Age burials in Thailand, as Oxenham (2015) points out, NNT is ostensibly poor in grave goods while BNW is comparably rich. The BC burials were also described by Higham (2014, 157) as decidedly poor. Oxenham (2015) argues this variety in expression of burial rites is a reflection of the mosaic state of sites, influenced by a range of different political and social aspects.

Both Oxenham (2015), and Bellwood (2015a) agree that Vietnamese sites provide the best and clearest evidence for the two layer hypothesis. Oxenham (2015, 1221) argues Vietnam sees: "a virtual eruption of Neolithic sites across the region c. 4,000 BP, overlapping with the terminal phase of the southern Chinese Neolithic, which no doubt fuelled (in terms of genes and technology) the major transformations observed among its more southerly neighbours." However, Oxenham (2015, 1222) also argues that work at MB, An Son, and Rach Nui shows "there was no standard Neolithic response to subsistence in MSEA" and that domesticated plants and animals played a relatively minor role initially. A parallel argument has been made for the Neolithic in China, which is significant as the purported origin of this change in MSEA.

3.7. Conclusion to Chapter three

The diversity of flora and fauna in SEA makes this region of the world a unique area of study. The geographic position of SEA not only shapes its ecological diversity but also bears significance to the history of MHS as they travelled out of Africa and across the Asian continent. Although archaeology of SEA has been hampered by Eurocentric models of behavioural modernity, many multidisciplinary and international projects have revealed these ideologies to be based on false assumptions. Zooarchaeological research has played a major role in challenging and changing this view by portraying the diversity in human behaviour and responses to broad-spectrum or Neolithic 'revolutions'. Zooarchaeological literature in Asia is part of the larger international collection of scholarship that shows significant variability in when and how people across the world transitioned from hunter gathering to agricultural economies (Cohen 2011; Crawford 2011; Denham 2011; Fuller 2011; Lee 2011; Barker and Richards 2012; Smith 2012; Zeder 2012a; 2012b; Hunt and Rabett 2014). Many of these scholars challenge traditional single cause 'push' models that advocate either climatic or demographic changes as being the main impetus for this transition.

Despite these clear advances, much more interdisciplinary work in fields such as zooarchaeological, palaeobotany and geomorphology is needed in SEA to help address these wide archaeological questions and debates. These problems need to be explored on a local site-by-site basis in order to extrapolate broader regional patterns.

CHAPTER FOUR

Domestication Reconceptualised

4.1. Introduction

The development of domestication and agriculture were processes that fundamentally affected the trajectory of human history. Consequently, this field is of major interest to a multitude of interdisciplinary researchers from philosophy and anthropology, to the biological and physical sciences. Zooarchaeology has a key role to play in this discourse due to its ability to pin point when and how these major changes in human-animal relations occurred. However, much of the rhetoric surrounding the discipline has been rooted in Optimal Foraging Theory (OFT) models that are often too anthropocentric and reductionist, due to their tendency to reduce animals solely to caloric or meat value (Zeder 2012a; Smith 2014; 2015). Conversely, Post-Processual approaches have frequently focused primarily on symbolic meanings of animals, which downplay the physical reality. Recent zooarchaeological literature has emphasised the necessity to move beyond dualistic narratives of considering animals exclusively as either nutritional or symbolic resources (Argent 2010; Lindstrøm 2012; O'Connor 2013b; 2013a; Sykes 2014; Russell 2015). These approaches also seek to destabilise the anthropocentricity of seeing animals purely for the benefit of human exploitation.

In parallel with this movement is niche construction theory (NCT), a development out of evolutionary theory, which offers a more holistic approach to conceptualising the environment and the organism. Melinda Zeder (2012a) and Bruce Smith (2012; 2014; 2015) have argued that NCT has the most potential as a framework for furthering our understanding of the process of domestication and agriculture. Further, NCT complements new approaches to animal agency developing in zooarchaeology.

This combined approach of utilising NCT and animal agency has the potential to aid our understanding of the SEA record without the necessity of fitting into simplistic models, which have frequently dominated the discourse in the past (see Chapter three). Further, zooarchaeology in SEA has received relatively limited theoretical development. This partly mirrors a reluctance to engage in social theory in the sub-discipline itself due to its ancestral links with taxonomy (Overton and Hamilakis 2013), but also the fact that SEA is an understudied region of the world where zooarchaeology remains a relatively poorly developed discipline. This thesis attempts not only to bring a valuable data set of zooarchaeological information into studies on prehistoric SEA human-animal interactions, but to also add new theoretical development by providing new frameworks for conceptualising the zooarchaeological record in SEA.

Domestication has received major interest from scholars working in a variety of fields precisely because of its ability to involve researchers from numerous backgrounds in sciences and humanities. This chapter briefly outlines the main concepts of zooarchaeology before detailing scholarship on domestication of animals. It highlights the importance of applying multiple theoretical methods to understand domestication, especially in the early stages of domestication, because domestication is both a biological and cultural process. The next section attempts to approach domestication through the lens of new concepts of agency in social zooarchaeology along with NCT. Both frameworks have yet to be employed within the context of SEA archaeology. Domestication is relevant to the sites CCN and MB given the hypothesis that Đa Bút and Phùng Nguyên period sites are respectively hunter-gatherer and agricultural-based societies (see Chapter one). This chapter contends that NCT and agency have great potential for understanding CCN and MB and the transition between foraging and farming in SEA.

4.2. Zooarchaeology: main approaches

Two main approaches have characterised research on zooarchaeology. The first approach was popularised by Processual Archaeology of the 1960s, which put at the forefront of its interest subsistence patterns and reconstruction of palaeoecological conditions (Crabtree 1982, 20–3; 1990, 155; Lyman 1994b, 2–3). These studies place an emphasis on species composition and taphonomic processes to distinguish between natural and human induced assemblages or patterns (Lyman 1994b, 6). For scholarship on Neolithic or early food producing societies, differentiating between wild and domesticated animals is a large component of dietary and environmental reconstruction (Larson et al. 2014; Zeder 2015a). OFT models are frequently used as an interpretative framework in prehistoric contexts, especially with scholars who are particularly interested in subsistence or paleoecological based research (Lupo 2007; Broughton et al. 2010; 2011). For research on initial domestication or agriculture diet breadth models are often employed, where resources are ranked in a cost versus benefit scheme where decisions are always assumed to lead to ‘optimisation’ (see Smith 2015, 223–4 for a succint summary). These scholars contend OFT to be a ‘scientific’ method for hypothesis testing, such as, ‘testing’ resource depression by the occurrence of low meat-yielding elements in the assemblage. One example of OFT used in a nuanced manner is Broughton (2010), who combines the approaches of OFT and NCT to understand resource depression in Late Holocene hunter-gatherer populations in Central California and agriculturalists in New Mexico. However, this study has grown out of decades of research in these areas where the record is relatively well understood compared to SEA.

The second major approach to zooarchaeology developed out of Post-Processualism during the 1980s. These researchers objected to the dominance of subsistence-orientated research, which they argued, was an over-simplification of the complex relationship between animals and humans (Crabtree 1990; DeFrance 2009; Campana et al. 2010). Scholars contended that the role socio-political factors play in the resource acquisition had been ignored and emphasised that animals embody multiple meanings in societies (Hodder 1982; Crabtree 1990; DeFrance 2009; Campana et al. 2010).

Simultaneously, developments in the concepts of agency, identity, personhood, and gender in anthropology and social sciences led to an interest in incorporating these ideologies into archaeology (Hamilakis 2003; Robb 2010; Hill 2013; Overton and Hamilakis 2013; Lindstrøm 2015). Scholars that employ this second major approach to zooarchaeology are often critical of OFT as they argue models based on OFT are too reductionist or biologically deterministic (Zeder 2012a; Smith 2014). Instead, ‘particularlist’ models such as NCT are often employed due to its flexible approach to human/organism behaviour (Crawford 2011; Denham 2011; Rowley-Conwy and Layton 2011; Hunt and Rabett 2014).

Both of these major approaches to zooarchaeology were influential developments and arguably contributed immensely to the field. However, there is a bias in scholarship as subsistence and palaeoecological orientated research is largely the domain of scholars working in prehistoric societies. Conversely, socio-political themes are usually explored by scholars working in Late Holocene ‘complex societies’, where a wider variety of material culture encourages specific questions. This bias in disciplinary segregation was also noted by Starr (2005) for Mesolithic versus Neolithic scholarship in Europe. As Crabtree (1990, 155–6) has quipped, without the thrill of Neolithic firsts, innovative questions focusing on specific attributes of human-animal socio-cultural behaviours are necessary in Late Holocene sites, as there is no point in conducting elaborate studies to determine whether eighteenth-century farmers in New Jersey kept domesticated cattle. Thus, recent approaches in zooarchaeology have attempted to align with developments within the wider academic animal studies community of multispecies theory, which aims to incorporate the agency of the animal into the analysis and narrative (Argent 2010; Armstrong Oma 2010; Russell 2011; Overton and Hamilakis 2013; Poole 2014).

4.2.1. Domestication as a biological and social phenomenon

Domestication of plants and animals has been a major theme within archaeological and biological research since Darwin and Mendel's theories on human-induced variation in plants and animals. Understanding what circumstances lead to domestication and why agricultural economies emerge was recently listed as one of the grand challenges in archaeology (Kintigh et al. 2014). In the past couple of decades there has been a major theoretical and methodological shift in the discourse surrounding domestication. This includes a more complex understanding of domestication combined with the realisation that multiple methodologies are necessary in the study of early potential domestication events and the origins of domesticates. One of the major shifts has been a cessation in the dichotomy between wild and domestic and an emphasis on domestication as a sustained process over multiple generations (Fuller et al. 2011; Zeder 2012b; Larson and Fuller 2014; Larson et al. 2014). Zeder (2015a, 3191) offers the following as a definition of domestication:

> Domestication is a sustained multigenerational, mutualistic relationship in which one organism assumes a significant degree of influence over the reproduction and care of another organism in order to secure a more predictable supply of a resource of interest, and through which the partner organism gains advantage over individuals that remain outside this relationship, thereby benefitting and often increasing the fitness of both the domesticator and the target domesticate.

The key point to draw from Zeder's definition is that domestication involves a human-animal relationship where people control and intentionally manipulate the animal. However, this often benefits both parties and increases their fitness, in an evolutionary sense. Zeder's emphasis on human intentionality has received some criticism, as it suggests a pre-determined end-result (Gremillion et al. 2014). A more straightforward definition is offered by Larson et al. (2014, 6140) who define domestication as "a selection process for adaptation to human agro-ecological niches and, at some point in the process, human preferences." The control over animals via genetic selection and manipulation of their reproduction leaves a real biological change known as the 'domestic phenotype', although this may take thousands of years, and in many instances is still ongoing. This process takes place within the context of human societies and results in a complex variety of human-animal relationships. For these reasons domestication is understood as both a biological and social process.

Unlike mutualism, which is a beneficial relationship that can exist between numerous non-human species, Zeder (2015a, 3191–2) argues a key difference in domestication is the ability of humans to consciously manipulate an organism to their benefit over a sustained period of time through our capacity to learn and pass knowledge through generations. Management, as defined by Zeder (2015a, 3193) "centers on the actions of the manager in attempting to enhance the returns of a resource of interest." Thus, although there is a continuum between management and domestication, management is not necessarily a precursor to domestication. The distinguishing aspect of domestication is the emphasis on a coevolving relationship between the manager and managed resource where both can respond and benefit, but the relationship is often asymmetrically favouring human interests (see section 4.2.4. for further discussion on asymmetrical relationships).

4.2.2. Multiple lines of evidence: identifying domestication

Given the understandings of domestication as a social and biological process, it is important not to see a simple dichotomy between wild and domestic species or hunting and gathering versus agricultural communities. The reality is that modern relationships between plants, animals, and humans are complex now and are likely to have been equally multifaceted in the past. As such, multiple lines of evidence are necessary as Zeder (2015a, 3195) succinctly argues, "No one marker - genetic, phenotypic, plastic, or contextual is sufficient to definitively document domestication." Domestic animals display a range of different behavioural, phenotypic, morphological, and genetic changes (Zeder 2012b; Larson and Fuller 2014). Accordingly, there are numerous zooarchaeological techniques and methods that can be used complementarily in assessing the managed or domesticated status of animals from archaeological sites (Table 4-1).

Some of the methodological issues and debates around these techniques are discussed below with particular attention paid to morphometric analyses, age at death profiles, relative proportion of taxa, and archaeological context. This is followed by a theoretical discussion on how different scholars have conceptualised domestication. This last aspect leads into the next section of the chapter, which will focus on current theoretical approaches to zooarchaeology.

Table 4-1 Summary of main methods and techniques used to assess domesticated animals.

Method	Technique
Size / shape change	Measurement, GMM
Age at death profiles	Tooth wear, bone fusion
Relative proportion of taxa	NISP, MNI, %
Archaeological context	Burial, art, artefacts, writing
Species outside of natural range	Paleoenvironmental reconstruction
Genetics	aDNA

4.2.2.1. Morphometric comparisons and age-at-death profiles

Measuring and comparing the morphology of animal bones is useful not only for establishing domesticated animals but also for distinguishing between different species or sub-species (Groves 1999; Albarella et al. 2009; Cucchi et al. 2011; Germonpré et al. 2012). Previously, morphological change was often used as the main criterion to identify a domesticated animal. This is because domesticated animals are, generally speaking, smaller than their wild counterparts and display numerous phenotypic and behavioural changes (Morey 1992; Groves 1999; Zeder 2012b). More recently, geometric morphometric (GMM) analysis has been used to distinguish between species and wild and domesticated fauna. In particular, regional comparative studies of pig molar size and shape have been fruitful (Dobney et al. 2008; Rowley-Conwy et al. 2012).

However, the challenge is that only some of these changes may be readily visible skeletally. A problem for archaeologists working in early cases of domestication or management is that skeletal morphological changes do not occur until after several generations of genetic isolation. This conundrum has been particularly examined through the work of Zeder (Zeder and Hesse 2000; Zeder 2001; 2006b; 2006a; 2008; 2011; 2012b) who analysed the earliest stages of domestication in the fertile crescent. Zeder (2001; 2008) demonstrated that animals do not undergo morphological change in early stages of domestication, as phenotypic change does not become significant until genetic flow has been severed with wild animals, which may take thousands of years.

Yet, Zeder and Hesse (2000) and Zeder (2001) were able to determine that goats (*Capra hircus*) from the Zagros Mountains were under early management by studying their age at death profiles. In sexually dimorphic species, measurements of the length and width of bones will naturally separate into two clusters, larger (usually male) and smaller (usually female). By noting the stage of fusion at the joints it is possible to build an age at death profile for males and females. Zeder (2001, 73) found in her sample from Ganj Dareh that female goats had a delayed kill-off pattern whilst male goats were killed younger, around 12–24 months.

By comparison, goats from the site Asiab are believed to represent a wild population, showed a kill-off pattern significantly different where older prime-age males but also females and young animals were being targeted (Zeder 2001, 75). On the other hand, Ganj Dareh resembles the demography of a typical herd managed to produce a reliable meat yield whilst still maintaining the population of the herd (Zeder 2001, 75–6). This strategy still predominates amongst the pastoralists in the region today.

Recently, Rowley-Conwy et al. (2012) reviewed methods used to assess pig domestication. According to them, Zeder's successful result with goats from the Zagros Mountains was a best-case scenario and that the situation was more complicated for pigs. This is partly to do with the biology and differential management of pigs, in that it makes more 'sense' to kill younger piglets (Rowley-Conwy et al. 2012, 24–8). They advocated the use of a variety of methods when attempting to determine the domestic status of pigs. In particular, they demonstrated that comparing variation in size can be a useful method of assessing the domesticated status of pigs when sites potentially contain a combination of both wild and domesticated animals (Rowley-Conwy et al. 2012, 22). Nonetheless, the results of this method still require a degree of interpretation and certain scenarios will be hard to interpret. An aspect that hinders interpretation is obtaining comparative reference material. This problem is particularly relevant to SEA where comparative skeletal collections are limited. See Chapters eight and twelve for discussions on how limited availability of appropriate reference collections have affected this project, and suggestions for future improvement.

4.2.2.2. Relative proportions of taxa and archaeological context

Another influential line of investigation to support domestication is the relative proportion of animals within an assemblage and the archaeological context. For example, the Neolithic site of Xipo along the Yellow River in China contained an assemblage of fauna that was dominated by pigs (Ma 2005). The size of the pigs were variable, some falling within the expected range of domestic stock, whilst others were larger, comparable to wild boar. However, age profiles and the extreme domination of the taxa led Ma (2005) to conclude that they were domesticated. At the Early Neolithic sites of Cishan and Jiahu in the Yellow River valley, dogs and pigs were also identified as being domesticated based their relative proportion in the assemblage and a diet high in C4 plants, likely millet (Yuan and Flad 2002; Yuan 2010). Geometric morphometric analysis of the lower M2 by Cucchi et al. (2011) also suggested a significant change in size and shape from wild pigs. Further, contextual evidence of their burial and special treatment was crucial in showing how important changes had occurred in their relationship with humans.

Studies attempting to demonstrate Early Holocene domestication based solely on one line of evidence are questionable. A recent example is Xiang et al. (2014) who argued for the presence of domesticated chicken in China from as early as 10,000 BP at Cishan and Nanzhuangtou on the basis of mtDNA, which is an unfortunate example of how some researchers deem mtDNA to be the only evidence necessary to confirm domestication in absence of any other supporting data. This study has come under fire for a number of methodological reasons placing doubt on the validity of the DNA results (Peng et al. 2015; Peters et al. 2015). Crucially, from an archaeological point of view, the identification and provenance of the ‘chicken bones’ are unclear leading to the distinct possibility they are intrusive. Furthermore, even if the bones have been correctly genetically identified as Gallus this does not automatically imply they are domesticated chickens, they could represent wild jungle fowl. This underlines the importance of archaeological context and the use of a variety of methods and pieces of evidence when attempting to determine domestication at Early Holocene sites.

Nonetheless, even when multiple methods are employed the zooarchaeological record is often difficult to interpret. For instance, the relationship between pigs and humans in the Jōmon period (c. 10,000–2,500 BP) of Japan is puzzling. Firstly, although pigs play a dominant role in the diet the overall trend is a decrease in the proportion of pigs and an increase in deer (Anezaki 2007). Contrary to expectations, the size of pigs appears to increase from Early to Middle Jōmon before a substantial decrease. Secondly, age and sex distributions are not consistent with those of a managed population until the later Yayoi period (c. 2,500–1,700 BP; Anezaki 2007). Finally, according to genetic research East Asian domesticated pigs do not contain any contribution from Japanese wild boar, which suggests these pigs were never part of the domestic clade (Larson et al. 2010, 7687). These factors led Anezaki (2007, 300) to conclude that dog was the only clearly domesticated animal during the Jōmon.

Despite these factors there is considerable archaeological evidence of an interesting and complex relationship between pigs and humans. At Middle and Late Jōmon sites there are burials of newborn pigs accompanied with human infant burials as well as evidence that pigs were translocated to offshore islands by Jōmon people as early as 9,000 BP (Anezaki 2007; Crawford 2011, S336). There is also considerable inter-site variability in age at death profiles, which indicates exploitation strategies were different between sites. Anezaki (2007, 306) argues that while it is possible some pigs were brought under intentional manipulation, this was not extensive until the preceding subsequent Yayoi Period.

Overall, the complex relationship between pigs and humans in the Jōmon defies typical expectations and definitions of 'wild' and 'domestic'. Crawford (2011, S336) argues people during the Jōmon Period were significant ecological engineers or niche constructors who actively engaged with their environment. Bearing in mind that simple divisions between wild and domestic, hunter-gatherer and agricultural societies are often blurry and false dichotomies, it is nonetheless essential to establish definitions and attempt to characterise taxa on a site-by-site basis. As complex as the process of domestication is, there is still a definite biological and social change that occurs that needs to be defined as best as possible.

4.2.3. The conceptualisation of domestication

Defining domestication and identifying domesticated animals is only one of the major aspects of scholarly literature on the topic. Much debate and contemplation has characterised research on the conceptualisation of domestication and human-animal relationships. Particularly influential has been the scholarship of Ingold (2000a; 2013) who has worked at breaking down nature/culture dichotomies and problematizing how anthropocentrism underlies Western scholarship. In his seminal paper on domestication, Ingold (2000d) restructured the dialogue arguing the nature/culture divide that prevails in academia had permeated the way we discuss non-human animals, who are not 'allowed' intentional agency. He suggests that domestication should be seen as a transition involving a change of engagement in how we relate to one another. He frames this transition as one of 'trust' to 'domination'. This was based on evidence from the contemporary hunter-gatherer Cree in northern Ontario, whom Ingold (2000d, 69) argues have a relationship with the environment that could be characterised as trust – a combination of reciprocal autonomy and dependency. By contrast Ingold (2000d, 72) argues pastoralists depend on animals and may even be benevolent towards them but animals are not expected to reciprocate. Domesticated animals are simultaneously protected and controlled.

This somewhat pessimistic view of domestication as an enforced domination of animals has been influential. In Hodder's (2014, 30) recent summation of domestication he sees the process in terms of an exponentially increasing entanglement or dependence "in which humans got increasingly entrapped." Hodder's framework has been influenced by Latour's (2005) Actor Network Theory, which rejects nature/culture and human/object divides and instead focuses on relations between humans-objects-animals. However, Hodder (2014, 32) critiques Latour's focus on relationality as he argues Latour appears to show little interest in the things themselves. Hodder argues large-scale processes are produced within local practices by a combination of heterogeneous and interrelated factors. Thus, large explanatory abstractions for the origins of domestication, such as population increase, obscures and oversimplifies the actual processes that occurred. Although Hodder acknowledges that causation is always difficult to identify, he argues part of the reason for this is that it is dispersed within a heterogeneous entanglement of a multitude of factors.

This ground-up approach to large-scale processes is a valuable and integral part of archaeology, and Hodder has arguably been one of the greatest contributors to the field. However, Hodder's definition of 'entanglement' and human-object-animal relations is somewhat fatalistic in its approach, mirroring current concerns on climate change and environmental destruction. There is a sense of longing for the past and seeing domestication and agriculture in terms of irreversibility.

Ingold's (2000a; 2000d) work has been incredibly stimulating to social sciences and has resulted in a reassessment about the manner in which we write on domestication. In zooarchaeological theory there is a concerted effort to move beyond anthropocentrism and human exceptionalism with an emphasis on animal agency, which is partly a legacy of Ingold's work (see Argent 2010; Kirksey and Helmreich 2010; McNiven 2010; Russell 2010; Losey et al. 2011; Lindstrøm 2012; DiNovelli-Lang 2013; Poole 2014; Thomas 2015a, for a few examples). However, the pessimistic approach to human-animal relationships is also a product of Ingold's legacy. Somewhat ironically, what both Ingold's and Hodder's approaches lack is an acknowledgement of animal agency. While human-animal relationships are often asymmetrical, the dualistic model of 'trust to domination' or 'autonomy to entrapment' is too simplistic to characterise such a complex phenomenon as domestication. It supposes that all stories of domestication are the same across the globe and between species. This last point is particularly important, as each domesticated species should not be conflated into one concept of a domesticated animal. This supposition in itself is anthropocentric in origins, as it incorrectly assumes homogeneity among domesticated animals (Calarco 2008). As Zeder (2012a) argues, there were multiple and varying pathways to domestication and much of this variation is due to the distinctive nature of each domesticated species. Knight (2005, 4) directly critiqued Ingold on this oversight when he pointed out Ingold's narrative is based on an idea of generic hunting rather than the encounter between the individual hunter and individual animal. This suggests that "prey animals are experienced not as individuals but as types" (Knight 2005, 4).

This highlights one of the issues with both Ingold's and Hodder's take on domestication; they are arguably too influenced by the present ethical predicament of the livestock industry and discussions on the Anthropocene. Ingold (2000d, 75) himself concedes; "Only with the advent of industrial livestock management have animals been reduced, in practice not just in theory, to the mere 'objects' that theorists of the Western tradition…had always supposed them to be." Yet, this telling statement is towards the end of the paper and Ingold does not seem to reflect upon this as troubling his model of trust to domination.

4.2.4. Traditional Asian approaches to animals

With the rise in growing concerns about the negative impacts humans were having on the environment throughout the 20th century, biologists and social scientists searched for inspiration outside of Western ontologies. This was significant in shaping anthropological discourse towards a wider and more inclusive understanding of how different cultures perceive their environment (Descola and Palsson 1996). Generally speaking, in dominant Asian cosmologies such as Hinduism and Buddhism, humans play reduced roles compared to Judeo-Christian conceptions of the world. In Hindu mythology, animals play a crucial role as both symbolic representations and actual living creatures (Horn 2006; Thiyagaranjan 2017, 42). Similarly, the fundamentals of Buddhism teach impermanence and interdependence, that humans do not exist in isolation and our actions ripple through a world of beings (Johnston 2006; Thiyagaranjan 2017, 42). Asian conceptions of nature are no less complex than Western, however, the idea that nature is "not culture" is not shared, though there may be other dualities (Bruun and Kalland 1995, 10). Bruun and Kalland (1995, 11) suggest that some variety of nature/culture distinctions are found everywhere, though these are highly contextual and variable. Further, Asian cultures tend to contextualise oppositions between nature and culture (wild and tame, human and deity etc.), and there is no absolute good or evil, or morality (Bruun and Kalland 1995, 11–2). Thus, obligations towards nature and other animals are contextual. For instance, in Buddhist cosmology nature is illusory and impermanent, like everything else. There is no clear-cut distinction between humans and nature, so neither are there clear distinctions in morals or ethics (Bruun and Kalland 1995, 12). Contextual morality implies these concepts need constant redefining and they are potentially subject to manipulation.

Indigenous and Asian perceptions became popular within academic discourse because of the belief that these views offered more holistic ideologies of our place in nature (Johnston 2006). However, As Bruun and Kalland (1995, 2) critique, "An underlying assumption in much of this work is that Asian cosmologies have made Asian people more successful than others in taking care of nature…" Yet, these underlying perceptions have had little effect in preventing environmental destruction, and this is not a recent phenomenon. Further, Brunn and Kalland (1995) stress there is no such thing as the Asian perception of the environment, and the variety of attitudes are not static throughout time. Similarly, Boomgaard (1995) questions the link between the prevalent perceptions of nature in societies, and the actual actions and behaviours they take. Thus, the myth of Asian ecology mindedness needs to be questioned rather than assumed. When looking to Asian ontologies or epistemologies to resist the domination of Western ideologies, Thiyagarajan (2017, 42–3) argues we must ask, who is sacrificed, oppress or marginalised within these belief systems? For instance, although Hindu philosophy and practice often exalt animals, it does so over Indigenous and Muslim people (Thiyagaranjan 2017, 42–3). Thus, just like any other ontology, these approaches should be not used without question. The purpose of understanding cultural differences in perceptions of animals is not to homogenise these perspective, but to appreciate the diversity.

4.3. Recent approaches to multispecies studies

Current trends in archaeology and 'social zooarchaeology' are part of a larger academic zeitgeist influenced by the Post-Structuralist school of Continental philosophers. There is a shift from an anthropocentric to what Lindstrøm (2015, 211) defines as an 'omnicentric' perspective, which precludes the necessity of explaining the human 'purpose' or 'meaning' behind everything. This mirrors recent approaches to archaeology that have been critical of Post-Processualism's overly anthropocentric perspectives and marginalisation of the actual materiality of things (Lindstrøm 2012; Watts 2013; Hodder 2014; Lindstrøm 2015; Thomas 2015a; 2015b). Lindstrøm (2015, 210) argues that although Post-Processualism was incredibly fruitful with its emphasis on multiple meanings, this was almost to the point of oblivion of the material objects themselves.

Within disciplines such as philosophy, anthropology, sociology, feminist studies, and science studies there has been groundbreaking work on interspecies or multispecies studies (Noske 1997; Derrida 2002; Knight 2005; Calarco 2008; Haraway 2008b; Simmons 2009; Tsing 2012). Zooarchaeology is only beginning to engage in the dialogue, which seems unusual given the unique potential zooarchaeology has for investigating human-animal relationships across time periods and cultures. Overton and Hamilakis (2013, 113) suggest one of the reasons for the disciplinary reluctance to engage in social theories is due to the ancestral links with zoology, taxonomy, and use of optimal foraging models.

4.2.4. Asymmetrical relationships

Recent anthropological research on the relationship between humans and other animals has been greatly influenced by the work of Donna Harraway. Haraway's (2003; 2008b; 2016) 'Post-humanist' writing on human-animal relationships is cutting-edge and a useful tool for conceptualizing domestication. Her concern for the predicament of animals and the often-asymmetrical relationship we have with them is paramount in her writing. However, Haraway emphasises, asymmetry does not necessarily have to be the defining characteristic of the relationship nor does it have to be essentially negative. The problem with defining human-animal relationships in this light is that it denies agency or personhood to the animal and relies on the 'Great Divide' between humans and animals:

> Many critical thinkers who are concerned with the subjugation of animals to the purposes of people regard the domestication of other sentient organisms as an ancient historical disaster that has only grown worse with time. Taking themselves to be the only actors, people reduce other organisms to the lived status of being merely raw goods or tools. The domestication of animals is, within this analysis, a kind of original sin separating human beings from nature, ending in atrocities like the meat-industrial complex of transnational factory farming and the frivolities of pet animals as indulged but unfree fashion accessories in a boundless commodity culture…To be animal is exactly not to be human and vice versa.
> Haraway 2008a, 206.

Another aspect of the 'domination' view of domestication is that it overlooks the fact that human-human relationships are usually asymmetrical as well. Thus, asymmetry itself is not necessarily a defining characteristic of human-animal relationships. In Armstrong-Oma's (2010) critique of Ingold, she uses the notion of domestication as a social contract, largely developed from gender studies. In this perception, social contracts are often asymmetrical, creating a bond between unequal partners. Crucially, a social contract in human-animal terms does not imply equality or sameness but it allows agency and acknowledges the variety of roles animals play. As Armstrong-Oma (2010, 181) states, "Each relationship is unique, and the asymmetrical nature of human-animal relationships leaves animals vulnerable to brutality and abuse of power." But importantly, this abuse of power does not characterise the relationship as it does in Ingold's and Hodder's analysis.

Likewise, Skyes (2014) and Knight (2005) are critical of casting domestication in the role of human domination. Skyes (2014) chooses to see domestication as an increasingly intimate relationship between humans and animals. Knight (2005, 5) and Skyes (2014, 33) argue rather than seeing domesticated animals as human property the relationship is closer to kin. Sykes (2014, 35–6) contends this active stripping of the individual identity of domestic animals is probably more of a testament to modern factory farming. The persistence of the human-animal divide initiated from the Enlightenment has served as a useful barrier in our modern detachment from knowledge of where our supermarket meat comes from. This is a massive ethical dilemma in itself, as Haraway contends, but should not cloud our judgement in the way we write on initial domestication. Our modern and largely Western detachment should not be assumed for other cultures or time periods.

4.3.1. Agency and intentionality

So-called Symmetrical Archaeology or New Materiality is one of the new theoretical developments in the field, defining itself as a return to 'things in themselves' (Olsen et al. 2012). Importantly, this is not the equivalent of Processualism with its emphasis on counting, cataloguing, and categorising. It is an emphasis on agency combined with the 'thingliness' of 'materiality' (Lindstrøm 2015, 210). Recent approaches to zooarchaeology have also mirrored this with a return to animals themselves, emphasising species-specific characteristics but also relationality and co-creation (Argent 2010; Lindstrøm 2012; Poole 2014). Thomas (2015a, 1288) argues this 'animal turn' in New Materialism is the most significant shift in perspective. However, as with any new theoretical development, there is much debate and disagreement. In particular, the concept of agency (and who or what has it) is lacking consensus. Ingold (2013, 246) captures this debate neatly when he critiques that it seemed obvious that all humans were agents, but whether all agents are human is less apparent, and on this matter this has been sharp and continuing disagreement.

In the past decade the term ‘agency’ has become a buzzword in social sciences and is a popular explanatory concept in archaeology. The theoretical foundation for agency is largely based on the densely intellectual work of Continental, Post-Structuralist philosophers, such as, Heidegger, Bourdieu, Giddens, and Latour (Dobres and Robb 2000, 4). Initial archaeological interest in agency can be traced back to the 1970s and 1980s with Post-Processualism, although the term ‘agency’ was not yet employed (Robb 2010, 496). Discussions of agency were centred around political power and ambition exerted by individuals and their ability to affect their will or intention (Robb 2010; Lindstrøm 2015). However, there were a number of problems with this traditional view as it is too simplistic in its description of agency as defined through power and action; life was seen as a zero-sum game of antagonistic competition among elite individuals (Robb 2010, 496). Post-Structuralist philosophy emphasised social agents not as omniscient, rational, or free-willed beings, but socially-imbedded and often impractical (Dobres and Robb 2000, 4).

The current conception of agency is in ‘relational’ terms of how people and things interact. There were two major influences for this ‘relational agency’: Latour’s Actor Network Theory and the concept of personhood. Latour (2005, 71, 75–6, 83) argues that the division between the material and the social is an artefact of disciplinary disputes. The choice between these positions is unrealistic and not “sufficient to describe the many entanglements of humans and non-humans” (Latour 2005, 84). As a consequence, Latour sees both humans and objects as actors with agency. This does not necessarily mean that objects directly ‘cause’ action but it is an acknowledgment that there are various shades between causality and inexistence (Latour 2005, 71–2).

The concept of ‘personhood’ developed from Melanesian ethnographic insights, which emphasised that what constitutes an ‘individual’ or ‘person’ is culturally variable (Fowler 2004; Robb 2010, 501–2). In some indigenous societies particular animals or objects are regarded in a similar way as persons (Fowler 2004; Hill 2013). For instance, among the hunter-gatherer Chewong people in Malaysia, personages can be literally anything (Howell 1996, 133). The body is seen as a cloak characterising that species but able to be exchanged, and personages can move between of bodies (i.e. a frog could be a person and vice versa; Howell 1996, 135). Howell (1996) emphasised that Ingold’s question of ‘what is an animal?’ would be meaningless within their worldview as they have no overall concept for ‘animal’. Though they have numerous named species, the underlying principal is equality rather than hierarchy, and humans are not set uniquely apart. Like many hunter-gatherer people, they have an intimate knowledge of the forest and nothing is semantically neutral.

Agency as an idea has been endorsed in some form across the spectrum of academia. However, there is considerable disagreement among scholars as to what constitutes an ‘agent’ and the actual meaning of the term. Dobres and Robb (2000, 8–13) gave a succinct summary of the key issues facing agency theory at the time, many that still prevail in literature today. One of the reoccurring themes was the notion of intentionality. Although most scholars would argue being an ‘agent’ does not imply knowledge, awareness or foresight, this remains one of the big divisions between anthropology and archaeology in how agency is discussed. Many anthropologists would apply personhood and ‘agency proper’ to material things, providing that a person endowed that object with such attributes (Ingold 2013, 247). This is rather paradoxical and anthropocentric in itself, as Ingold (2013, 247) critiques, why are humans invariably always in the picture? Conversely, archaeologists, tend to separate the attribution of agency on a material object compared to how people possess agency. Dobres (2000, 132) emphasises:

> People and social collectives are the active agents of prehistory: not stone tools, pots, nor artifact physics; not the environment, efficiency, nor biological capacity; not relationality, functional need, nor practical reason. People and social collectives are the active agents of their technologies.

Robb (2010, 505) and Latour (2005, 71) argue that the concept of objects having agency loses its shock value if we stop treating the primary definition of agency as cognitive intentionality. According to Robb (2010) this makes perfect sense in relational agency, where people interact with things as much as they do with other groups or individuals. The question becomes one of ‘how’ do things relate rather than ‘why’.

What should become apparent is that the focus of the debate has been between humans and objects. For the most part non-human animals and plants have been sorely neglected within Post-Processualist and New Materialist debates. Schneider (2013, 30) critiqued that although previous ethnographic and anthropological work on pig exchange in Melanesia was fruitful in questioning Western assumptions about gender and agency, it was still very human-biased. In the end, it is always the humans who manage the pigs for human purposes, and pigs are neither the agents or cause of these relationships. Dobres and Robb (2000, 9) summarised at least 12 different ways social theorists and archaeologists have conceptualised and used the concept of agency. Overall there was a tendency to emphasise the individual, social relations, and materiality. These definitions are very human, which begs the question; where does this leave room for other species? If it is possible for an inanimate object to possess agency within the relational view, how have other species been so neglected from this concept?

This neglect is starting to be addressed within the field of zooarchaeology and archaeobotany (Argent 2010; Hill 2011; 2013; Lindstrøm 2012; Poole 2014; van der Veen 2014). Although this is definitely a positive move, it has resulted in more concern and debate regarding terminology. Since the agency of animals is often so neglected in comparison to humans and inanimate objects, some zooarchaeologists have reemphasised the necessity of bringing action and intentionality back into the frame. Lindstrøm (2015) argues the use of the term agency is in danger of losing all meaning if it is indiscriminately applied to everything. She argues there is a need to differentiate between ‘agency’ and ‘effect’ and to maintain the division between the lifeless and the living in order to have a meaningful definition of the term agency (Lindstrøm 2015, 221). Her definition of agency involves four core concepts as influenced by human psychology: intentionality, forethought, self-reactiveness, and self-reflectiveness (Lindstrøm 2015, 223). Based on these criteria Lindstrom argues that animals, especially vertebrates, can be considered to have primary agency.

Although Lindstrøm presents a complex and engaging paper, the problem with this argument is that there are vast differences between species. Our attempts to demarcate differences or similarities are inherently biased by the simple fact that we can only know the perspective from our own species.[1] As Calarco (2008, 9) argues attempts to define human, animals, and agency often leads to new types of exclusions and a different type of anthropocentrism. The problem becomes one of where to draw the line. Derrida (2002) was concerned that the result of effacing the indivisible line between humans and animals would result in a simplistic and reductionist biological continuum where every species becomes homogenised. However, Calarco (2008, 148–9) argues this is a false dilemma and instead of redrawing and refining this line we should resolutely refuse the comfort of the human-animal distinction altogether.

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[1] Some theorists would retort we can never really ‘know’ anyone, even ourselves (Haraway 2008a, 226).

Clearly, there is still sharp disagreement between scholars on how to define agency and who can be endowed with it. The primary debate revolves around whether aspects like intentionality should play an important role in the definition or whether we should attempt to 'let go' of this construct. This 'letting go' is much easier theorised than actually performed in practice. Human exceptionalism is instilled in much academic thought and everyday practice. Haraway (2008b, 262) acknowledges this when she states; "There is no general answer to the question of animals' agential engagement in meanings, any more than there is a general account of human meaning making." Whether one contends objects can be endowed with primary agency, or whether this concept should be solely left to the living is not an issue that will be quickly resolved. Nonetheless, these are important discussions to have and the net result of shifting our emphasis away from anthropocentrism is immeasurable.

4.3.2. Ethnographic examples in SEA

Compared to other parts of SEA, not as much ethnographic research querying multispecies relationships or human perceptions of the environment has been undertaken in Vietnam. There is some interesting research done for specific species, such as whales from an historical perspective (see section 11.6.5. for discussion on whales), but most anthropological work has been conducted within the context of ISEA (see Howell 1996; Schneider 2013, for extensive research). Given the complex and diverse ethnographic makeup of Vietnam, and MSEA more generally, there is a need for more work specifically addressing different perceptions of animals and the environment.

An ethnic minority that has been studied in detail, albeit mostly analysing recent socio-political diaspora, is the Hmong people in northern MSEA. Hmong belief that all creatures and objects are infused with agency and a soul (Tapp 1989; Lee 2005). In Tapp's (1989) study of the White Hmong in northern Thailand he described them as Pantheists, believing in a variety of natural and spiritual forces living in and animating all things. Their cosmology is strongly influenced by Chinese ideologies of reincarnation, and upon death humans can be born again in any animal, vegetable or human form (Tapp 1989, 60). The self is believed to have combinations of animal, vegetable, and human parts and each part may possess a 'shadow self' that can wander and interact (Tapp 1989, 75–6). As discussed in section 4.2.4., the Hmong worldview is comparable to other Asian perspectives or Howell's (1996) study of the Chewong people in Malaysia in that human, animal, and object are not distinct boundaries, and the idea of everything having agency and affect is familiar.

In other areas throughout MSEA, recent multispecies studies have emphasised the complex and often contradictory relationship people have with animals. In Locke's (2013, 87) research of elephants and the Tharu people in Nepal, he defines the relationship as a combination of domination, companionship and veneration, creating unstable boundaries between animality and personhood. The Tharu have detailed knowledge of elephants as they have been training elephants for at least 300 years (Locke 2013, 90). However, there is varied significance and uses of elephants. They are violently captured and tamed, but also subject to loving care, and can be symbols of prestige, vehicles of transport, used for hauling, and in agriculture (Locke 2013, 90). These contradictory facets conflict and coexist in their relationship.

At Padangtegal Temple in Bali, the relationship between macaques and local Balinese portrays a shared perspective and understanding of spatial boundaries between species (Fuentes 2010). The locals variably see the monkeys as occasional nuisances, or sometimes as emissaries of natural forces between the human and spirit world (Fuentes 2010, 608). However, there is a shared mutual understanding that locals will not steal food from macaques and vice versa. Conversely, the relationship with foreign tourists and monkeys is fraught with more conflict, which Fuentes (2010, 613) attributes to the way tourists treat macaques as though they are furry humans and naughty comedians, creating a false sense of understanding. The tourists do not occupy the same place in the multispecies relationship as the local Balinese, and the macaques recognise and react to this.

Amongst herders in the Khangai Mountains of Mongolia, Fijn (2011) found some interesting perceptions of 'wild' and 'domestic' animals. Domestic animals are seen as part of the extended family, being fed and nurtured by humans. Comparatively, wild animals are predominately understood as animals that are fearful of humans. Fijn (2011, 202) argues rather than perceiving these animals in separate domains of categories, 'wild' is more of a behavioural characteristic. These thought processes are apparent in the way wolves and dogs are perceived and treated. They are not viewed as similar animals, because they hold different roles and statuses (Fijn 2011, 208). The wolf is thought to be a 'high' or 'spirit' animal, whereas the dog is an 'honest friend' guarding the encampment against human strangers and wolves. Wolves are perceived in a combination of good and bad characteristics, as intelligent, strong and courageous, but something that people should be wary of least they harm their herd. Generally, the herders prefer not to eat dog or wolf meat, but specific body parts of used in medicine and pelts may be used for clothing (Fijn 2011, 213).

Across many human cultures, people categorise animals and plants at a species level, which is similar to Western scientific taxonomic traditions (Descola 1996; Fijn 2011, 202). However, how animals are categorised is relatively variable and these case studies highlight the complexity in relationships people have with animals throughout Asia, portraying there is no single perception of the environment, animals, or even a particular species. This means that when making ethnographic comparisons we need to emphasise these as examples, rather than direct relationships. These examples help to stress the need to continually challenge our assumptions, and when studying cultures that are thousands of years in the past, like CCN and MB, this is even more the case.

4.3.3. Animals and agency

A shift of emphasis to acknowledging animals as autonomous beings with their own perspective is long overdue in zooarchaeology. Overton and Hamilakis (2013) argue new conceptions of agency are yet to be fully realised within zooarchaeology, as while we are prepared to grant (at least some) agency to objects we have mostly failed to do so for non-human animals. Further, they argue while the relationship is often asymmetrical, the ability animals have to elicit responses, communicate, and engage with people demands the recognition that animals are more than just an economic resource (Overton and Hamilakis 2013, 114).

Recently there have been a number of concerted efforts in zooarchaeology to engage in human-animal relationships in a more nuanced manner, recognising that agency and personhood does not just apply to humans (Argent 2010; Hill 2011; 2013; Lindstrøm 2012; Overton and Hamilakis 2013; Poole 2014; Sykes 2014; Russell 2015). Argent's (2010) reinterpretation of Pazyryk human-horse burials in the Altai Mountains dating to c. 350–250 BC has been an influential study. Previous interpretations argued that the ten elaborately dressed horses reflected the status of the man who was buried with them. Argent reverses this interpretation and instead asks whether the costumes reflect the status and identity of the horses. She was able to show the clothing became more complex and elaborate with the age of the horse, which suggests growing status and respect (Argent 2010, 164). Further, each costume had unique iconography suggesting they were treated as individuals and valued not just for their economic or functional purpose but also because of shared experiences and histories with humans (Argent 2010, 164).

The challenge to zooarchaeology is how to bring these new conceptions of agency into prehistoric periods where we often know very little about how people actually perceived their world. This impedes the extent to which we can make interpretations beyond simplistic or broad statements. That people in prehistoric periods acted with particular motivations or goals is not disputed, but attempting to understand what these were is compounded by our inability to relate. Robb (2010, 508) expressed this sentiment in his attempt to theorise Italy's Neolithic, a period which appears to be characterised by little change, or status and gender distinction. The general picture is that: "People acted with agency but not as the kind of individuals we expect to encounter on the basis of our own experience" (Robb 2010, 514).

However, hunting, domestication, and feasting arguably provide some of the best and most interesting examples of interspecies engagement. Much has already been discussed on domestication in this chapter but less on other modes of interaction. With regards to literature on hunting, Hamilakis (2003) has undertaken interesting work on hunting in Mycenaean Early Bronze Age Greece, a period which relied mostly on farming for subsistence. Within this context, hunting acquires values beyond subsistence. Hamilakis (2003, 240–1) argues rather than simply 'controlling the wild', hunting was linked to exercising and legitimising power as well as negotiating a complex combination of new conceptions regarding gender, age, and socio-political roles. In this sense, hunting becomes more of a social performance.

Similarly, feasting and consuming of meat is often argued to be a social performance, one that is usually connected to some form of ritual (Dietler and Hayden 2001; Hayden and Villeneuve 2011). Hayden (2012, 26) refers to feasting as 'social technology' in that it creates and maintains social relations with the ultimate goal of establishing subsistence and defensive alliances. Robb (2010, 509–11) points to the value of animals, especially cattle, that are guarded and traded. Building a herd involves long-term investment and planning. Animals such as cattle would have provided quantities of meat greater than one household could consume. Thus, rearing, killing, and the consumption of the animal becomes an important social event.

More recently, Overton and Hamilkis (2013) have engaged with agency and personhood in whooper swans from the Mesolithic site of Aggersund in Denmark, this time taking a more 'bird's eye view' of the relationship between humans and swans. The authors argue there was an interesting relationship based on shared experiences. The swans migrate to the site during the winter months, which parallels the seasonal movements the people themselves would have undertaken (Overton and Hamilakis 2013, 123). The authors argue people would have experienced these swans as simultaneously similar and different from themselves, engaging in seasonal movements broadly analogous to human mobility, whilst being specific to swans (Overton and Hamilakis 2013, 123).

An interesting relationship is implied through the inclusion of swan bones in a number of human burials. Further, a bone point made from a swan long bone with a highly polished edge was interpreted as a tool for constructing nets for hunting (Overton and Hamilakis 2013, 126). The authors point to the irony of hunting with an artefact made from the material of the hunted animal. In this sense the artefact retains its 'animalness' and is not just a symbol of the animal.

These new approaches resist condemning all human-animal relationships as necessarily oppressive or objectification. Rather than finding a 'voice for the other' Kirksey and Helmreich (2010) argue the goal is to radically rethink the categories of our analyses. Scholars such as TallBear (in Munoz et al. 2015) point out that in many indigenous ontologies people have never 'forgotten' that animals are agential beings, or that the nature/culture distinction was never made. This gestures towards New Materialist feminist studies where the pendulum is swinging back towards an interest in nature, biology, and interspecies relationships (Alaimo and Hekman 2008; Barad 2008; Haraway 2008a). Haraway (2008b, 74) argues, 'unfree' is not necessarily a useful category for conceptualizing domesticated animals. Just as most human relations are not entirely symmetrical in their nature, neither are interspecies ones.

4.4. Niche construction theory

The increased emphasis on mixed methods and multidisciplinary approaches in social sciences have their equivalents within the biological sciences. Relatively young fields such as NCT emerged out of a discontent over what was seen as an overly reductionist, deterministic, and gene-centric emphasis within evolutionary science; a response to the 'gene-centric' approach to evolution championed by Neo-Darwinism (such as Dawkins 1989). The ideas surrounding NCT were first introduced to evolutionary biology by Lewontin (1982; 1983) who argued that modern biological theory had a fundamental contradiction in seeing natural selection as a process of trial-and-error adaptation; "The environment poses the problem while the characteristics of organisms are regarded as their solution" (Lewontin 1982, 157). In this view, adaptation is seen as a linear process towards a 'goal' of producing organisms that are increasingly 'improved'. Lewontin (1982, 159) argued that this is not only an inaccurate view of how natural selection works but it alienates the organism from the environment:

> There must be a challenge for there to be a response, a problem for there to be a solution. That is, the metaphor of adaptation begins with a world in which an organism's environment is somehow defined without reference to the organism itself, but as a given to which the organism adapts itself.

The problem, according to Lewontin (1982, 167), is that the environment is always something 'out there' that appears as a challenge or problem to be solved. Thus, it is always the organism that responds to the environment and never vice versa. One of Lewontin's main points was that the organism and the environment cannot be separated as they lose meaning without reference to each other; "organisms assemble their environment out of the bits and pieces of the world. Indeed, an environment is nature organized by an organism" (Lewontin 1982, 160, original emphasis). His second main point was that organisms do not passively adapt to the environment, they actively construct and alter it (Lewontin 1982, 160–3).

4.4.1. NCT and archaeology

Lewontin realised NCT had particular significance regarding human behaviour (1982, 168) but Odling-Smee et al. (2003) and Laland and O'Brien (2010) were the scholars to specifically appeal to archaeology and other social sciences as being a fundamental part of understanding this new perspective. Odling-Smee et al. (2003, 27) sympathised with the frustration felt by social scientists that genetically determinist evolutionary theory has little to offer due to the assumed exclusiveness of genetic inheritance that "renders all the other consequences of human cultural activities evolutionarily irrelevant." Instead, they argue humans are the 'ultimate niche constructors', which places archaeology alongside biological sciences in its potential to contribute to our understanding of evolution.

In recent years, archaeologists from numerous backgrounds have welcomed NCT as an intuitive way of understanding the record especially within the context of agricultural origins and/or domestication (Crawford 2011; Rowley-Conwy and Layton 2011; Smith

2012; Zeder 2012a; Hunt and Rabett 2014). In particular, Zeder (2012a; 2014; 2015b) and Bruce Smith (2012; 2014; 2015) see NCT as an alternative to OFT models that have dominated much archaeological theory. Both argue the problem with OFT models mirrors that of Neo-Darwinism as it situates people within a one-way adaptive framework where they are constantly being forced to adapt to negative changes surrounding them. This is particularly true for the explanatory frameworks surrounding agricultural origins and domestication; where diversification or intensification of resources is usually explained within the context of resource depression caused by population growth or environmental deterioration (Zeder 2012a, 241). However, Zeder (2012a, 241) argues numerous examples do not fit this explanation, in particular resource abundance is often shaped partially "by deliberate human efforts at ecosystem engineering intended to promote resource productivity."

These sentiments chime well with archaeologists working within Asia who have been unsatisfied with the current discourse surrounding agriculture and domestication as there are increasingly numerous examples that do not fit 'push models' of optimal foraging, environmental stress, or climatic change (Cohen 2011; Crawford 2011; Denham 2011; Aikens and Lee 2014; Hunt and Rabett 2014; Piper and Rabett 2014). Denham (2011) argues that definitions of agricultural/domestication origins that focus on domestication of plants or animals miss a large part of the story, a sentiment also expressed by Cohen (2011). Both stress the importance of social factors and deliberate choices people make. Further, Hunt and Rabett (2014, 25) argue the assumption that forests in SEA are 'untouched' is a Eurocentric one, as is the dichotomy between foraging and farming; "distinctions between 'wild' and 'cultivated' plants, or between 'foraging' and 'farming' lifestyles (are) at best blurred and at worst meaningless". They argue there is evidence that 'management mentality' (i.e. niche construction) was in existence in SEA long before the 'Neolithic' and these niche-constructing activities developed alongside traditional hunter gatherer economies rather than replacing them (Hunt and Rabett 2014, 30–1).

This mirrors arguments made by Crawford (2011) for agricultural origins in the Holocene of Japan where there is no evidence for resource depression or population packing. In particular, the Jōmon period has always been conceptually debated as it cannot be pigeonholed into any one description: "The orthodox view that the Jōmon developed and sustained itself for millennia relatively passively in a naturally rich environment is an oversimplification if not incorrect" (Cohen 2011, 334). Crawford argues there is significant evidence of increased niche construction activities from the Jōmon period onward. For example, peaches (Prunus persica) are a fruit not native to Japan but they appear at the Early Jōmon site of Ikiriki by 6,700–6,400 cal. BP (Zheng et al. 2014, 7). Based on seed size the authors suggest that this may represent early domestication but it also hints at early contact with the Chinese mainland (Zheng et al. 2014, 7). Further, soy beans and millet also significantly increase in size and there are differences between wild forms of plants and those excavated at Jōmon sites which suggest deliberate and sustained exploitation of specific resources (Crawford 2011, 333–5). Likewise, as discussed before (section 4.2.2.2) the use of pigs (*Sus scrofa*) during the Jōmon does not fall neatly into any particular category. Although the pig was one of the most important food resources, they were the same size as wild boar and their age and sex distributions did not match expectations of a managed population (Anezaki 2007). However, it is clear that from the Early to Mid Holocene, these 'wild boars' were treated differently to other wild animals, through inclusion in human burials and translocation to offshore islands (section 4.2.2.2.).

These examples show why NCT is becoming a popular explanatory framework. The more we learn from the archaeological record in the SEA region the less it fits into our presupposed models of human development. It allows for the introduction of concepts such as agency into the frame.

4.4.2. Critiques of NCT

Although some proponents argue that NCT and OFT are not mutually exclusive viewpoints (Broughton et al. 2010; Broughton et al. 2011; see comments O'Brien and Laland 2012; Smith 2013) the debate has been characterised by heavy disagreement. Gremillion et al. (2014) have been critical of the recent surge in interest of NCT and Zeder and Bruce Smith's rejection of OFT. They argue the peaked interest in NCT, 'particularism', and agency is a result of the increase in data around the world which portrays variability within the pathways by which people adopted food production (Gremillion et al. 2014, 6171). However, they argue that agency is ultimately constrained by natural selection and that NCT is in danger of suggesting people purposely invented agriculture and domestication, or that it emerged randomly (Gremillion et al. 2014, 6175).

This concern over the definition of 'agency' is occasionally mirrored in the biological sciences. Within NCT, the re-emphasis on the organism as an active participant allows for the inclusion of concepts that evolutionary biology always had difficulty with: agency, intentionality, and the nature of consciousness (Cartmill 2000; Cartmill and Lofstrom

2000; Griffin 2000). In biology, Morgan's Canon is a rule against attributing human-like mental states to other animals, otherwise known as anthropomorphism. Cartmill (2000, 841) argued this rule was not only inhibiting scientific inquiry but was also unhelpful in the attempt to understand consciousness, as denying animals mental states does not resolve the problem. In recent years Morgan's Canon has come under increasing fire from a number of disciplines. This is partly due to increasing research into the complexity of animal behaviour (Allen-Hermanson 2012; Herman 2012; Andrews and Huss 2014) but also the influence of Post-Humanist scholars such as Derrida (2002) and Haraway (1990; 2008b).

The concern Gremillion et al. (2014) have over 'agency' is largely based on different understandings and definitions of the term. Sceptics of its use in domestication or evolution tend to understand agency as intent or conscious action. This is opposed to current conceptions of agency which emphasise the ability to act, engage, affect, or influence in a relational manner (see section 4.3.1.). As discussed above, intent or conscious action do not necessarily have to be involved. Eric Smith (2013, 115) argues that evolutionary theory models do not necessarily deny the importance of human agency, cultural variation and historical change. He argues that those who remain sceptical often have an idea of biology as fixed and predetermined, while culture is seen as mutable and agentive (Smith 2013, 115). This is ironically the exact dualism that many social scientists and humanists are attempting to avoid.

Even strict proponents of OFT concede there are problems with some of the basic assumptions. Lupo (2007, 173) admits that zooarchaeological analyses: "often proceed as if currency and proximate goal are well known and invariant. Most analysts assume that foragers always attempt to maximise the long-term net rate of gain." Lupo (2007, 174) also points out that researchers studying other animals do not presume goals to be static and in fact studies show that goals can be quite variable within different contexts and circumstances. Nonetheless, Lupo (2007, 148–9) maintains that these issues do not invalidate the use of OFT, though a higher degree of complexity underlies human resource choice than previously imagined.

Eric Smith (2013, 114) sees more similarity in OFT and NCT than either of its proponents would allow and quips that the current debate "seems to be more concerned with labels and alliance formation." However, I suggest it runs much more deeply into the heart of academia. Ingold (2000b, 29) gave a devastating critique of OFT, outlining the inherent paradox in defining 'Western humanity' by 'reason' while hunter-gatherers and animals are defined by Darwinian rationality and any deviations from optimal foraging expectations are explained by ‘culture’. Ultimately, the assumptions that underlie OFT are bound up in the ‘Great Division’ between nature/culture and a reliance on human exceptionalism. In this sense, NCT mirrors the current Post-Structuralist academic zeitgeist, which seeks to undermine these divisions and expose the assumptions they rest on.

4.5. Application of theory to the Southeast Asian archaeological record

As covered in Chapter one (section 1.2.1.) there are three main research questions relating to theoretical frameworks that are the driving forces behind this chapter. The first question relates to whether there is a perceivable shift in the faunal composition between CCN and MB, and if this relates to domestication? The second is how can the transition to agriculture and domestication be characterised in Vietnam and SEA? Finally, what can be inferred about human-animal relationships in CCN and MB, and how can domestication be reframed into a less anthropocentric perspective?

In this chapter I have argued that an emphasis on the agency of the animal is necessary to developing our understanding of domestication. Specifically, I have suggested Haraway’s (2008b) use of asymmetrical relationships is a particularly useful tool for conceptualising human-animal relationships, and how domestication occurred. Further, NCT offers a more holistic approach to understanding large-scale processes without the necessity of falling back onto climatic change, or population and resource pressure as explanatory factors.

Through the lens of NCT the ‘boundary’ between hunter-gathering and agriculturalist-based societies are permeable. Using these frameworks and previous research in SEA my expectations are that while there may be a perceivable difference in the faunal records of CCN and MB, the transition to domestication will be a complex process. As was argued in Chapter three, even when domesticates begin to be introduced into SEA, they do not stimulate the wholesale replacement of hunted fauna. It is expected this pattern will be perceived in my comparison of CCN and MB, as well as the regional meta-analysis of fauna. Further, there will probably be some overlap between hunter-gather and agricultural based sites, and potentially some interesting outliers.

Similarly, the duality between wild and domestic is problematised. As shown through case studies in SEA, people’s relationship to animals is complex, and although a similar system of species identification or characteristics may be used, categories or definitions of ‘wild’ and ‘domestic’ are not always meaningful or used in the same way. In relation to MB, previous work by Sawada et al. (2011, 106–7) suggested the pigs showed an early kill-off pattern, and there was a dominance of pigs compared to other mammalian fauna. However, Sawada et al. (2011, 106–7) noted morphological features were consistent with wild populations. Thus, they suggested the pigs were a domesticated population with some portion of wild individuals. This thesis expects to find similar results, bearing in mind it sometimes takes thousands of years for a species to skeletally portray signs of domestication (Zeder 2012b; Larson and Fuller 2014, also see section 4.2.2.), it is likely the pigs from MB will not display the full traits of domestication.

Although a duality between hunter-gathering and domestication/agriculture, or wild and domestic is argued to be too simplistic, this thesis nonetheless ultimately seeks to understand how this transition can be characterised by considering the differences in how people related to animals within this crucial time frame. The fact that both CCN and MB are burial sites plays an important role in the interpretation of the faunal record and human-animal relationships. Are the faunal remains at the site just middens relating to the consumption of meat, or is something else at play, such as rituals or special treatment of remains? Is there a perceivable difference in how some species are treated? If domesticated or managed animals are identified, does this change the relationship with wild taxa? How did the people from CCN and MB perceive their environment and the animals surrounding them? Aside from pure subsistence, how were these animals understood and how can that engagement be characterised? Reflectively, what does this say about the societies of CCN and MB? These queries are explored in detail in the discussion (Chapter eleven, section 11.4.–11.7.).

4.6. Conclusion to Chapter four

Zooarchaeology in SEA has so far had limited theoretical development. This chapter posits that domestication and changing human-animal relations during the Holocene can be approached using conceptions of agency and NCT. The aim of this viewpoint is to attempt to destabilise the anthropocentrism that has largely characterised the field. It will be attempted in this thesis to avoid dualistic narratives of animals exploited by human as either functional or symbolic purposes, and to acknowledge that they are agentic contributors in their own right. As Haraway (2008b, 76) puts simply, it is the recognition that animals can be both someone and something, subject and object, just as humans are.

CHAPTER FIVE
METHODOLOGY

5.1. Introduction

THIS chapter details and provides the rationale for the various methodologies used in this thesis, which includes: the excavation and recovery techniques, taphonomic analyses, taxonomic identification, quantification, statistical analyses, and radiocarbon dating. These analyses include a combination of traditional zooarchaeological techniques as well as more experimental analyses (such as enamel radiocarbon dating). The scarcity of detailed zooarchaeological research in Vietnam means these ‘traditional’ techniques will add crucial data to an understudied area. The biases affecting the data set are outlined and the main issues relating to availability of material and time restrictions. In particular, the majority of the faunal material is held at the Institute of Archaeology in Hanoi, Vietnam. This impacted on the availability of reference collections and restricted the amount of material that was feasible to analyse (see sections 5.2.2., 5.2.4., and 5.4. for more detail).

5.2. Excavation and recovery techniques

5.2.1. Cồn Cổ Ngựa: The excavation

The 2013 excavation of CCN was a joint Vietnamese and Australian project between the Institute of Archaeology in Hanoi and the Australian National University, Canberra. Marc Oxenham led the Australian component of the team. The exact location of the 1980 excavation could not be determined, however, a test pit from the previous year was located.

An excavation pit measuring 12x7 meters was divided into 1x1 meter squares (A1–12 to G1–2, Figure 5-1). Due to the density of human burials, the trench was slightly extended to the east and north during the investigations. Since the site is located in a modern rice paddy field there was an issue with drainage of water. A trench was dug around the perimeter of the pit and a pump was used to help remove excess water.

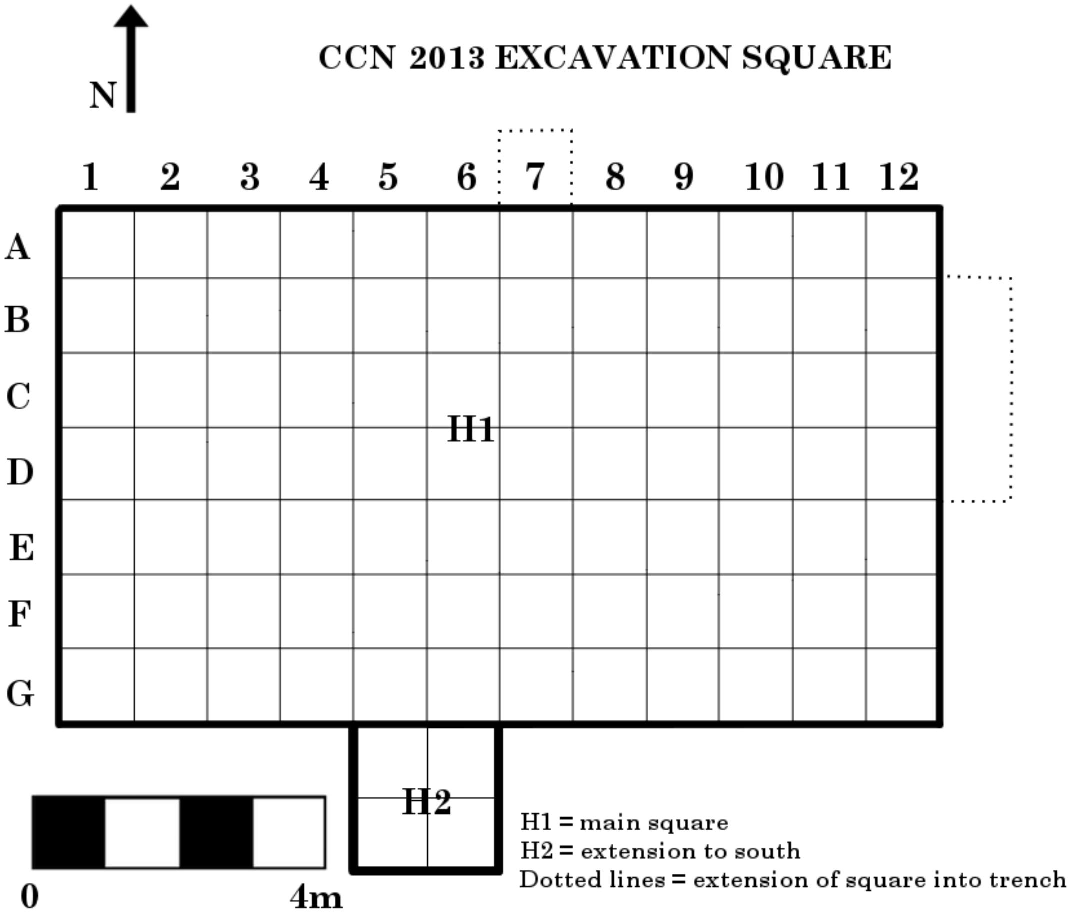

Figure 5-1 Map of Cồn Cổ Ngựa 2013 excavation pit.

The top 10–20 cm of soil was removed rapidly as it was clearly related to modern agricultural activity. Excavation was carried out in 10 cm spits per layer. Faunal material was recovered through hand collection and wet-sieving (5.5 mm and 1.6 mm sieves) and was washed in the adjacent stream. The samples were then dried, bagged, and labelled according to spit, square, feature, or burial. The artefacts and skeletal remains from the excavation were stored in the Institute at Hanoi. To date there are 252 individual human skeletons excavated from the 1980 and 2013 seasons.

5.2.2. Cồn Cổ Ngựa: Sampling and method of recovery

The majority of the faunal material was recovered through hand collection. Faunal material was bagged separately and labelled according to layer, spit, and square, feature, or burial number. Wet-sieving and flotation were employed for each burial and for 19 features and squares (Table 5-1). Although it is recognised that wet-sieving results in greater recovery rates of small bones, it was not logistically possible to employ this strategy for all spits and squares. Further, the main objects of this project rely on the

Table 5-1 Lists the features and squares where wet-sieving and flotation were employed. *samples taken to Canberra

SIEVE FRACTION SAMPLES AND FLOTATION SAMPLES						
Sample	**Date**	**Context**	**Sieve**	**Flotation**	**Note**	**Square**
1	3/7/2013	13.CCN.H1.L2.1.F6	X		Feature 6	D-E 4
2*		13.CCN.H1.L2.1.F11	X		Feature 11	D-E 5-6
3	3/8/2013	13.CCN.H1.L2.1.F22	X		Feature 22	D-E 9-10
4		13.CCN.H1.L2.1.F28	X		Feature 28	E-F 11-12
5		13.CCN.H1.L2.1.F8	X		Feature 8	A7
6	3/19/2013	13.CCN.H1.L2.3.B1	X	X		B1
7		13.CCN.H1.L2.3.C4	X	X		C4
8		13.CCN.H1.L2.3.D3	X	X		D3
9		13.CCN.H1.L2.3.E7	X	X		E7
10	3/20/2013	13.CCN.H1.L2.3.D10	X	X		D10
11*		13.CCN.H1.L2.3.G11	X	X		G11
12	3/26/2013	13.CCN.H1.L2.4.E10	X	X		E10
13*		13.CCN.H1.L2.4.B5	X	X		B5
14		13.CCN.H1.L2.4.D3	X	X		D3
15*		13.CCN.H1.L2.4.D5	X	X		D5
16*	3/28/2013	13.CCN.H1.L2.4.G1	X	X		G1
17*	3/30/2013	13.CCN.H1.L2.2-L2.3.E2	X	X	Red soil	E2
18*	4/3/2013	13.CCN.H1.L3.1.E9-E10	X	X	Red soil	E9+10
19	4/4/2013	13.CCN.H1.L2.2.E4-F4		X	Red soil M53, 54, 90	E4+F4

analysis of larger vertebrates (Chapter one, section 1.2.), rather than microfauna.

During the 2014 post-excavation analysis of the CCN, only faunal material from hand collection was analysed. During the 2015 season, fauna recovered from burials that had been wet-sieved was analysed. The rest of the wet-sieved material that had been sampled from squares and features was out of the scope of this study. In order to properly analyse the material, a high-resolution microscope is necessary and this was not available in Hanoi. A sample of five bags were taken back to Australia so they could be analysed by another student at a later date. The decision to not analyse the wet-sieved material will create some bias in the data, as small vertebrates such as rodents and small fish or reptiles may be under represented.

5.2.3. Mán Bạc: The Excavation

MB was first excavated by the Vietnamese Institute of Archaeology in Hanoi and

Ninh Binh Museum in 1999 (30 m^2, 11 burials); the same group in collaboration with the Sapporo Medical University and the Australian National University in 2004–05 (36 m^2, 35 burials), and finally the same multi-national team in 2007 (pit H1 12 m^2 15 burials, pit H2 24 m^2 32 burials; Figure 5-2; Matsumura and Oxenham 2011, 2). The pits were divided into 1x1 meter squares and labelled alphabetically W–E and numerically N–S. No recording sheets for the 1999 or 2001 excavations were available, but it is assumed the methodology was similar to the 2004–05 and 2007 excavations. The 2004–05 pit was essentially an extension to the west of the 2001 pit. The 2007 H2 pit directly abutted the southern edge of the 2004–05 pit to the northeast, and 2007 H1 pit to the northwest.

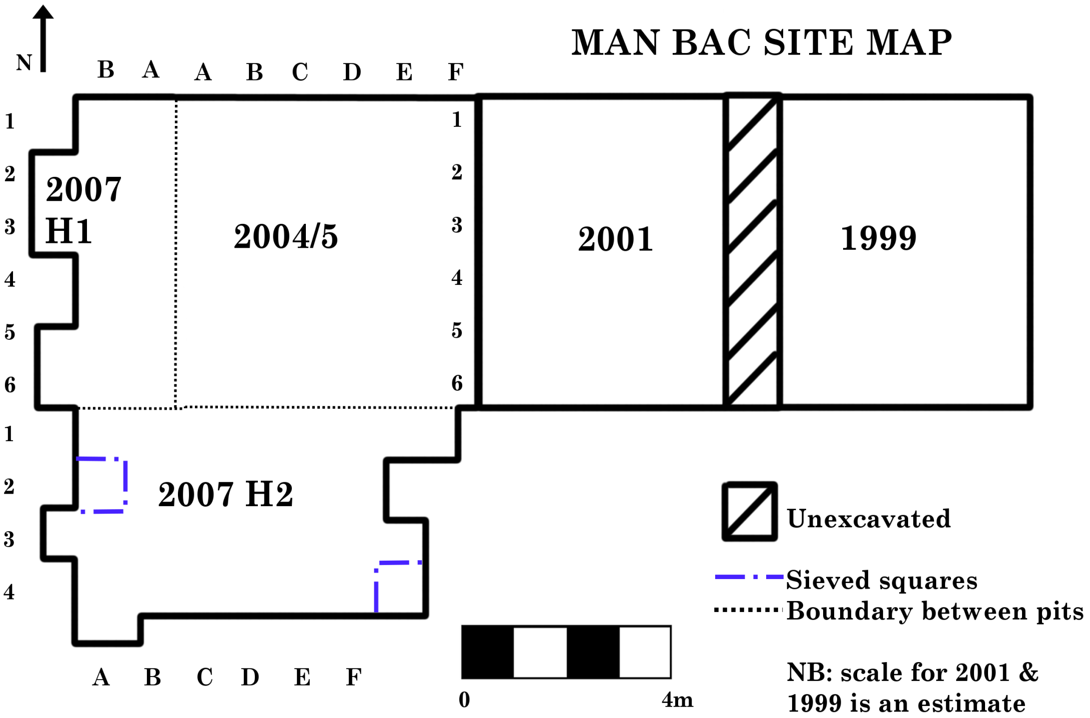

Figure 5-2 Site map of Mán Bạc and excavation seasons 1999, 2001, 2004–05, and 2007.

For the 2007 excavation, the methodology was as follows from Oxenham's (2007) field notes. From previous excavations at MB the site was known to have uncomplicated stratigraphy comprising two cultural Layers (I and II) and a lower burial Layer (III). Layers I and II were excavated in 10cm spits but Layer III was excavated according to burial layout. The top 10–20 cm of soil was removed at the beginning as this consists of modern agricultural deposits. This activity may have affected the integrity of Layers I.2–3. The artefacts and skeletal material were bagged and stored at the Hanoi Institute of Archaeology, however, some special finds were taken by the local museum including an elephant tusk and maxilla excavated from H2, Layer III.15–17 in squares A and B1. In 2015 attempt was made by RKJ to contact the museum and gain access to the elephant maxilla but unfortunately the specimen was not on display.

5.2.4. Mán Bạc: Sampling and method of recovery

Post-excavation analysis of the MB faunal material was undertaken in 2015 at the Hanoi Institute of Archaeology. Five large boxes from the 2001, 2004–05, and 2007 excavations were stored at the museum. The majority of the faunal material from MB was recovered by hand collection. In the 2007 H2 pit, squares A2 and F4 were sieved throughout Layers I and II (Oxenham 2007). According to Sawada et al. (2011) squares E3 and G1 were intensively sieved, but this may refer to the 2004–05 pit. All of the faunal remains were cleaned and labelled with the site, date, square, layer and spit.

Two previous analyses of the vertebrate and fish remains from MB influenced the procedure of this analysis. The vertebrate analysis of the mammalian remains by Sawada et al. (2011), although useful, was mainly a preliminary study that focused on the cranial (especially dental) data. Thus, all of mammalian material was reanalysed. Some of the material required initial sorting into categories: bone, shell, rock, and human remains. Fish were separated from the rest of the fauna. Once the terrestrial vertebrate remains were completely analysed the decision was made not to analyse the fish material. Though it is recognised fish provide invaluable information, fish were not a key component of the project and there were several factors impacting the feasibility of their analysis. Primarily, there were significant amounts of fish remains and a lack of comparative fish collections or specialists in fish identification in Vietnam. These conditions would have made it difficult to thoroughly analyse the fish assemblage. Further, there is a relatively detailed analysis of the 2004–05 fish material (Toizumi et al. 2011), which can give a representative idea of the species of fish exploited. Thus, the fish material was left for another researcher to study in future.

5.3. Taphonomic analyses

All bone fragments were subjected to taphonomic examination for surface modifications largely based on Lyman (1994b; 2008), which included; weathering stage, burning, abrasion/pitting, breakage pattern, surface staining, carnivore bite marks, rodent gnawing, and butchery. All of this information was recorded in order to gain an understanding of the biostratonomic and pre- and post-depositional taphonomic processes that influenced the preservation and destruction of the assemblages.

5.3.1. Weathering stage and breakage pattern

Behrensmeyer's (1978) five-stage weathering scale was used to help determine the length of time the bones had been left on the surface exposed to the elements. The scale was slightly modified with 1 being no/little evidence of weathering (as opposed to 0 being bone that is still greasy) to 5 being extremely weathered. Differential weathering on a fragment was also recorded, such as, if one surface had a higher weathering stage than another. Behrensmeyer (1978, 153) noted that the surface of the bone that is exposed usually has a higher weathering stage than the surface with ground contact. This can help to indicate the level of post-depositional disturbance within the assemblage, as elements that have been exposed to the surface primarily on one side indicates there was minimal disturbance.

Additionally, Lyman (2008, 271, 273) notes that NISP is the unit used for quantifying weathering stage but also adds that determining whether there is a difference between unidentified fragments and NISP may be of interest. For instance, if unidentified fragments show a proportionally higher weathering stage that would suggest long-term exposure.

The general breakage pattern of the edge of the bone was noted as angular, angular and rounded, or rounded (Figure 5-3). The 'angular' category does not refer to fragments with recent breakage. These categories will help to determine the amount of post-depositional disturbance that occurred. Rounded edges and polished surfaces suggest abrasion through physical force such as, water transportation, wind erosion, or soil bioturbation (Fisher 1995, 33–4; Samper Carro 2011, 22–3). Conversely, angular edges imply quick deposition and minimal abrasive action. Given that the environment surrounding CCN is thought to have been wet with fluctuating water levels

Figure 5-3 A fragment of mammalian bone from CCN that shows relatively heavy manganese staining, rounded edges, heavy weathering, and some abrasion on both the exterior (above) and interior (below) surfaces. Specimen ID: CCN-319. Scale = 4 cm.

throughout time (Nguyen Viet 2005), some of the skeletal elements may have been transported by water from their original depositional location.

A basic category system was developed to measure the size of each fragment, for instance; 0–50 mm; 51–100 mm. This was combined with a NISP:MNE ratio to allow for a comparison of the levels of fragmentation between sites (Lyman 2008, 150–1). As Lyman (2008, 251–2) explains, the NISP:MNE ratio measures fragmentation intensity and is calculated by the ratio of anatomically incomplete specimens to the MNE of those elements. The ratio then signifies fragment size, so higher ratios suggest smaller fragments. This allows the ranking of elements in order from the most fragmented to least, which enables comparison of specific elements between sites, such as, fragmentation intensity of deer humeri between CCN and MB (see Chapter six, 6.3.1. and Chapter seven, 7.3.1.).

Lastly, each fragment was weighed and recorded in grams.

5.3.2. Surface staining and burning

Surface staining and colour of the bone were recorded. Manganese (Mn) staining and burnt bone can be easily confused without careful examination under a microscope. Manganese will usually adhere to the surface of the bone like a crust and is usually patchier than burning, it also does not demonstrate the fine-striated cracking or shrinkage caused by heat exposure (Figure 5-3). Manganese can form due to three main taphonomic reasons (see López-González et al. 2006, 713–4; Marín Arroyo et al. 2008). Firstly, it may derive from the surrounding limestone bedrock or from the presence of groundwater, both of which contain minor amounts of manganese. Secondly, in a humic/decomposing environment the degradation of organic remains into the soil produces metal-organic complexes that act as carriers of trace elements. Lastly, bacteria and fungi release manganese ions when utilising the organic part of complex molecules. Thus, it is important to attempt to distinguish between burnt bones and manganese staining as burnt bones in an archaeological context potentially implies human activity, while manganese staining is a natural geochemical process. In limestone cave environments, manganese staining on bone is probably a result of the surrounding bedrock. Conversely, CCN and MB are open-sites that contain human burials and large midden deposits, which suggests a humic soil environment is probably causing the manganese staining.

The presence of burnt bone was recorded and a differentiation was made between bones that were slightly burnt, heavily burnt, or calcined. Burnt bone is black in colour because as the collagen is heated, the specimen becomes carbonized. Calcined bone is typically white or bluish-grey as it has been exposed to continued heating of above 600 °C, which has oxidized the carbon (Lanting et al. 2001, 250; Lyman 2008, 275). The spatial and temporal distribution and abundance of burnt bone can potentially provide information on human activity and site use, such as location of hearths or an increase in burning activity.

5.3.3. Carnivore, rodent, and anthropogenic modifications

Carnivore bite marks and rodent gnaw marks were recorded. In cases where carnivore marks were ambiguous it was noted with a question mark. Carnivore activity can leave a variety of different marks such as, tooth bites in the shape of pits, tooth scraping along the surface of the bone, and acidic marks through digestion (Fisher 1995, 36–43). Rodent teeth leave characteristic gnawing marks on bone (Klippel and Synstelien 2007). The presence of carnivore or rodent marks attests to exposure of skeletal remains long enough for scavengers to gain access to them. It also demonstrates that humans were not the only agent of modification in the assemblage.

Butchery marks were identified, recorded, and described following the conventions established by Potts and Shipman (1981) and Greenfield (1999). Cutmarks are grooves with an asymmetrical V-shaped cross-section that often contain fine, parallel striations within the groove (Potts and Shipman 1981, 557), though sharp metal knives usually produce a distinct and smooth V-shape with no or minimal striations (Greenfield 1999, 803–4). Chopmarks are produced by striking the bone surface at a roughly perpendicular angle, and often produce broader V-shapes that do not show striations (Potts and Shipman 1981, 557).

Anatomical placement was noted with the purpose of deciphering butchery methods. For instance, placement of cutmarks could help distinguish skinning versus disarticulation of limbs. Following Rixson (1989) and Amano et al. (2013), placement of cutmarks was used to develop a chaîne optératoire of five generalised butchery practices (see Chapter six, 6.3.5, and Chapter seven, 7.3.5.). Adaption of Rixson (1989) and Amano et al. (2013) was as follows:

Primary: slaughter, skinning, and evisceration of carcass, may include removal of antlers, head, or feet.
Secondary: initial division / gross dismemberment of carcass into major portions at the joints to produce meat-yielding units, e.g. front and hind limbs

Tertiary: reduction or disarticulation to reduce major units into smaller pieces for cooking or further processing, e.g. defleshing
Fourth: Marrow exploitation
Fifth: working of bone, artefact production

Bone artefacts were given a detailed examination and analysed for use-wear and residue. Ultimately, the bone artefact analysis is not covered in this thesis as it was determined to be out of the scope for this project. Instead the artefact analysis will be undertaken in future research projects.

Bone artefacts, butchery marks, carnivore bite marks, and rodent gnaw marks were analysed under a Dinolite microscope (AM313 FUT) and images were taken using the software DinoXcope Mac version 1.9.7. Macro images were taken using a Canon EOS Rebel XSi and images were edited using the software Gimp. Some particularly important artefacts were taken to ANU for further analysis under higher microscopy including SEM analysis.

5.4. Taxonomic identification of bone

Both the CCN and MB bone assemblages are housed in the Archaeological Institute of Hanoi and are unable to be removed from the location. Vietnam does not have a thorough skeletal reference collection in any museum but skulls and mandibles of several different sizes of pigs, deer, and bovines were available for comparison at the Institute. Nonetheless, this meant a great deal of identification was based on the following manuals: (Pales and Garcià 1981; Hillson 1986; Cohen and Serjeantson 1996; Hillson 1999; White and Folkens 2005). Further, a digital archive of modern comparative specimens housed at different museums developed by my supervisor PJP and myself was also highly useful. Several online sites were of great value for fish 'Osteobase' (Tercerie et al. 2015), birds 'Aves 3D' (2011), and carnivores 'ArchéoZoo Thèque' (Carpentier and Coutureau 2015). Distinctive fragments of bone were identified to the lowest taxonomic level possible. Anatomically, bones were identified to element, portion/landmark, and side. Where appropriate, state of fusion was noted and tooth wear (see section 5.6.).

For mammalian specimens that could not be identified more precisely to a taxonomic family, genus, or species, a size category was used based upon the type of taxa present in

Table 5-2 Mammalian category sizes used for specimens that could not be further identified taxonomically.

Mammal size categories		
Category	**Comparative animal**	**App weight**
Small	Rodents, primates	<10kgs
Medium	Dogs, pigs, deer	<300kgs
Large	Large deer, bovines	>300kgs

the environment (Table 5-2). Although it is recognised there may be overlap this was done for practical comparison purposes.

5.5. Quantification and terminology

Quantification methods are an inherent aspect of all studies in zooarchaeology. The main purpose of quantification methods is to establish relative frequencies of taxa and whether any changes over time can be interpreted as human or environmental induced change (Lyman 2008). Terminology and methodology applied was based on Grayson (1984) and Lyman (1994a; 1994b; 2008). Following Lyman (2008, 5), “a skeletal element is a complete discrete anatomical unit such as a bone, tooth or shell”, while a “specimen is a bone, tooth, or shell, or fragment thereof.” A specimen was considered identified if it was identified to a biological taxon and/or skeletal element (Lyman 2008, 6). Lyman (2008, 27) terms the NSP as the total number of specimens including unidentifiable bones, this is interchangeable with the term TNF (total number of fragments). Conversely, NISP is the number of specimens identifiable to a taxon and/or element.

5.5.1. NISP versus MNI

Much ink has been spilt over the benefits and disadvantages of NISP and MNI. Grayson (1984) and Lyman (2008) outlined in detail the problems with both techniques and concluded NISP was more useful and less problematic than MNI. The main problem with NISP is that specimens may suffer from interdependence, that is, an NISP of 50 may actually represent one individual (Grayson 1984, 26; Lyman 2008, 36–7). Other problems can be dealt with through careful consideration of recovery techniques and methodology. For instance, NISP varies intertaxonomically because different taxa have different frequencies of skeletal elements. This can be controlled by either not counting elements that vary in number between taxa (for example, phalanges), or by dividing the NISP by the total number of elements for each taxa (Lyman 2008, 30–1).

MNI became more popular than NISP in the 1970s and was introduced into archaeology to counter problems of interdependence within NISP (Grayson 1984, 20, 27). However, as Grayson (1984) realised MNI only fixes the problem of interdependence within a clearly defined assemblage or aggregate. The number of aggregates (such as, spits, stratigraphic levels, or cultural boundaries) will change the MNI values. One large aggregate will produce a smaller MNI than a number of small aggregates combined (Lyman 2008, 58; table 1). For each project the aggregates must be defined according to the research problem and specific taphonomic or site formation information available. The calculation of MNI for CCN and MB takes into account different stratigraphy and site formation processes (section 5.5.2.).

An important point first noticed by Ducos (1968, 6–7) was that NISP and MNI values are closely related to one another and can be mathematically explained as a curvilinear relationship. As NISP increases it takes progressively more specimens to add new individuals. Ducos (1968, 6–7) also found that this curvilinear relationship could be made linear if both NISP and MNI values were log transformed; when graphed the relationship between MNI and NISP is more easily understood when linear. In this linear relationship, the slope of the best-fit regression summarises the rate of change in MNI relative to the rate of change in NISP; the larger the number, the steeper the slope (Lyman 2008, 50–1). This means that MNI can be predicted based on NISP values, which led Grayson (1984, 52–5) and Lyman (2008, 70) to argue MNI was effectively redundant. This has prompted a reversal in popularity as many researchers now use NISP over MNI or if they are conducting a thorough analysis they may compare NISP and MNI values (Ma 2005; Amano 2011; Bellwood et al. 2011; Piper and Rabett 2014; Oxenham et al. 2015).

At this point, both NISP and MNI have one major problem that researchers need to be aware of: interdependence and aggregation. This means that using powerful statistical analyses needs to be undertaken with caution because NISP and MNI values will not provide a direct ratio scale of species abundance (Grayson 1984; Lyman 2008, 71). This is because MNI values are the minimum while NISP values are the maximum and the actual number of individuals probably lies somewhere in between. However, the rank order of abundance in mammalian taxa is often similar between NISP and MNI (Grayson 1984; Lyman 2008). Thus, although NISP and MNI do not produce an exact ratio measurement they do provide an ordinal scale of measurement. Provided that the separation in abundance of taxa A remains significantly different to taxa B, the less likely changes in aggregation or specimen interdependence will alter the order of abundance (Grayson 1984, 99; Lyman 2008, 74–5). For this reason, Grayson (1984, 98) argued, rare taxa should not be included within ordinal scales but should be treated in a presence/absence sense.

This discussion on which scale of measurement should be used with MNI and NISP has important implications to all zooarchaeological research. It is a reminder that our target variable (the actual number of individuals in an assemblage) is a number that we probably cannot know. Therefore, NISP and MNI cannot be taken directly at face value, but an ordinal rank is sufficient to interpret the relative frequency or importance of taxa.

5.5.2. Calculating the MNI and MNE

The minimum number of individuals (MNI) of a taxon was calculated by taking into account side, age, sex, and size of the specimen (see Appendix 2 for methodology). For CCN context, such as layer, spit, square or trench, was not used to determine MNI. Rather, the site was treated as one aggregate because the length of occupation and use of the site is not fully understood and treating each layer as a separate aggregate could potentially result in inflated MNIs. Practically, this means the MNIs for CCN were calculated very conservatively, and the count certainly represents the minimal number. For MB, the deposit is much deeper than CCN and could potentially reflect a greater time span. MNIs were calculated using two methods: treating the site as one context and treating each layer as a separate context.

The minimum number of elements (MNE) is "derived by determining the minimum number of skeletal elements necessary to account for an assemblage of specimens of a particular skeletal element" (Lyman 1994a, 289). This is implemented by examining each skeletal element, such as left femora, for anatomical overlap (Lyman 2008, 220). If there is anatomically overlapping specimens, this must represent unique elements from different individuals. Thus, the MNI value of a particular taxon is derived from the methodology of determining the MNE for each skeletal element and choosing the highest value (see Appendix 2 for methodology). MNE counts can help to answer why some skeletal elements are abundant while others are not, it is what Lyman (2008, 216) calls the ultimate taphonomic question. MNE counts can provide insight into butchery practices and technologies. A differentiation in body part frequencies may give insight into social or economic practices of how a carcass was processed. For instance, a near complete representation of skeletal elements of a taxon may indicate the carcass was processed on site, vice versa, only a few selected elements could indicate part of the carcass was transported to the site (Marshall and Pilgramb 1991; Stiner 2002; Lyman 2008).

5.6. Tooth wear and epiphyseal fusion

Mortality patterns can help our understanding of behavioural decisions related to hunting and slaughter strategies, land use, and seasonality (Stiner 1990). The relative timing and slaughter for pigs, deer, and bovids was estimated using tooth eruption, wear stages, and postcranial fusion following Grant (1982), Bull and Payne (1982), Grigson (1982), Amorosi (1989), Higham (1968), O'Connor (2003), Lemoine et al. (2014), and Zeder et al. (2015). See Appendix 1 for methodology of tooth wear and fusion data, and Appendix 3 for results.

For bovids, tooth wear analysis following the alphabetical category system devised by Grant (1982) was employed and compared to descriptions in Grigson (1982), Amorosi (1989), Higham (1968), and O'Connor (2003) to obtain an age. The references are mostly in agreement, although, Amorosi (1989) tends to be more cautious and gives larger age ranges. Given the high occurrence of single teeth and only one fragmentary mandible in the assemblages there were issues with comparing the data to the systems above. The majority of the descriptions employed by the authors above are designed for complete mandibles and many do not mention premolars, thus, best estimates of wear were made for single teeth. An attempt was made to use Stiner's (1990) method of ageing based on wear stage but this requires using only mandibular dp4s and P4s which greatly reduced sample size. The fusion of postcranial elements were analysed using Amorosi (1989). In general, this data was less helpful as many elements have a late fusion period.

For cervids, the tooth wear stages for caprids in Grant (1982) and Bull and Payne (1982) are often used as their teeth are similar in morphology. Mariezkurenna (1983) analysed the wear stage and fusion of selected postcrania for red deer (*Cervus elaphus*) aged 8, 20, and 32 months. Munro et al. (2009) analysed wild gazelle which was also used for comparison, however, it was found to be not as useful as gazelle mature earlier.

For pigs, Grant's (1982) tooth wear and Bull and Payne's (1982) tooth eruption and epiphyseal fusion systems are often employed to compute age. However, new ageing systems devised by Lemoine et al. (2014) and Zeder et al. (2015) combine and update these conventions (Table 5-3). Lemoine et al.'s (2014) methodology for ageing based on tooth wear allows for the inclusion of maxillary teeth, as their study proved there is little difference between the wear stages of maxillary and mandibular dentition. The method also allows for inclusion of incomplete samples or singular teeth with the acknowledgement that archaeological samples are often highly fragmented and whole mandibles or maxillae are rare. The reasoning behind the inclusion of maxillae, singular teeth, and both right and left sides is to increase sample size and capture data that would be otherwise lost if samples were restricted to only mandibular rows. The authors acknowledge this may lead to double counting of some individuals but argue the benefits of increasing sample size outweigh the disadvantages of possible double counting (Lemoine et al. 2014, 181).

Table 5-3 Summarising ageing of pigs using dental wear and postcranial fusion based on Lemoine et al. (2014) and Zeder et al. (2015); developed from Grant (1982) and Bull and Payne (1982).

Specific	Specific age estimate	Simplified A	Simplified A age estimate	Simplified B	Simplified B age estimate	Fusion age class
1	≤1m	A	≤1m	I	0-12m	A
2	3-5m	B	3-8m			B
3	6-8m					C,D
4	8-12m	C	8-12m			E
5	12-16m	D	12-16m	II	12-52m	E,F
6	18-30m	E	18-52m			F,G
7	30-52m					G,H,I
8	52-72m	F	52-96m	III	52-96m	H,I
9	72-96m					I,J
10	>96m	G	>96m	IV	>96m	J,K

Molar wear was calculated using Lemoine et al.'s system (2014). Age categories for three systems (Specific, Simplified A, Simplified B) were calculated for samples that fell into one age category (Lemoine et al. 2014, 187). Mortality and survivorship scores were calculated following the procedure outlined by Lemoine et al. (2014, 188).

For postcranial fusion, each element was divided into fusion age class following Zeder et al. (2015). Elements were labelled as 1 = unfused, 2 = fusing, and 3 = fused and totalled for each category. Survivorship and mortality scores were calculated following Zeder (2015, 142). These scores were converted into profiles to allow for comparability with tooth wear scores as per Lemoine et al. (2014, 188) and Zeder et al. (2015, 144–55). For a summary of all ageing data see Appendix 3.

5.7. Morphometric identification of taxa

Measurements of skeletal elements followed von den Driesch (1976). To define body-size and help determine whether the pigs, dogs, or bovines could be assigned as wild or domestic, these measurements were compared with comparative data from SEA (see references per section). Both male and female specimens were included in the modern comparative assemblages to take into consideration any variability related to sexual dimorphism.

5.7.1. Bovine biometrics

Postcranial measurements followed Driesch (1976). For single bovine teeth, length and breadth measurements were taken at the widest or longest part of the tooth (Figure 5-4). For bovine teeth that were still within the mandible or maxilla measurements were taken at the enamo-dentine junction.

The distinction between *Bos* and *Bubalus* can sometimes be defined based on differences in morphology and size (see Chapter six, 6.4.11. for specific details). In general, *Bubalus* elements are more robust than *Bos*, although, this is not the case for *Bos gaurus*, which is among the largest and most morphologically robust of the tribe Bovini (Choudhury 2002; Duckworth et al. 2008). Higham's (1975b) measurements of Bovinae cranial and postcranial elements from Non Nok Tha in Thailand is a good comparison for Vietnam. However, for dentition Higham's (1975b) measurements often only includes lengths of teeth and no breadths, which make comparison to other datasets difficult. For details on specific measurements taken and comparative samples used see Chapter eight, 8.6.

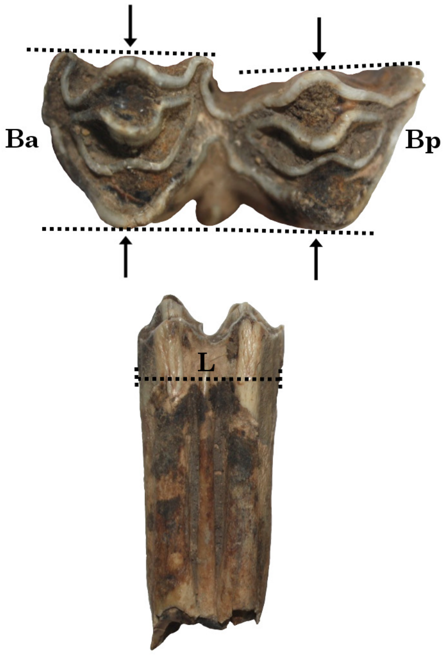

Figure 5-4 Showing method of measuring singular bovine molars at the widest and longest point. Ba = anterior breadth; Bp = posterior breadth; L = length.

5.7.2 Pig biometrics

The primary goal in measuring pig dentition was to differentiate between wild and domestic individuals. As covered in Chapter four, there are issues with identifying early domesticated animals solely through size reduction, which is why multiple methods are essential. For this thesis measurements are used in conjunction with other methods, such as age profiles, and relative composition of taxa.

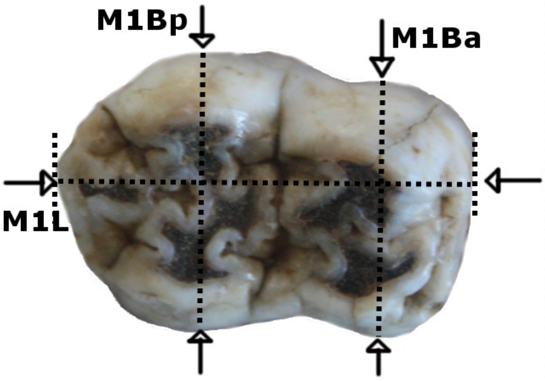

Figure 5-5 Method of measuring pig molars. L= greatest length; Ba= greatest anterior breadth; Bp= greatest posterior breadth. NB: measurements were at the cento-enamel junction.

A standard length and breadth of each premolar and molar column was taken (Figure 5-5). Measurements were taken at the cento-enamel junction rather than the occlusal surface because measurements of the occlusal surface will vary depending on how worn the tooth is.

In terms of pig taxonomy, there are a number of endemic species spread throughout Asia (Table 5-4). Pigs that have been domesticated all belong to the genus *Sus* (Groves 2007, 21). The most widespread taxon is *Sus scrofa* (wild boar) or *S. scrofa domestica* (domestic form). There are a number of different endemic species in ISEA but their current and historical range is restricted to ISEA and the Malay Peninsula. Similarly,

Table 5-4 List of different species of pig in SEA following Groves (2007).

Species	Common name	Range	ICUN reference
Babyrousinae			
Babyrousa babyrussa	Babiroussa	Indonesia	(Macdonald et al. 2008)
The *S. scrofa* group			
Sus scrofa	Eurasian boar	Most widespread, native to most of Europe and Asian regions. Currently spread to every continent expect Antartica.	(Oliver and Leus 2008)
The *S. verrcosus* group			
Sus verrucosus	Javan warty pig	Indonesia	(Semiadi et al. 2016)
Sus bucculentus	Indo-Chinese warty pig	Vietnam, Laos; more is information needed	(Groves and Meijaard 2016)
Sus celebensis	Sulawesi warty pig	Sulawesi, Indonesia	(Burton and Macdonald 2008)
Sus barbatus	Bearded pig	Malay Peninsula (below Isthmus of Kra), Sumatra, Bangka, and Borneo	(Kawanishi et al. 2008)
Sus ahoenobarbus	Bearded pig	Palawan, Philippines	(Oliver 2008a)
Sus cebifrons	Visayan warty pig	Visayan Islands, Philippines	(Oliver 2008b)
Sus philippensis	Philippine warty pig	Philippines	(Oliver and Heaney 2008)
Sus oliveri	Oliver's warty pig	Mindoro, Philippines	(Schütz 2016)

there were a number of different genera within Suidae in China but they became extinct during the Pleistocene or earlier (Liping et al. 2002) and are therefore not relevant to CCN or MB.

The subfamily Babyrousinae are distinguished from *Sus* by their size, skull shape, size and shape of male canines, and their body hair (Groves 2007). Groves (2007, 20) places the genus *Babyrousa* into three distinct species. Although there is potential evidence for human-mediated island translocation of *Babyrousa*, the genus has never been domesticated (Groves 2007). There have been some recorded finds of *Babyrousa* pigs in MSEA, but only during the Pleistocene (Bacon et al. 2008, 1643). This means the most likely species in the archaeological record at both CCN and MB is *Sus scrofa*, hence the primary aim in analysing the pigs at both sites is differentiating between wild and domestic forms of this taxon. Comparing measurements of pigs is notoriously difficult as size can be greatly affected by climate and regionality (Rowley-Conwy et al. 2012). Albarella and Payne (2005, 596–7) suggest that the most useful measurements are; width of lower M1 and M2, width and length of lower M3, the distal breadth of the tibia, and the greatest lateral length of the astragalus. Although the problem with using the astragalus is that it does not fuse, so it is difficult to know whether you are measuring a fully developed adult or a juvenile.

Albarella and Payne (2005, 596–7) warn against only using lengths of molars as it tends to be variable and hard to measure if teeth are closely impacted (Albarella and Payne 2005). Rowley-Conwy et al. (2012) advocate the use of coefficient of variation (CV) as a measure of variability within an assemblage and suggest that a CV >5 probably represents two different populations. However, when attempting to assess domestication of a species in early contexts where management may be just establishing, it is best to combine multiple methods, as discussed in Chapter four, 4.2.2. (Zeder 2001; 2011; Rowley-Conwy et al. 2012).

5.7.2.1. Cluster analysis of pig biometrics

To help determine whether size and shape formed statistically significant differences between pigs, cluster analysis was performed using the software SPSS. The lengths and cusp breadths of upper and lower pig M1s, M2s, and M3s from MB and CCN were compared to Asian *Sus scrofa*. Wild and domestic modern samples as well as archaeological material were used for comparison. Reference material was limited to Asian *Sus scrofa* based on Rowley-Conwy et al.'s (2012) findings that regionality and climate can affect the size and shape of molars. Although comparative material of pigs from Europe and Australia are easily accessible it is questionable whether they can be directly compared to Asian pigs. Yuan and Flad (2002, 725) have suggested that Chinese *Sus scrofa* cannot be compared to European material as wild boar in China are larger on average. For more details of the archaeological and modern samples used in these analyses see Tables 8-1 and 8-2 in Chapter eight, 8.2.1.

Hierarchical clustering using Ward's method was initially used as this technique gives a good indication of the possible number of clusters (Burns and Burns 2008, 557). The dendrogram allows the user to employ their knowledge of the samples to help assess how many clusters there should be. For instance, the user can determine a cluster based on known species affiliations of a modern reference sample of domestic *Sus scrofa*. K-means clustering then allows the user to specify the number clusters. In general, this method produces clusters with the greatest possible distinction (Burns and Burns 2008, 557). Burns and Burns (2008, 557) advocate the use of both techniques successively. To test whether the difference between the clusters was statistically significant, a between-groups one-way ANOVA was conducted. To evaluate the nature of the differences within the ANOVA a post hoc-test Tukey HSD was conducted. See Appendix 6 for a summary of Kmeans, ANOVA, and hierarchical dendrograms.

Both of these methods were employed for length versus anterior (or mesial) breadth; length versus posterior (or distal, mid-breadth for M3s) breadth; anterior versus posterior (mid-breadth for M3s) breath; and lastly all measurements combined. A 3D scatterplot graph helps to visualise the results of all three combined measurement cluster results, while simple bivariate plots are sufficient for two variables.

5.7.3. Canid identification and biometrics

There are a number of different canid species within Asia including; the dhole/Asian wild dog (*Cuon alpinus*), the golden jackal (*Canis aureus*), wolves (*Canis lupus* spp.), and domesticated dog (*Canis familiaris*), which must be taken into consideration when identifying skeletal remains. Differentiation between the genera *Cuon* (dhole/Asian wild dog) and *Canis* (wolves, jackals, domestic dogs) can be achieved based on some morphological cranial and postcranial differences (Table 5-5 and Figure 5-6 to 5-9; Ripoll et al. 2010; Pionnier-Capitan et al. 2011; Boudadi-Maligne et al. 2012; Piper et al.

2012). For instance, the LM1s on *Canis* have two posterior cusps while *Cuon* has one and *Cuon* does not have a lower M3. Further, the upper dentition is morphologically distinct between these genera. In general, the upper and lower cusp morphology of *Cuon* is simpler than *Canis*. In *Canis* UM1s the cingulum and hypocone extends lingual-distally and the cusps tend to be rounder in *Canis* and more pointed in *Cuon*. Differentiating *Cuon* and *Canis* in postcrania has been recently detailed by Pionnier-Capitan et al. (2011). There are numerous postcranial differences but the distal tibia and humerus were most helpful in this study (Table 5-5).

Differentiating within *Canis* can also be achieved due to morphological and size differences. *Canis lupus* (Grey wolf) is much larger in size than *Canis familiaris* (domestic dog), particularly from the Mid Holocene onward the difference in size is distinct (see

Table 5-5 Summary of major skeletal differences between *Cuon*, *Canis*, and *Canis aureus*, and *Canis lupus* and *C. familiaris* used in this study.

Feature	*Cuon*	*Canis*	References
LM3s	Absent	Present (though may be variable)	Boudadi-Maligne et al. (2012, 5)
Morphology of cusps	Pointed	Rounder	RKJ observed
UM1s	Single cusp on protocone, lingual aspect. Paracone and metacone more developed compared to talon.	Talon more complex. Cingulum and hypocone extends lingual-distally	Ripoll et al. (2010, 441); RKJ observed
LM1s	Single cusp on talonid at caudal end	Two cusps on talonid	Piper et al. (2012); Boudadi-Maligne et al. 2012, 5)
Tibia	a) Distal end in cranial view malleolus less angular and prominent, b) distal border angular, c) no oblique groove on lateral edge	a) Malleolus more angular and prominent, b) distal border rounder, c) in lateral half small oblique groove	See Figure 5-9 Pionnier-Capitan et al. (2011, 2126, 2129)
Humerus	Distal extremity in cranial view: f) Proximal edge of the trochlea articulation is longer and straight until medial extremity. g) Medial epicondyle more developed in medio-distal direction.	Distal extremity in cranial view: e) Region between medial epicondyle and supratrochleal foramen is thicker and studier. g) Medial epicondyle medio-proximal direction.	See Figure 5-8 Pionnier-Capitan et al. (2011, 2126, 2127)

Feature	*Canis aureus* (Jackal)	Wolves, dogs	References
UM1s	Elongated paracone and metacone. Rhombus-shaped.	Broader labial-lingual. Oval-shaped.	Amano (2011, 112)
LM1s	Lingual margin. Caudal end more elongated.		Higham et al. (1980); Piper et al. (2012)

Figure 5-6 *Cuon* (dhole) lower right mandible. Note the absence of an M3, one cusp on the talonid of the M1, and simpler morphology of cusps. Image from Cranbrook (2014 Figure 12.1a).

Figure 5-7 *Cuon* (dhole) upper left maxilla. Note single cusp on UM1 protocone and generally simpler cusp morphology. Image from Cranbrook (2014 Figure 12.2b).

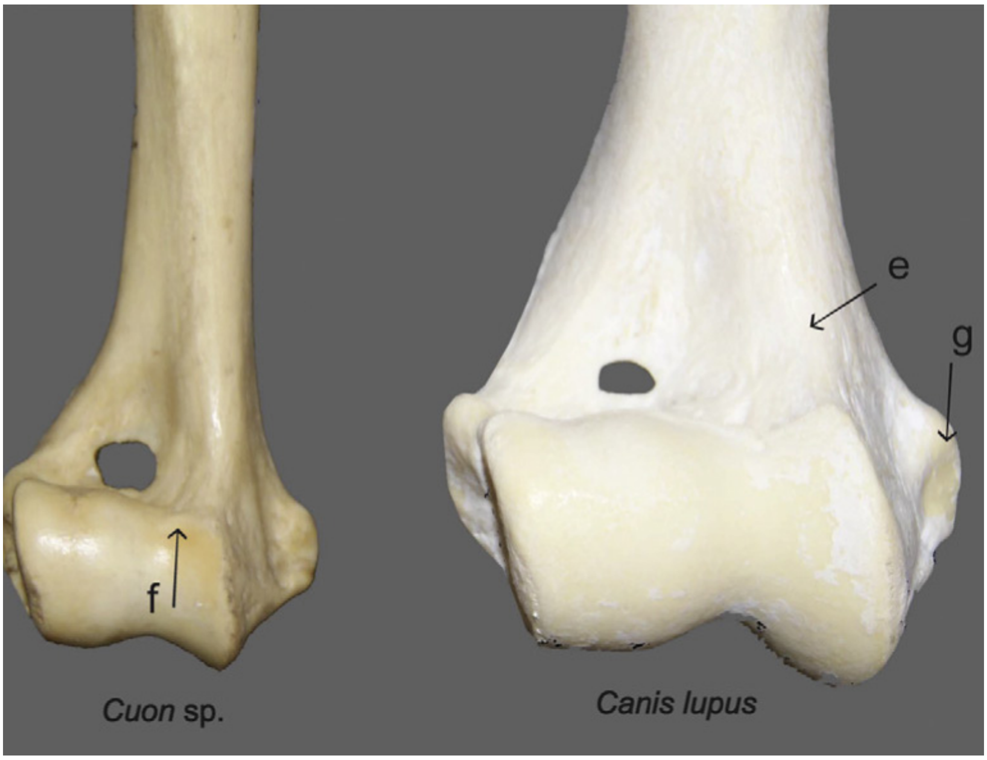

Figure 5-8 Distinguishing morphological differences between *Cuon* and *Canis* in the distal humerus. See Table 5-5 for explanation of features. Image from Pionnier-Capitan et al. (2011, 2127, Figure 2).

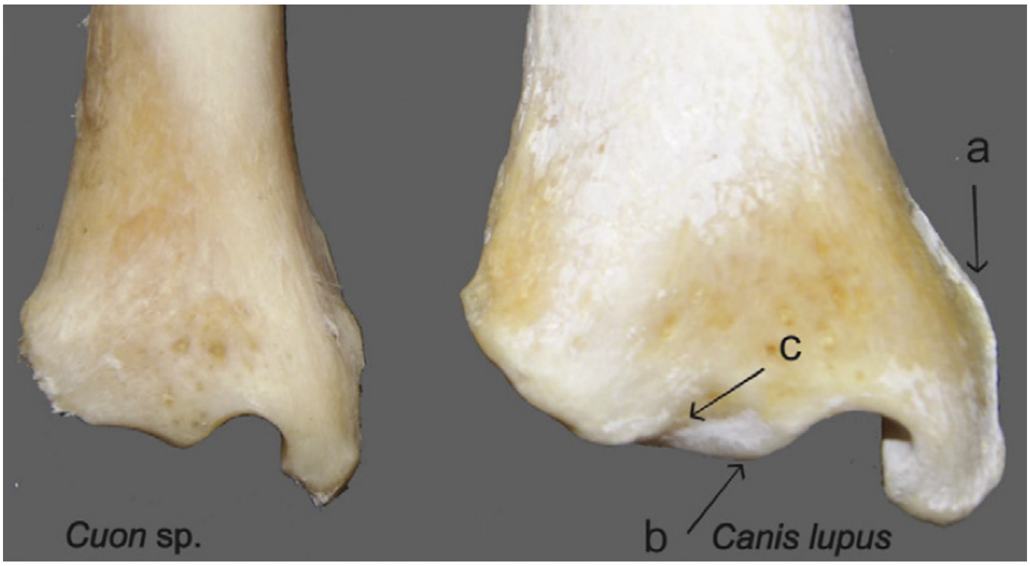

Figure 5-9 Distinguishing morphological differences between *Cuon* and *Canis* in the distal tibia. See Table 5-5 for explanation of features. Image from Pionnier-Capitan et al. (2011, 2129, Figure 4).

Chapter eight, 8.5). In regards to jackals, according to Higham et al. (1980, 157) the LM1 on *Canis aureus* (Golden jackal) has a small extra tubercle on the lingual margin and the innermost lingual tubercle is longer. Piper et al. (2012) observed that when viewed from above the caudal end appears more elongated in jackals than in dogs.

In upper dentition, Piper et al. (2012) point out the UM1s in dogs are broader in the labial-lingual direction. Amano (2011, 112) also adds the paracone and metacone are extremely elongated in jackals. This creates a rhombus shape (squashed square) in jackals while wolves and dogs have a more oval-shaped UM1.

For specific details on what elements were identified as domestic dog in the MB assemblage see Chapter seven, section 7.4.7. Distinction between the grey wolf and the dog was based on biometric differences in size between the species. Measurements of Canidae teeth and postcrania were compared to archaeological and modern data, see Chapter eight section 8.5 for more details.

5.7.4. Deer antlers

Different genera of deer can sometimes be distinguished based on morphological and metrical size differences in antlers (Jin 2010; Piper et al. 2012). Unfortunately, the high fragmentation of deer antlers in the assemblages made morphological differentiation difficult. However, there was a distinct difference in size in some specimens which made distinguishing between *Cervus* and *Muntiacus* possible. See Chapter six, section 6.4.10 for more details.

5.8. Taxonomic structure and composition of Cồn Cổ Ngựa and Mán Bạc

The aim of measuring the taxonomic structure and composition is to compare the faunal assemblages between different sites, time periods, and/or geographic locations. These comparisons allow questions such as; do the faunal assemblages differ and if so, how, and why? Lyman (2008, 172) notes the ‘why’ question leads to the ultimate question; is the change or pattern within the assemblages caused by human behaviour or the environment? The methodology used largely follows Lyman (2008).

5.8.1. NTAXA and taxonomic 'richness'

One of the simplest ways of comparing assemblages is to compare the number of species/taxa within an assemblage, this is also known as species richness. NTAXA is used in Chapter eight to compare CCN and MB with other sites in SEA, as this technique gives an indication of whether sample size (NISP) has an effect on the number of taxa identified in the assemblage.

When calculating the NTAXA Lyman (2008, 174) emphasises the same taxonomic level (such as species, genus, family) needs to be used otherwise the same taxon may be counted twice. One of the potential issues with counts of NTAXA is that it is often affected by sample size (Grayson 1984; Lyman 2008). This can be easily checked by a comparison of the NISP versus NTAXA per assemblage. There are a number of potential avenues the researcher can explore if sample size is found to be a problem. One of them is rarefaction, however as Grayson (1984, 152) and Lyman (2008, 190) point out this method was designed to be used with quantification units that are statistically independent of one another. Whether one can use rarefaction based on NISP or NTAXA values is therefore questionable.

5.8.2. Taxonomic composition

There are a number of indices that have been developed in ecology to analyse what comprises a taxonomic assemblage. Two sites may have the same NTAXA but may not share any of the species within the assemblage. Three different indices were used to specifically compare the assemblage between CCN and MB at the genera level. Following Lyman (2008, 186):

The Jaccard index emphasises differences between faunas:

$$J = 100C / (A + B - C)$$

The Sorenson index emphasises similarities:

$$S = 100(2C) / (A + B)$$

In both the above examples:
A = NTAXA in assemblage A
B = NTAXA in assemblage B
C = NTAXA in common to both assemblages

The adjusted Sorenson index was also calculated to take into account variation of taxonomic abundance (Lyman 2008, 189):

$$Sq = 2CN / (AN + BN)$$

AN = ∑ of NISP in assemblage A
BN = ∑ of NISP in assemblage B
CN = ∑ of lesser of the two abundances of taxa shared between assemblages. For instance, if CCN has a NISP of 14 *Bos* and MB has 11, then 11 is used.

The answer is then multiplied by 100 for easier comparison to the previous indices. For the previous two indices NTAXA of genera were compared between CCN and MB. Since the adjusted Sorenson index relies on NISP values the comparison was made only between mammalian genera.

5.8.3. Taxonomic heterogeneity

The Shannon-Wiener index was used to compare the taxonomic heterogeneity between CCN and MB following Lyman (2008, 192). Heterogeneity is the summary measure of the relative (proportional) abundances of taxa. The index usually varies between 1.5 to 3.5; the larger the value, the greater the heterogeneity (Lyman 2008, 192).

$$H = - \sum [(P_i) * \ln(P_i)]$$

P_i = proportion (P) of a particular taxon/species (i) in the assemblage
ln = natural log
-∑ = (minus) total NISP

As Lyman (2008, 192) notes because proportions are <1, transforming them into natural logs results in negative values. The sum is converted back into a positive value by the minus (-) sign in front of the summation of the total NISP.

5.8.4. Taxonomic evenness

Taxonomic evenness is usually calculated alongside the heterogeneity index because this is influenced by both taxonomic richness, and evenness, and potentially sample size (Lyman 2008, 192). It allows the assessment of whether taxa are relatively evenly spread across the assemblage or whether the assemblage is dominated by a particular species. This index is constrained to fall between 0 and 1, with a value of 1 indicating all taxa are equally abundant. Evenness is calculated as:

$$e = H / \ln S$$

H = Shannon-Wiener index
ln = natural log
S = NTAXA

Lyman (2008, 201, 211) offers a final word of caution for the use of these indices. He emphasises they were developed from ecology using ‘real’, live animals rather than NISP. Since NISP is not an independent measure of unit caution is needed when interpreting the results. These indices should be interpreted as ordinal scales.

5.8.5. Statistical measures: chi square analysis

Neither the Sorenson nor Jaccard index takes into account the abundance of taxa. A simple way to assess the similarity of taxonomic abundance between two assemblages is to calculate a χ^2 analysis (Broughton et al. 2006; Lyman 2008, 187). The NISP of mammalian genera of CCN and MB were compared using χ^2 and Spearman’s tests to determine whether the assemblages were statistically significantly different. The correlations table produced during the χ^2 analysis and the adjusted residuals can then be used to compare observed versus expected abundances of fauna, and whether there is a statistically significant difference between particular fauna (see Lyman 2008, 188). These analyses were performed using the software IDL.

5.8.6. Taxonomic habitat index

To assist in comparison of ecological diversity and palaeoenvironmental reconstruction a taxonomic habitat index developed by Evans et al. (1981) and elaborated in Andrews (1990) was employed. This index is a cumulative value that scores species based on the range and type of habitats they inhabit. It has not been widely applied in archaeology, although some recent examples of its application include Wang (2011) and Rodríguez et al. (2011). The benefit of this method is that it does not rely on relative abundance of taxa and multiple taxonomic levels can be used. In this method, each species is given a maximum score of 1, which is proportionally broken down according to habitat preference (Evans et al. 1981, 102; Andrews 1990, 168). For example, Evans et al. (1981, 102) classified the African elephant as 0.33 forest, 0.33 woodland-bushland, 0.23 grassland, and 0.11 semi-desert. The scores for each habitat are then added together and divided by the total number of species to give an average cumulative index per habitat. This average score can then be used and compared between assemblages or periods to give an approximation of diversity and paleoenvironment. It should be noted that this method is relatively subjective and descriptive in that it relies on current information about the behaviour and ecology of taxa. Thus, although it is a useful general descriptive comparison of assemblages, the results should be treated with a degree of caution. Further, this does not take into account that environmental preference may change over time.

The types of habitats used can be varied according to needs of each researcher. For this study, five habitats were used: 1) dense forests; 2) woodlands; 3) mountainous and rocky environs; 4) shrub and grasslands; and 5) aquatic resources: marshes, riverine, estuarine environs. The rationale for using these five categories was the taxa in both assemblages mainly inhabit these environmental niches, as was determined by consulting the IUCN Red List website (2016) and the Animal Diversity website (Myers et al. 2016) per taxa.

5.9. Multivariate analysis: regional site comparison

One of the aims of this thesis was to conduct a regional meta-analysis of faunal assemblages in SEA in order to contextualise the sites of CCN and MB. The main questions driving this analysis were:

1) **Are there regional patterns in faunal assemblages in diversity or abundance of fauna?**
2) **Is there a perceivable change in faunal composition from assumed hunter-gatherer sites to agricultural sites with domestic fauna?**
3) **How do CCN and MB compare to their wider regional and temporal context?**

A database of sites across SEA was created from published, and some unpublished material (see Chapter nine, 9.4. for more details). Since my main interest was in the relative abundance of fauna between sites with hunted and domesticated fauna NISP was the unit of measure employed. One of the major problems with doing an analysis such as this is that only in relatively recent times do reports include NISP of fauna, rather than simply a list or description of taxa. A further problem is recovery techniques are variable between excavations. In order to enable the best comparison possible, data was limited to mammalian families of medium-large taxa. Hence, taxa the size of *Rattus* were eliminated due to difference in recovery techniques. Reptiles, birds and fish were not analysed because of the need to keep consistency with the unit of measure. For instance, the issue that NISP has of interdependence is compounded in measures of turtles because fragments of carapace and plastron are particularly hard to identify further than 'plastron' or 'carapace' fragment. A report may indicate over 3,000 fragments of turtle bone, but this may represent only one turtle carapace or plastron. Further, there are few sites in SEA where turtles have been comprehensively analysed, which limits the extent to which comparative studies can be undertaken.

5.9.1. Principal component analysis

For PCA, NISP for nine mammalian families were collated for 37 sites. Families that were compared in the PCA analysis were: Bovinae, Suidae, Canidae, Cervidae, Cercopithecidae, Felidae, Viverridae, and Mustelidae (Table 5-6). These families were selected partly to keep the NISP values comparable (see above), and because they are the most common mammalian taxa that appear in SEA faunal assembalges. The square root of each NISP was used in order to help eliminate differences in sample size. During the trial and error process samples that were <100 NISP were eliminated. For Ban Chiang, even though the reported NISP by Higham and Kijngam (1979) was only for square 5, the total NISP was still well over 100. Thus, the decision was made to keep Ban Chiang in the PCA. For the purposes of this analysis, the NISP counts of Pacung and Sembiran were combined as the two sites are contemporary and sit adjacent <400m apart. The final PCA analysis comprised of 32 sites across Asia ranging in age from the Late Pleistocene to the Iron Age (Table 5-6).

The methodology for PCA followed Norman and Streiner (2014). Rotation was performed using varimax (Norman and Streiner 2014, 217). SPSS and JMP were used for explorative phase of PCA and final statistical results were created using SPSS. To create the graphs PAST was used.

Table 5-6 Summary of sites used in PCA analysis. C= cave, R= riverine, R/E= riverine/estuarine, CO= coastal. For location of sites see Figures 3-2, 3-4, and 3-5 in Chapter three.

Site	Country	Site type	Period	Reference
Hang Boi	Vietnam, Ninh Binh	C	Hoabinhian	Rabett et al. (2011)
Lang Trang	Vietnam, Thanh Hoa	C	Upper Pleistocene	Vu The Long et al. (1996)
Niah Cave-Lobang Hangus	Malaysia, Borneo	C	Terminal Pleistocene	Piper et al. (2008b)
Niah Cave- West Mouth	Malaysia, Borneo	C	Terminal Pleistocene	Piper et al. (2008b)
Braholo Cave	Indonesia, Java	C	Late Pleistocene – Early Holocene	Amano et al. (2015)
Laang Spean	Cambodia	C	Hoabinhian	Forestier et al. (2015)
Dingsishan	China, Guangxi	R	Early Holocene	Zhang and Hung (2012, 20); Lu: (2010, 98)
Zhongri	China, Upper Yellow River	R	Mid Holocene	Flad et al. (2007, Table 1)
Qinweijia	China, Upper Yellow River	R		
Dahezhuang	China, Upper Yellow River	R		
Jiangzhai	China, Wei River	R		
Baijiacun	China, Wei River	R		
Kangjia	China, Wei River	R		
Miaozigou	China, Arid north	R		
Shihushan	China, Arid north	R		
Dabagou	China, Arid north	R		
Zhukaigou	China, Arid north	R		
Karuo	Tibet	R		
Xipo	China, Henan	R		Ma (2005)
Wayaogou	China, Wei River	R		Wang (2011)
Con Co Ngua	Vietnam	R/E		This study
Man Bac	Vietnam	R/E		This study
An Son	Vietnam, Mekong delta	R/E		Bellwood et al. (2011)
Rach Nui	Vietnam, Mekong delta	R/E		Oxenham et al. (2015)
Ban Lum Khao	Thailand, Khorat Plateau	R		Higham and Thosarat (2004a, 160)
Khok Phanom Di	Thailand, Gulf of Thailand	CO		Grant & Higham (1991); West (1991)
Non Nok Tha	Thailand, Khorat Plateau	R		Higham (1975b, 125, 135)
Ban Non Wat	Thailand, Khorat Plateau	R		Kijngam (2010, 189)
Ban Chiang	Thailand, Khorat Plateau	R		Higham & Kijngam (1979, Table 1, NB this NISP is only for square 5)
Phum Snay	Cambodia	R	Late Holocene	Voeun (2008, 8, 22, and appendices)
Nagsabaran	Philippines	CO	Mid–Late Holocene	Amano (2011, 55)
Pacung & Sembiran	Indonesia, Bali	CO	Late Holocene	RKJ data; (Fenner et al. 2017)

5.10. Radiocarbon dating

Radiocarbon dating was an essential aspect to the project for two reasons. Firstly, the dating of CCN was reliant on relative dates based on ceramic and lithic typologies. This made it necessary to attempt accurate scientific dating. Based on previous attempts to radiocarbon date human skeletal material, as well as attempts undertaken in this study, no collagen was preserved in the bone (see 5.10.1. below). There was also a lack of other well-associated archaeological material, such as charcoal. Although shell was available there are numerous complicated issues with dating shell in limestone environments (see 5.10.4.). Thus, it was necessary to radiocarbon date enamel from human and animal teeth. The pretreatment, radiocarbon analysis, and calibration of dates were carried out by the author (RKJ) under the guidance of Dr Rachel Wood at the Australian National University (ANU) Radiocarbon Laboratory in the Research School of Earth Sciences (RSES).

The issues with enamel dating are covered below (in 5.10.3.), the main problem is that enamel dates tend to be younger than collagen dates (Zazzo and Saliège 2011). However, this appears to be less significant for Mid and Late Holocene sites than Pleistocene sites (Zazzo 2014, 168, 173). Within the context of the Mid Holocene in northern Vietnam, a couple hundred years 'too young' would not significantly effect interpretation of the chronology of CCN. As outlined below (5.10.3.), the dates for CCN should be treated as minimum ages. The purpose in dating CCN was to determine the relative age of CCN compared to MB, hence, to demonstrate that CCN is significantly older.

Secondly, collagen dating on select dog (*Canis familiaris*) and pig (*Sus scrofa*) bone from MB was performed. For the dogs it was clear based on morphological criteria (outlined in section 5.7.3) that they represented domesticated animals. The domesticated status of the pigs in the assemblage was less certain but this thesis argues they were in the early stages of domestication (see Chapters seven, eight and eleven). Thus, it was essential to date the dogs and pigs using collagen in order to securely pin a date for the introduction of domesticated animals into northern Vietnam.

5.10.1. Nitrogen percentage test

The N% is a proxy for how much collagen is left in the bone and whether ^{14}C dating will be successful (Brock et al. 2010; 2012). This is because the majority of nitrogen in bone and dentine is found in collagen, which is the protein targeted for dating. A good N% is considered to be >0.7% and borderline between 0.5–0.7%, however, this can be extended to 0.2% if the date of the sample is particularly important (Brock et al. 2012, 885–86; Rachel Wood 2014, pers. comm.). Eleven CCN and 26 MB samples were tested. Samples were drilled with a Dremel variable speed drill to extract approximately 2 mg of powder from bone or dentine.

The untreated powder was weighed into tin capsules and nitrogen content measured in a Sercon 20–22 isotope ratio mass spectrometer connected to an ANCA GSL elemental analyser operating in continuous flow mode at RSES, ANU. An in-house gelatine reference was used, and data were compared to an in-house bone and alanine standard.

The CCN samples all failed the N% test with 0.0%N (Appendix 1). This is not unusual for arid and tropical regions as the protein degrades rapidly (Nielsen-Marsh and Hedges 2000; Collins et al. 2002; Hedges 2002). Two MB samples passed with good N% (>0.7%) and several were borderline (0.2-0.7%; Brock et al. 2012). Based on the N% test, four samples from MB were selected for dating. As collagen was not preserved in the CCN samples, 15 samples of faunal and human enamel and calcined deer antlers were selected for dating. See Appendix 1 for results of N% test.

5.10.2. Radiocarbon dating Mán Bạc samples using collagen

Extracting collagen for ^{14}C dating followed standard pretreatment procedure of Brock et al. (2010). This consists of a series of acid and base washes to remove carbonates and base-soluble organics prior to gelatinisation, filtration, and ultrafiltration to dissolve the protein and remove large insoluble and small soluble contaminants. Subsequently, collagen was combusted in a sealed quartz tube with copper oxide wire and silver foil, and the resulting carbon dioxide collected and purified cryogenically prior to conversion to graphite in the presence of hydrogen over an iron catalyst (Fallon et al. 2010). Finally, the samples were placed into a NEC single stage AMS at RSES, ANU (Fallon et al. 2010). All dates have been normalised against $\delta^{13}C$ measured by AMS and calculated according to Stuvier and Polach (1977).

Collagen quality was assessed by measuring carbon and nitrogen stable isotopes on a second aliquot of the collagen in an isotope-ratio mass spectrometer (IRMS, cf. %nitrogen equipment). Van Klinken (1999) gives what is considered adequate quality (>1% yield, CN 2.9-3.5, %C >30%, reasonable stable isotopes for fauna/ environment).

5.10.3. Radiocarbon dating CCN samples using enamel

Due to the failure of the N% test and lack of other well-associated materials (such as charcoal), dating enamel was the last viable option for ^{14}C analysis. Although there was an abundance of shells at CCN, there are two major issues that complicate the reliability of dating gastropod shell: the 'limestone problem' and open-system feeding behaviour (Goodfriend and Stipp 1983; Pigati et al. 2013). The 'limestone problem' was outlined by Goodfriend and Stipp (1983). Their study showed results that were highly variable and up to 3,120 years too old even within the same species of shellfish. It was hypothesised that the feeding behaviour of terrestrial gastropods is responsible for the incorrect results. Gastropods are known to ingest limestone when moulding their shells, although some smaller species of gastropod appear to not ingest limestone even when living in carbonate environments (Pigati et al. 2013, 116). The ingested limestone can result in ^{14}C ages that are too young or old depending on the age of the additional carbon contaminants (Goodfriend and Stipp 1983; Pigati et al. 2013).

The potential issue with dating enamel is that the dates may be affected by carbon contaminates and few studies have attempted to understand the degradation process (Zazzo and Saliège 2011; Zazzo 2014). Dates resulting from enamel tend to be 100s–1000s of years younger than collagen dates (Zazzo and Saliège 2011). Currently, pretreatment involves a series of acid washes after the surface is removed by abrasion but it is clear that this method does not always remove the contamination (Zazzo and Saliège 2011; Zazzo 2014). A study by Zazzo and Saliege (2011) suggested that enamel dates from arid environments in Africa and the Arabic Peninsula were reliable but several samples from Europe and America suffered from 'younger' dates. In a more recent study, Zazzo (2014, 173) found that enamel samples from Early–Mid Holocene sites were always less than 300 years younger than collagen dates (there was one exception), while Late Pleistocene samples are less reliable as the difference increases the older the sample gets. Zazzo (2014, 168, 173) warned the difference in collagen and enamel dates can start to become significant after c. 8,000–9,000 BP but that it is also quite variable between sites. Where there is a difference in age, the enamel date is always younger.

Haynes (1968) was the first to show that this is the result of two types of contamination: the addition of secondary calcite into the porosity of the bone and the isotopic exchange between bicarbonate ions from the burial environment and carbonate in apatite (enamel). Zazzo and Saliege (2011) suggested that the reason why samples from temperate environments are less favourable to preservation of the geochemical composition is probably because the presence of water in the soil makes isotopic exchange possible. Zazzo and Saliege (2011, 60) and Zazzo (2014, 176) found that carbon-isotopic exchange is a process that affects both enamel and bone. As Zazzo (2014, 176) notes, this is counterintuitive to expectations, as despite enamel being structurally denser than bone this does not provide better protection from carbon isotopic change. It is not understood why this is the case, although, it has been suggested that collagen acts as a barrier to the diffusion of soil biocarbonates into the fossil (Zazzo 2014, 176). As yet, it is not known whether certain parts of the tooth are altered more than others parts, such as, the enamel surface or along micro cracks (Zazzo and Saliège 2011). Wood's (2016) FT-MIR (fourier transform mid-infrared spectroscopy) scan of pig teeth showed contamination along the surface and within micro cracks. This illustrates that it is important to properly clean all surfaces of the enamel, including inside micro cracks, in order to avoid contamination.

Despite these potential issues, the decision was made to attempt enamel dating on the CCN samples as it was the most viable option. The dates obtained from enamel provide the first scientific age for CCN. Crucially, rather than being viewed as a 'date', they should be treated as minimum ages.

5.10.4. Radiocarbon dating Cồn Cổ Ngựa calcined deer antlers

In the absence of other dateable material, deer antler was dated to attempt to provide a direct date and a comparison to the enamel dates. Radiocarbon dating of calcined bone has been attempted before with successful results (Lanting et al. 2001). In theory, calcined bone is structurally more similar to enamel than unburnt bone because when bone is heated to above 600 °C the bioapatite recrystallizes and larger crystal structures are formed (Lanting et al. 2001; Zazzo and Saliège 2011). During the recrystallization process the carbonate content is reduced by about 50% but the origin of the residual inorganic carbon is unclear, it may be partly derived from CO^2 within the environment but more work is needed to test this hypothesis (Zazzo and Saliège 2011). Lanting et al.'s (2001) comparison of dates from charcoal and calcined bone from the same context produced similar results, which suggests the method works. However, Lanting et al.'s (2001) samples were all from temperate northern Europe, and the greater water flow and warmer climate of Vietnam may have an effect in increasing the rate of diagensis (Collins et al. 2002). Like enamel, dates from calcined bone probably represent minimum ages.

5.10.5. Preparation for enamel

Pretreatment followed Zazzo and Saliege (2011) and Zazzo (2014). The surface was cleaned with a drill and attempt was made to remove most of the manganese staining off the surface of the tooth. Approximately 200 mg of enamel was broken off the sample. This was then crushed into a fine powder using an agate mortar and pestle under Milli-Q water. The samples were freeze-dried and treated with 1ml 1M acetic acid/50mg enamel. Two samples were then tested twice with varying amounts of acid to test the robustness of the technique. If the samples returned greatly varying ages this would indicate that something is wrong with the technique.

5.10.6. Pretreatment for calcined antlers

The calcined portion of the antler was distinguished from burnt antler by FTIR (fourier transform infrared spectroscopy) undertaken at RSES. Both samples had a splitting factor of between 5.2–6.9 and a C/P ratio of <0.1 (Olsen et al. 2008, 791–800). Samples were pressed into pellets with dry potasssium bromide, and measured on a Bruker Tensor 27 operating in transmission mode, 100 scans were undertaken at 4cm^{-1} with a resolution between 400–4000 cm^{-1}. After FTIR had identified the calcined areas, the surface of the calcined antler was cleaned using a low speed Dremel drill. To obtain the sample, approximately 1 g of white and/or light grey calcined material was removed from the antler using the Dremel drill.

The samples were treated to approximately 10 ml 1.5% sodium chlorite at pH3 for 48 hours, followed by 1 M acetic acid, 1 ml/ 50 mg material for 20 hours in an evacuated (<10^{-2} Torr) Vacutainer^{TM} at room temperature. Cleaned samples were reacted with 85% phosphoric acid in an evacuated VacunatinerTM and the carbon dioxide generated treated as the CO^{2} from combusted collagen.

5.10.7. Calibration of dates

The software used was OxCal version 4.2 (Bronk Ramsey 2009) and calibration curve IntCal 13 (Reimer et al. 2013). Radiocarbon dates that are calibrated are followed with “cal. BP”.

5.11. Summary of Chapter five

In summary, this chapter detailed the various methodologies used throughout the thesis. This included: excavation and recovery techniques, taphonomic analyses, taxonomic identification, quantification, statistical analyses, and radiocarbon dating. The majority of the zooarchaeological analyses used are traditional techniques largely based upon the work of Lyman (1994b; 2008). However, due to the scarcity of detailed zooarchaeological research in Vietnam this work is crucial. The more experimental side of analyses included the enamel and antler radiocarbon dating, which was necessary due to the lack of collagen in skeletal material. Further, the regional meta-analysis of faunal assemblages is a technique that has yet to be applied in SEA. The main biases affecting the data set was the availability of material and comparative collections in Vietnam, which restricted the taxonomic identification and the amount of material that was feasible to analyse.

CHAPTER SIX
TAPHONOMY AND TAXONOMY: CON CO NGUA

6.1. Introduction

This chapter provides a detailed taphonomic and taxonomic analysis of the vertebrate remains from the 2013 excavation of CCN.[1] The assemblage count and distribution is detailed first, which compares the spatial and temporal concentration of faunal remains. This is followed by a detailed taphonomic analysis covering the various post-depositional taphonomic influences that have affected the assemblage. The third section details the species recorded, compares their relative proportions, and provides a thorough description of the environmental niches each taxon inhabits to build a picture of the paleoenvironment and subsistence strategies of the inhabitants at CCN. This also includes body part representation and ageing profiles for *Sus* cf. *scrofa*, Cervidae, and Bovinae.

6.2. Assemblage count and distribution

A TNF of 9557 bone fragments were excavated from the 2013 excavation of CCN (Table 6-1). Within this count, 7019 fragments were attributed to a specific layer, 3959 to burials, and 2272 to a feature. The total number of unidentified bone fragments that could not be attributed to taxa or skeletal element (UNID) was 3972. The number of bones that could be identified to taxa or skeletal element (NISP) was 5753, or only counting identifiable taxa gave a NISP of 5585.

Table 6-1 TNF and NISP counts for the assemblage.

Totals	TNF	% TNF
TNF	9557	100.00
UNID	3972	41.56
NISP taxa	5585	58.44
NISP taxa/element	5753	60.20

Table 6-2 Distribution of TNF across layers.

Layers	TNF	%TNF
LI	180	2.56
LII	3565	50.79
LIII	3270	46.59
LIIII	4	0.06
Total	**7019**	**100.0**

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[1] Note, this analysis does not cover the sieved fraction, which should be taken into account when discussing fragmentation size and taxonomy. Reasons for not including the sieved fraction are discussed in Chapter five section 5.2.2.

In terms of distribution of bone fragments, the majority of the bones were recovered from Layer 2 (3565, 50.79%) and Layer 3 (2370, 46.59%; Table 6-2, Figure 6-1). Within Layers 2 and 3 there are three main spikes in faunal accumulation: Layer 2 spit 4, Layer 3 spit 1, and Layer 3 spit 2 (Figure 6-2).

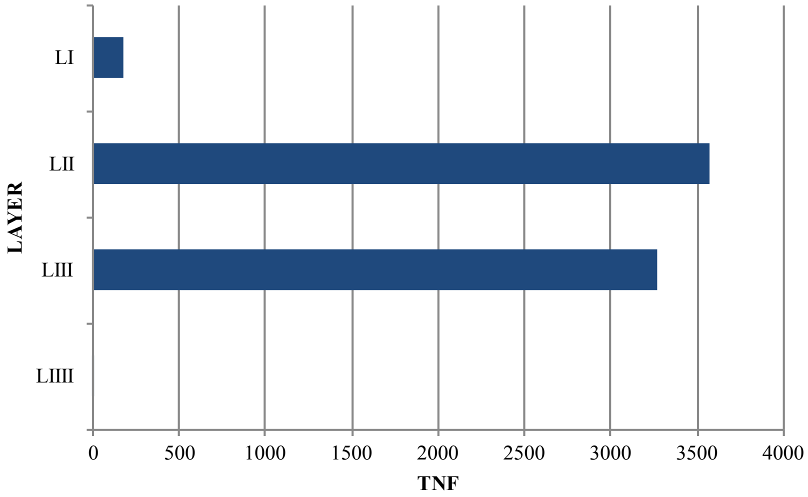


Figure 6-1 Distribution of TNF per layer, the vast majority of fragments come from Layer 2, followed by 3. TNF = 7019.

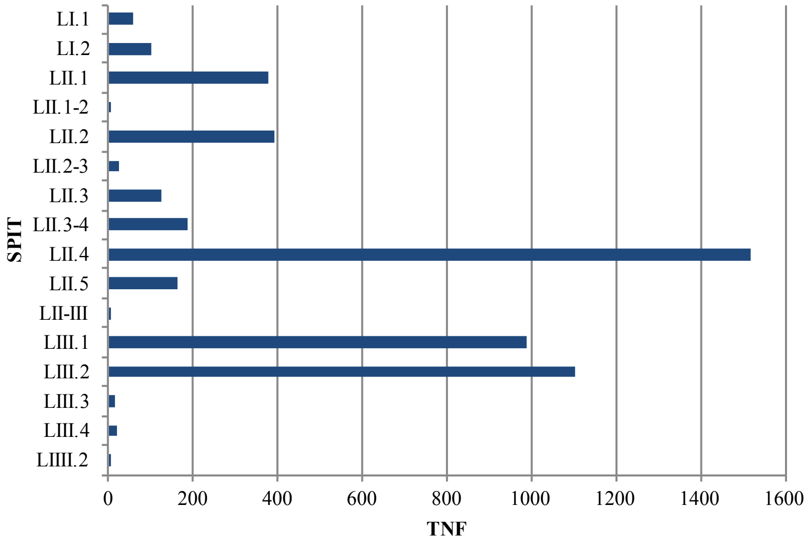
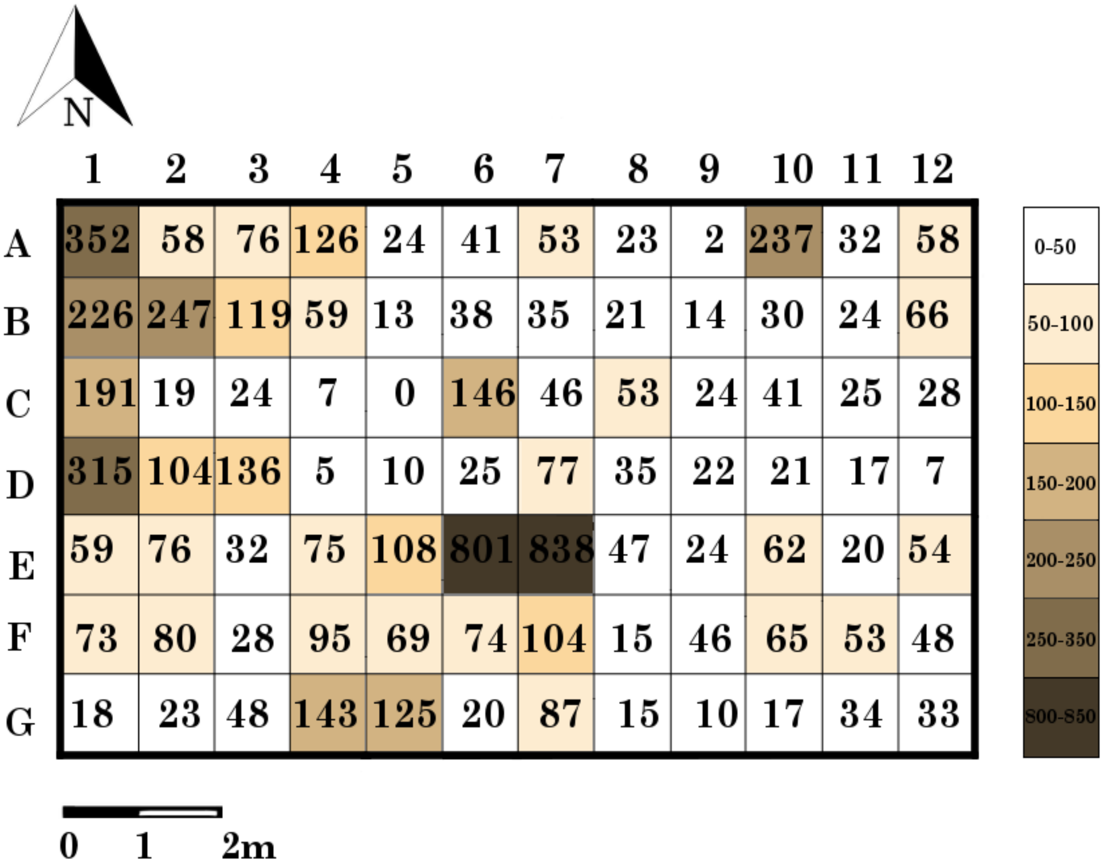


Figure 6-2 TNF per spit. NB: this was problematic as some artefacts were only recorded per layer and not spit. TNF = 6118.

6.2.1. Spatial analysis

It was difficult to perform a proper spatial analysis of the site due to the differential recording techniques employed by various recorders mentioned above. For instance, some bags only had the layer and spit recorded (2201 fragments) or had multiple square numbers (such as A–G 1). However, an attempt was made to combine square, burial, feature, and spit information to gain an idea of the main areas of concentration of fragments (Figure 6-3). Where multiple squares or burial numbers were noted the number was averaged across squares. For example, if the TNF for squares A1–2 was 20, a count of 10 was assigned to each square. An initial attempt was made to divide the faunal remains into each layer, but due to the discrepancy between the recording methods this became too subjective. Hence, it was necessary to combine all layers into one complete picture of the faunal concentrations across the site. The total TNF data used in Figure 6-3 is 6871 (71.89%), which means that 2686 fragments were not able to be used due to lack of information. Although, this should be taken with a degree of caution, there are some overall trends that can be discerned. The highest concentration of faunal remains comes from squares E6–7 (TNF = 1595), due to a deposit of calcined deer antlers in Layer 3 (Feature 43). These fragments of antlers were found both above and below burial M133 and were recorded as being part of Feature 43. Aside from this special deposit, the main concentration of bone fragments was in the northwest corner of the square.

Based on the distribution of human remains, Marc Oxenham and Anna Willis (pers. comm.) have stipulated that the trajectory of the adjacent stream may have moved its course throughout antiquity. According to Oxenham and Willis (2016, pers. comm.) the



	1	2	3	4	5	6	7	8	9	10	11	12
A	352	58	76	126	24	41	53	23	2	237	32	58
B	226	247	119	59	13	38	35	21	14	30	24	66
C	191	19	24	7	0	146	46	53	24	41	25	28
D	315	104	136	5	10	25	77	35	22	21	17	7
E	59	76	32	75	108	801	838	47	24	62	20	54
F	73	80	28	95	69	74	104	15	46	65	53	48
G	18	23	48	143	125	20	87	15	10	17	34	33

Figure 6-3 TNF per square taking into account burials and features.

stream is evident only on the top layer of the site and it did not affect the lower layers (Figure 6-4). The spatial distribution of the faunal remains seems to largely mirror this pattern, as there is a general paucity of faunal remains in the southeast corner (Figure 6-5). Further, the concentration of faunal remains in the middle and northwestern side of the square are mainly from the lower layers. This indicates that the changing course of the river may have affected the presence of faunal remains in the upper layers to a certain extent, especially the lighter fragments. However, one of the interesting differences between the burial and faunal distributions is the northwest corner (A1), where there are minimal burials but a relatively high NISP of animal bones.

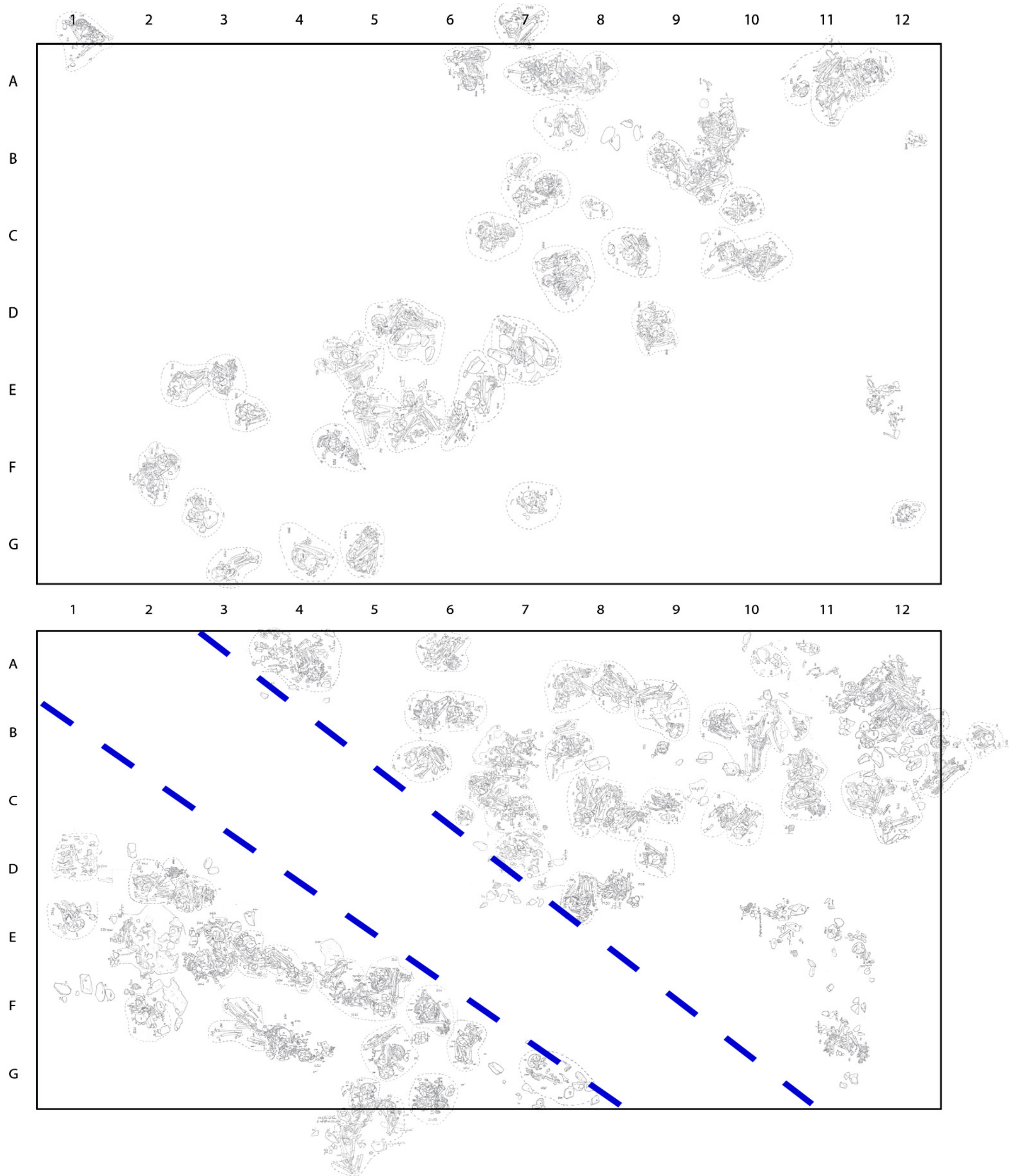


Figure 6-4 Top: lower burial layers, the burials were in a roughly NE/SW direction. Below: top burial layers, the stream running diagonally NW/SE through the site is approximated in dotted lines. Images courtesy of Anna Willis.

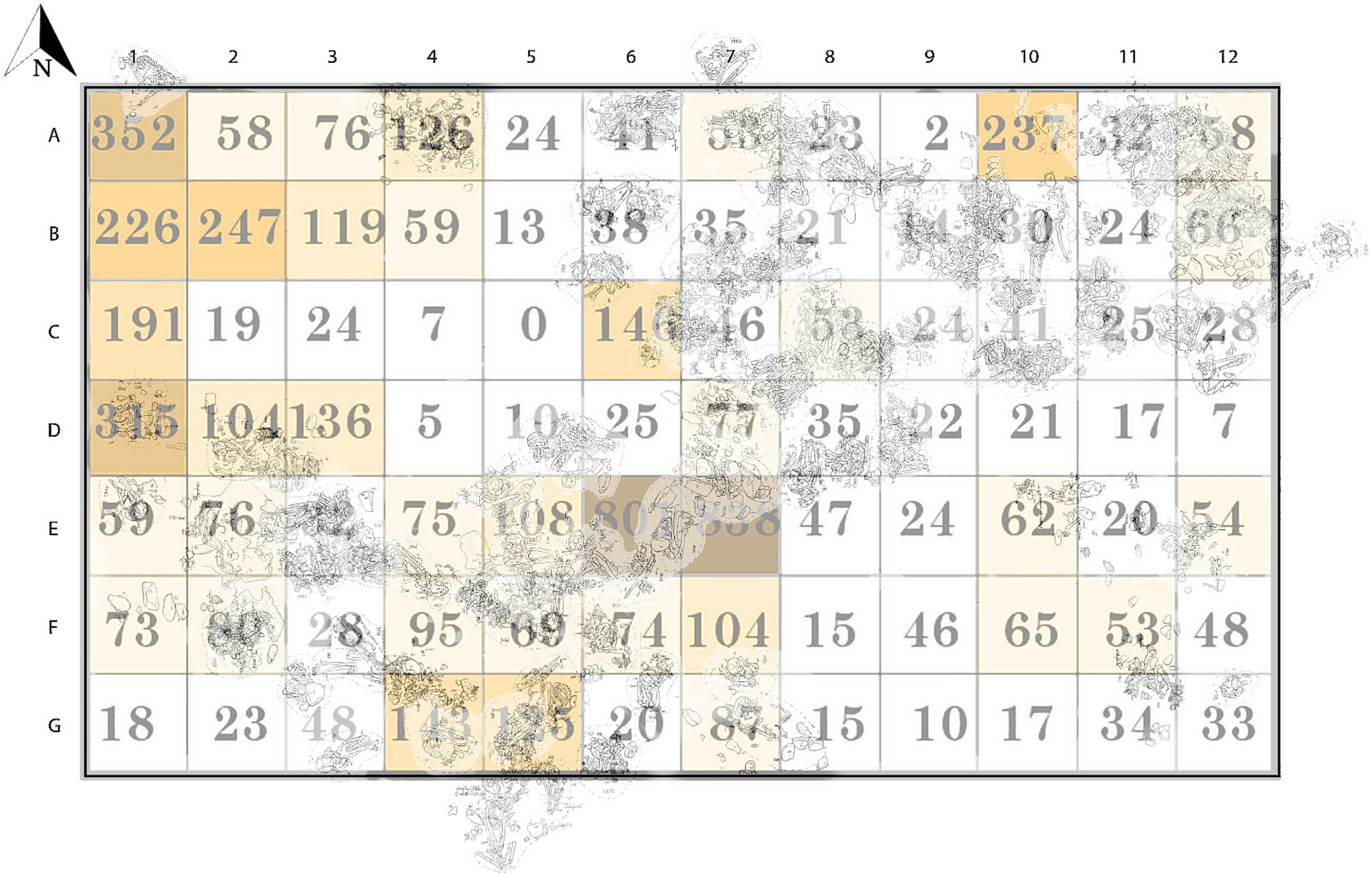


Figure 6-5 Overlay of upper burial layer and faunal distribution, the direction of the stream is evident.

6.3. Taphonomy

6.3.1. Fragment size and preservation of bone

Excluding the sieved fraction, the majority of the fragments were between 0–50 mm in size (TNF 7865, 82.38%, Table 6-3). There were 127 fragments of bone over 10 mm, of which by far the largest was a whale radius 90 cm in length and 16.3 kg. The entire weight of the faunal assemblage was 69.8 kg, including the whale radius.

The bone fragments were generally quite robust and well preserved. A complete left carpus of Bovinae sp. (Layer 2 spits 3–4, under M44; Figure 6-6) and a partial vertebral column of *Varanus* sp. (Layer 2 spit 3 A10) suggest that some skeletal portions were still partially articulated when they were discarded. It also indicates that at least in some areas of the site, there was little displacement of remains after deposition.

The fragmentation ratio was determined following Lyman (2008, 251–2) by comparing the NISP:MNE values per skeletal element for bovids, deer, and pigs (see section 6.4.1. below for NISP and MNE). This ratio gives a measure of fragmentation intensity, where higher ratios suggest smaller fragments. The taxon and skeletal element with the highest fragmentation ratio was deer antlers with a ratio of 19.4 fragments per complete element (Table 6-5), which is dominated by the deposit of calcined deer antlers in Layer 3 previously mentioned. Ignoring this feature, overall skeletal elements of bovids (Table 6-4) have a higher degree of fragmentation compared to those of deer or pigs (Tables 6-5 and 6-6). Further, the type of elements with higher fragmentation differs between the three taxa. Bovid and pig mandibles have a much higher fragmentation ratio than deer, and bovid humeri are also comparatively more fragmented.

Table 6-3 Fragmentation categories in assemblage.

Size (mm)	TNF	%TNF
0–50	7865	82.38
50–100	1554	16.28
100–150	108	1.13
150–200	18	0.19
200–250	1	0.01
900	1	0.01
Total	**9547**	**100.00**

Figure 6-6 A complete left carpus of Bovinae sp. photographed in anatomical position (Layer 2 spits 3–4, squares A–B 3–4, under burial M44). Mn staining is visible on the surface of the bone. Scale = 4 cm.

Table 6-4 Fragmentation ratio for Bovinae.

Element	NISP	MNE	NISP:MNE
Humerus	8	2	4:1
Mandible	16	4	4:1
Pelvis	6	2	3:1
Tibia	15	7	2.1:1
Radius	16	8	2:1
Femur	4	2	2:1
Metapodials	43	23	1.9:1
Phalanges	86	49	1.8:1
Scapula	3	2	1.5:1

Table 6-5 Fragmentation ratio for Cervidae.

Element	NISP	MNE	NISP:MNE
Antler	97	5	19.4:1
Femur	11	4	2.75:1
Humerus	7	4	1.75:1
Metapodials	39	23	1.7:1
Tibia	10	6	1.67:1
Radius	3	2	1.5:1
Mandible	3	2	1.5:1
Phalanges	61	42	1.5:1
Ulna	4	3	1.3:1
Scapula	1	1	1:1
Pelvis	3	3	1:1

Table 6-6 Fragmentation ratio for Suidae.

Element	NISP	MNE	NISP:MNE
Mandible	5	1	5:1
Metapodials	8	6	1.3:1
Phalanges	11	10	1.1:1
Humerus	1	1	1:1
Ulna	1	1	1:1
Femur	1	1	1:1
Tibia	1	1	1:1

6.3.2. Weathering, abrasion, surface staining

The majority of the bone fragments were recorded as stage 1 weathering, meaning the soft tissue has decomposed and the surface shows signs of cracking (TNF 9172, 97.6%; Behrensmeyer 1978, 151). This pattern was the same across taxa, with no difference between unidentified or identified fragment weathering stages. Some pitting caused by abrasion was observed, but it was not common. The majority of the recorded pitting was probably a result of carnivore digestion (see section 6.3.4.). Most of the fragments had angular or sharp breakage lines (TNF 8728, 93.5%), while 542 (5.8%) fragments were recorded with a combination of angular and slightly rounded edges, and only 65 (0.7%) were recorded as having rounded edges (see Chapter five, Figure 5-3 for an example). This contributes to the picture of relatively little post-depositional disturbance of the faunal assemblage.

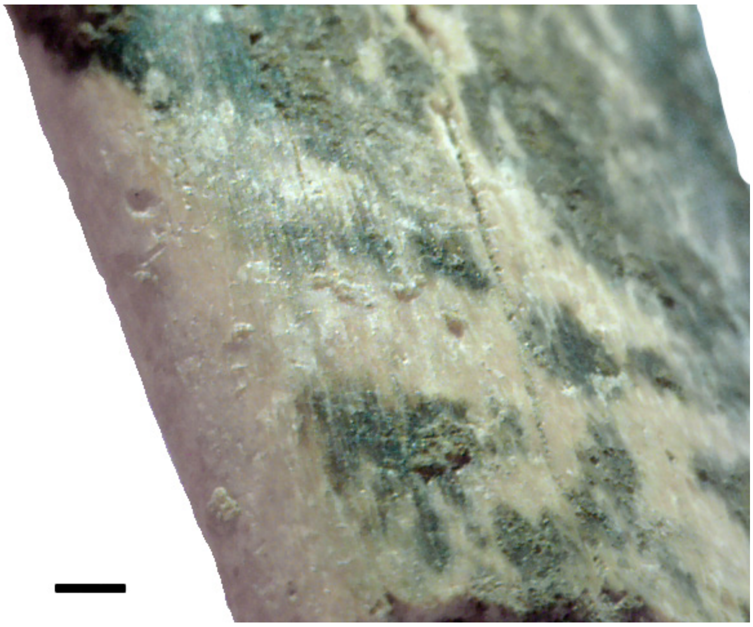


Figure 6-7 Close up of Mn staining on the bone surface of a possibly anthropogenically modified bone (2544, see Table 6-9). Scale = 1 cm.

Surface staining on bones was very common, with a total of 7977 (83.5%) showing signs of staining. The vast majority of this staining was interpreted as manganese oxide (Mn; TNF 7971, 83.4%; see Figure 6-7). The reason for such wide spread Mn staining could be due to a combination of the three factors mentioned previously (Shahack-Gross et al. 1997; López-González et al. 2006; Marín Arroyo et al. 2008; see section 5.3.2.). It is likely that a combination of a wet and decomposing environment surrounded by a bedrock of limestone produced a significant amount of Mn staining on the bones.

In general, these taphonomic factors suggests the vast majority of the assemblage was not exposed to the elements for long and that there was limited post-depositional movement. The high proportion of manganese staining indicates a wet, decomposing environment.

6.3.3. Burning

A total of 2076 (21.7%) bones displayed signs of burning. This figure is dominated by the calcined bone and Cervidae antler fragments associated with burial 133/Feature 43 (TNF 1590, Figure 6-8). At least two different species of deer are represented in this calcined deposit as well as fragments of turtle plastron. It is difficult to determine an MNI of deer for this deposit of antlers due to high fragmentation (Figure 6-7); however, based on size and morphology there is a least one *Muntiacus* and one *Cervus*. Apart from the calcined antler deposit, a total of 386 bones displayed slight to heavy burning and appear to be relatively evenly distributed between Layers 2 to 3.

Figure 6-8 Example of calcined and burnt *Cervus* antler fragments from Feature 43 / burial M133.

6.3.4. Modification by rodents and carnivores

There was some evidence of carnivore and rodent activity but it was surprisingly limited with only 12 specimens showing possible gnawing, bite marks, or digestion marks. A clear example of a carnivore bite mark is on a stork tarsometatarsus (see section 6.4.4., Figure 6-16).

6.3.5. Butchery modifications

There was a total of 68 elements that displayed distinctive evidence of butchery marks and a further 16 ambiguous marks within the assemblage. The majority of the skeletal elements with cutmarks came from Layers 2 and 3, and ten of which were associated with a burial (Figure 6-9). The majority of the butchery marks were on Bovinae skeletal elements, followed by large mammals (Cervidae or Bovinae sized; Table 6-7). For both Cervidae and Bovinae butchery marks are present on all areas of the body, but are concentrated in the extremities (Table 6-8). Astragali received the most cut and chopmarks, while long bone shafts were the only elements recorded with percussion marks.

Table 6-7 Frequency of skeletal elements with butchery marks per taxa.

Taxa	No. of elements
Bovinae	23
Cervidae	8
Cervidae or Bovinae	17
Suidae	3
Mammal UNID	5
Manis	1
Panthera tigris	1
Whale	1
Geoemydidae	3
Fish	1
UNID	4
Total	**67**

For Cervidae and Bovinae, butchery marks on a range of different skeletal elements, high and low meat yielding, suggesting that whole carcasses were being brought to the site and processed (Table 6-8). Although there are limited numbers of butchery marks, there is solid evidence of primary to tertiary processing, and the presence of bone artefacts illustrates that the fifth and final processing stage was taking place. Following Amano et al. (2013, 326) and Rixson (1989):

Primary: Skinning is suggested through cutmarks on phalanges, distal metapodials, and cranial elements, such as the base of the antler or premaxilla (Table 6-8). Cutmarks on the lateral aspect of the tiger mandible are suggestive of skinning (Figure 6-10). Gross dismemberment of the carcass at major joints is indicated by cutmarks to the axis and scapula (Table 6-8). A pig atlas with a single cutmark on the dorsal surface suggests the separation of the skull from the vertebral column.

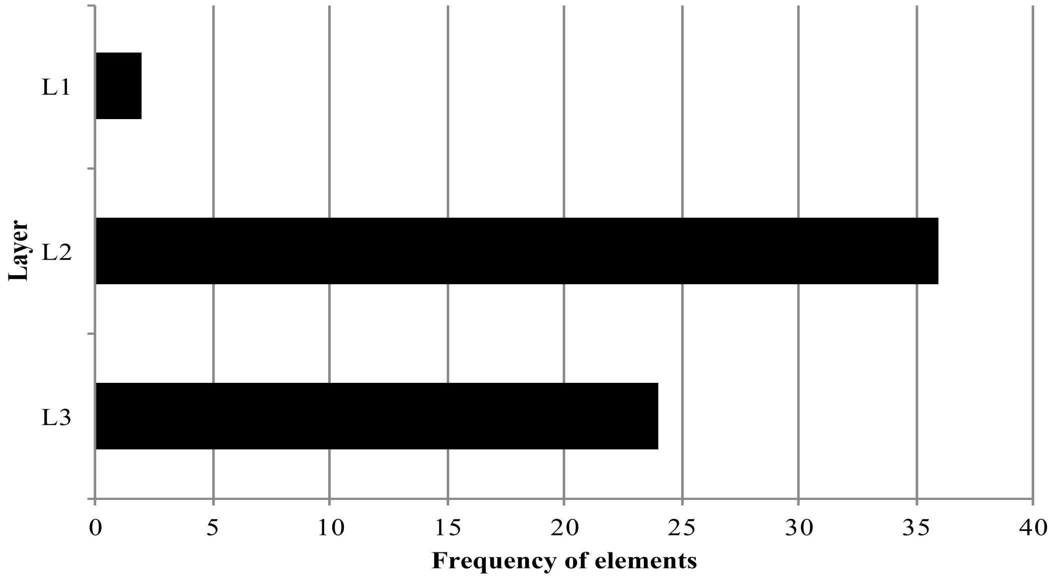


Figure 6-9 Frequency of skeletal elements with butchery marks across layers.

Table 6-8 Placement and type of butchery marks on Cervidae and Bovinae elements.

Cervidae & Bovinae				
Element	**Portion**	**Cutmarks**	**Chopmarks**	**Percussion**
Antler			1	
Premaxilla + maxilla		1		
Scapula	Spinous + glenoid process	1	1	
Radius	Proximal	1		
Ulna	Proximal	1		
	Shaft		1	
Rib	Proximal	2	2	
Axis	Cranial	1		
Lumba	Body		1	
Thoracic	Body		1	
Vertebra	Spinous process	1		
Tibia	Distal	2		
Patella		1		
Long bone	Shaft frags	4	3	4
Astragali		6	2	
Scaphoid		1		
Metacarpal	Proximal	2		
Metatarsal	Proximal	1		
Metapodial	Distal		1	
	Shaft	1		
Phalanx-B		2		
Phalanx-SubT		4		
Phalanx-T	Proximal		1	
Total		**32**	**14**	**4**

Secondary: Disarticulation of units into smaller portions is evident through cutmarks on the proximal and distal aspects of long bones (Table 6-8), as are cutmarks on a pig proximal right ulna and distal left humerus proximal to the lateral condyle of pig elements. A pangolin right ulna had a chopmark on the distolateral shaft, probably intended to separate the lower and upper limb. Also, three fragments of Geoemydidae plastron and carapace had chopmarks through the bone and a fish precaudal vertebra that was calcined had a sagittal chop through the body.

Tertiary: Defleshing is evident through cutmarks to ribs and long bone diaphyses of deer and bovids (Table 6-8). The whale radius was covered in deep cutmarks and chopmarks on all surfaces of the shaft, which may indicate removal of flesh (see discussion section 11.6.5.).

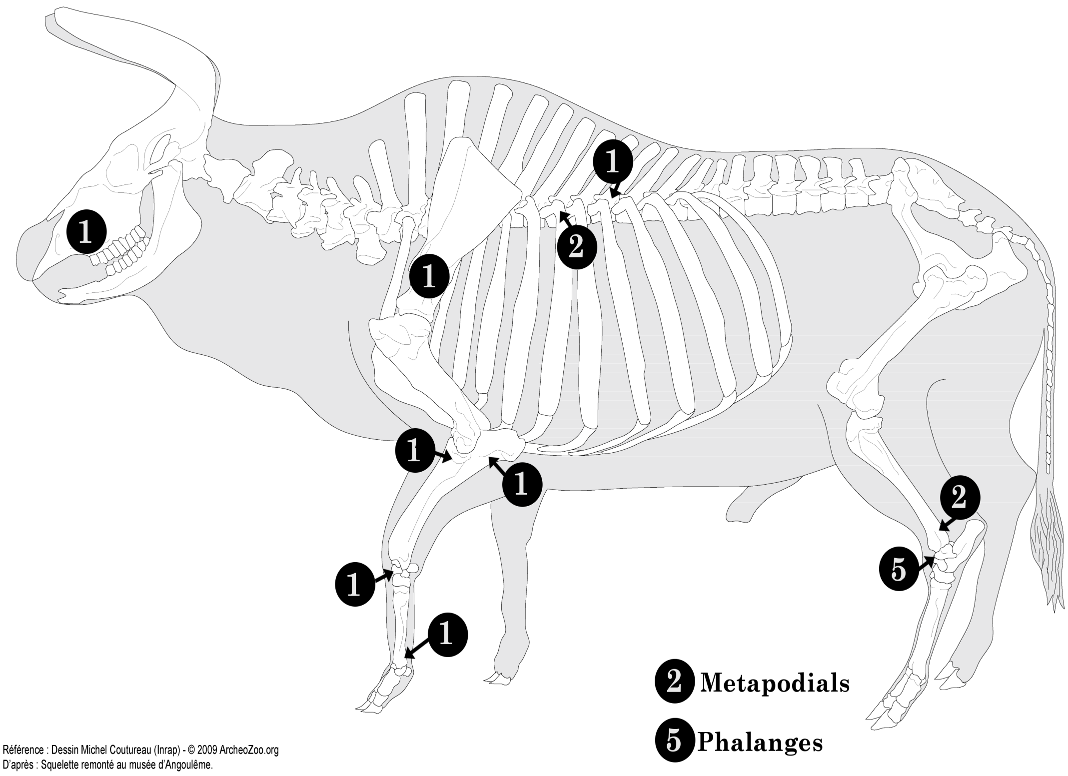
Fourth stage: utilisation for fat extraction is indicated through percussion marks to long bones and split phalanges which suggest marrow exploitation. There are four Bovinae basal phalanges that were broken transversely and two longitudinally, which indicate breakage for marrow (Figure 6-11). One Cervidae basal phalanx was also split longitudinally. Jin (2010, 16, 54, 59 Figure 2.7) found a similar pattern with Bovinae and large deer phalanges from the Early Holocene site of Tangzigou in southwestern China and suggested it was probably the result of marrow extraction. Jin (2010, 93–94) suggested that contrary to OFT expectations phalanges seem to have been processed during times of plenty, perhaps as a special luxury food due to its high content of unsaturated fatty acids compared to other long bones.

Fifth stage: Working of bone is demonstrated through the presence of bone artefacts at CCN. Although it is out of the scope of this thesis to analyse the bone artefacts, there was a total of 14 clear and distinctive bone implements/artefacts (or fragments thereof), and five elements that showed modification potentially relating to artefact production, and two possible modified elements (Table 6-9).

For Bovinae, five astragali displayed cut and chopmarks as well as, five phalanges, two metapodials, one metacarpal, one scaphoid, and two distal tibae (Figure 6-12). The cutmarks on the astragali were all on the medial aspect of the bone. If the intent was to remove the foot from the lower leg, cutmarks on the medial aspects of astragali potentially indicate an inexperienced butcherer, as the ligaments and tendons between the calcaneus head and distal tibia on the posterior aspect need to be severed (Philip Piper 2017, pers. comm.).

Figure 6-10 ***Panthera tigris*** **mandible with two parallel cutmarks on the lateral aspect, on the body of the right side. Specimen ID: 13CCN-339.**

Figure 6-11 Basal phalanx of a *Bubalus* (13CCN-1737) that has been split transversely through the shaft. Distal view (left), dorsal view (right).



Référence : Dessin Michel Coutureau (Inrap) - © 2009 ArcheoZoo.org
D'après : Squelette remonté au musée d'Angoulême.

Figure 6-12 Placement of butchery marks on elements of Bovinae.

Table 6-9 Summary of artefacts and anthropogenically modified skeletal elements in CCN assemblage.

ID CCN-	Context	Taxon	Element	Anth modified	Description
2828	LI.2	UNID		Artefact	Shaped and rounded into a point. Surface appears polished.
65	LII.4 B,C,D1	Mammal large	Long bone shaft	Artefact	Shaft has been rounded at both ends and abrasion/use wear marks are visible at both ends. Polish on both surfaces.
2529	LII M77	UNID	Shaft fragment	Artefact	Similar to 065 but smaller
1843	LII.4 D10	Mammal	Long bone shaft	Artefact	Similar to 065 but smaller. Heavy Mn staining makes it difficult to see abrasion/use wear
1774	LII.1 F29	Medium mammal cf. Cervidae	Long bone cf. metapodial	Artefact	Shaft is split in half longitudinally and rounded and polished on edges. Distal end comes to a narrow point. Abrasions marks visible on surface
2865	LII.1 F26	Cervidae	Distal metapodial	Artefact	Similar to 1774
2866	LII.1 F26	Cervidae	Metapodial, shaft	Artefact	Attaches to 2865
2168	LII.4 M34	Cervidae cf. Rusa	Distal metacarpal	Artefact	Similar to 1774
2493	M53/54	Cervidae cf. Rusa	Left proximal metacarpal	Artefact	Similar to 1774
2749	LII.1 F26	Cervidae	Antler fragment	Artefact	Rounded, deep longitudinal grooves marks on surface, also smaller transverse and oblique marks
1779	M74	UNID Aves?	Long bone shaft	Artefact	Shaped and rounded along the shaft. The pointed end of the shaft has been shaped so there is a V projecting into the shaft, this end was also broken in antiquity. No sign of retouch after the end was broken.
2241	M22/23	UNID Mammal?		Artefact	Deliberately shaped into a roughly rectangular shape and rounded along edges. Bone is very thin. In two pieces.
2259	M22/23	*Sus* cf. *scrofa*	Lower left canine	Artefact	Inner surface has transverse abrasion marks and towards the root end there is a slight notch/groove.
2403	M92	*Leptoptilos dubius*	Proximal tarsometatarsus	Artefact	Abrasions marks and rounding along the shaft
2455	LII M66	Cervidae	Distal metapodial	Modified	Chopped through centre of condyle, small grooves
3135	LII.1 F29	Cervidae	Proximal metapodial	Modified	Probably similar technique to 1774, missing distal shaft

Table 6-9 Continued.

3209	LII.1 F9 B7	UNID		Modified	Abrasion/use wear marks visible
3188	LII.2	UNID		Modified	Clear groove marks on surface
2459	M6	Mammal medium-large	Long bone shaft	Modified	Two parallel grooves running longitudinal to shaft, possible artefact debitage
2544	M68	UNID	Shaft fragment?	Possible modified	Appears rounded and polished, no abrasion marks visible
2029	LI G10	Mammal?	Rib fragment?	Possible modified	Cutmarks on surface, possible debitage

6.3.6. Summary of taphonomy

Analysis of weathering and abrasion show the fauna from CCN is in relatively robust condition. This is in line with the human skeletal evidence, which also shows robust preservation. Modification resulting from the activities of rodents and carnivores is limited. The robust condition of the faunal remains with minimal evidence for rodent and carnivore activity and low weathering stage suggest a relatively quick burial with minimal disturbance or exposure to the elements. Manganese staining is extremely common throughout the assemblage, which is probably a product of a wet and decomposing environment.

Apart from the concentrated calcined deposit of deer antlers, there is minimal evidence for burning in the assemblage. Given the discrete concentration and abundance of these calcined antlers, it is likely they were intentionally deposited. Although the reasons for the deposition are unclear, the potential significance is discussed in Chapter eleven section 11.6.4.

The butchery marks on the faunal remains indicate that a variety of processing stages were occurring at or near the site. These stages range from skinning to producing bone artefacts. Further, the range of skeletal elements with butchery marks suggests that whole carcasses were being processed at or near the site, though the placement of butchery marks indicates considerable attention was paid to the extremities.

6.4. Taxonomy

This section covers the representation and quantification of taxa at CCN. As outlined in the methodology chapter (sections 5.4 and 5.5) the terminology and methods applied largely follow Lyman (2008). Quantification methods of NISP, MNE, and MNI are compared, followed by a discussion of the specific taxa represented and the environmental niches they occupy. Details are given on the criteria for identification of taxa. This is followed by an analysis of body part representation and ageing profiles based on dentition and epiphyseal fusion for pigs, deer, and bovids.

6.4.1. Taxa representation and quantification

From a total of 9557 fragments, 5585 (57.4%) fragments could be identified to at least taxonomic order, or 5753 (60.2%) fragments could be identified to order and/or skeletal element. Mammals dominated with a NISP of 4385 (78.5%), followed by reptiles (NISP 634, 11.4%), fish (472, 8.5%), sharks and rays (64, 1.1%), and birds (30, 0.5%; Table 6-10). In terms of more specific taxa, turtles dominate the NISP, but not the MNE, and they tie in equal first with Bovinae for MNI (Table 6-11).

Table 6-12 displays the complete taxonomic list of species identified in the CCN assemblage. Overall, there is a variety in the taxa recorded, though when comparing the NISP and MNE (Table 6-13 and Table 6-14) it is clear mammals dominate. The MNI is significantly lower for all taxa, which is a reflection of the methodology behind MNI calculations and emphasises the fact that it is very much a *minimum* count. More specific details on each taxon are given below.

Table 6-10 Showing NISP and %NISP of different orders of taxa.

Orders	NISP	%NISP
Sharks & rays	46	8.5
Fish	475	1.1
Reptiles	634	11.4
Birds	30	0.5
Mammals	4396	78.5
Total	**5581**	**100**

Table 6-11 Comparison of NISP, MNE, and MNI of dominant taxa in assemblage.

Taxa	NISP	MNE	MNI
Turtles	557	14	7
Suidae	50	42	3
Cervidae	298	124	5
Bovinae	378	248	7
Total	**1283**	**428**	**22**

Table 6-12 Species list for CCN.

Class	Order	Family	Taxon	Common Name	NISP
Crustacea (Subphylum)				Crabs, lobsters, crayfish	4
Elasmobranchii (Subclass)*				Sharks and rays	26
	Selachimorpha (Superorder)			Sharks	1
	cf. Lamniformes			Mackerel sharks	3
	cf. Orectolobiformes			Carpet sharks	1
	cf. Carcharhiniformes			Ground sharks	8
	Myliobatiformes			Rays	7
Teleostei (Infraclass)				Bony fishes	459
	Siluriformes			Catfish	4
				Perch-like fishes	2
	Perciformes	Serranidae		Basses, groupers	4
		Sparidae		Breams, porgies	4
		Scaridae		Parrotfish	1
	Tetraodontiformes			Ray-finned fishes	1
Reptilia				Reptiles	17
	Testudines			Turtles	119
				Hard-shelled turtles	392
		Geoemydidae	cf. *Cyclemys dentata*	Asian leaf turtle	5
			cf. *Siebenrockiella crassicollis*	Black marsh turtle	1
		Trionychidae		Soft-shelled turtles	40
	Squamata			Lizards and snakes	6
		Varanidae	*Varanus* spp.	Monitor lizard	30
	Serpentes (Suborder)			Snakes	24

Aves				Birds	20
	Galliformes	cf. Phasianidae		Pheasants, fowls	2
	Ciconiiformes	Ciconiidae	*Leptoptilos dubius*	Greater adjutant	2
		cf. Ciconiidae		Storks	1
	Pelecaniformes	cf. Ardeidae		Herons	5
Mammalia					2114
	Rodentia	Muridae	cf. *Rattus* spp.	Rats, mice	7
		Hystricidae		Porcupine	2
			Hystrix brachyura	Malayan Porcupine	1
			cf. *Atherurus macrourus*	Asiatic brush-tailed porcupine	1
		Sciuridae spp.		Squirrel, marmots etc.	2
			Small rodent		2
			Large rodent		2
	Primates	Cercopithecidae spp.		Old World monkeys	2
			Macaca spp.	Macaque	4
			cf. *Macaca* spp.		2
			Trachypithecus	Leaf monkey	1
	Pholidota	Manidae	*Manis* spp.	Pangolin	5

Mammalia	Carnivora				32
		Felidae spp.			1
			Panthera cf. *tigris***	Tiger (or possibly panther)	3
			cf. *Neofelis or Pardofelis*	Clouded leopard or marbled cat	7
		Viverridae spp.		Civet cats	3
			cf. *Viverra*		3
			Viverra spp.	Large Indian civet, large spotted civet	1
		Canidae spp.		Jackals, wolves, dhole, foxes	2
			Cuon alpinus	Dhole/Asian wild dog	1
		Mustelidae	Lutrinae	Otters	1
			Aonyx cinereus	Oriental small-clawed otter	5
		Phocidae		Seal	1
	Artiodactyla				22
		Suidae	*Sus* cf. *scrofa*	Eurasian pig	50
		Pecora		cf. Bovinae or Cervidae	16
		Cervidae spp.		Deer	114
			Cervus spp.***	Deer	99
			Muntiacus spp.	Barking deer	9
			Small Cervid		50
			Medium-large Cervid		27
		Bovinae spp.		Cattle, water buffalo, bison	236
			Bubalus sp.	Water buffalo	96
			cf. *Bubalus*		30
			Bos spp.	Cattle	6
			cf. *Bos*		10

Mammalia	Cetacea	Whale	1
	Unordered:		
	Mammal- small-medium (rodent-primate)		41
	Mammal- medium (pig-medium deer)		319
	Mammal- large (large deer-cattle)		1065
Total identified			5585
Unidentified			3972
Total			**9557**

*The taxonomic order of Elasmobranchii frequently changes, this is based on Vélez-Zuazo and Agnarsson (2011).

** These elements were identified as tiger because of their large size, though it is possible they could be panther. Unfortunately, it is difficult to differentiate between members of the family Felidae as they are morphologically similar and distinction is mainly based on size and geographical boundaries.

*** See explanation in section 6.4.10. for allocation of large Cervidae taxa into *Cervus*, as opposed to *Cervus/Rusa*.

Table 6-13 Comparison of NISP, MNE, and MNI for mammalian taxa.

Taxon	NISP	MNE	MNI
Rodentia large	2	2	
Rodentia small	2	2	
cf. *Rattus*	7	7	2
Hystrix spp.	4	4	1
Sciuridae	2	2	1
Cercopithecidae	2	2	1
Macaca spp.	4	4	1
cf. *Macaca* spp.	2	2	
Trachypithecus	1	1	1
Manis spp.	5	5	3
Panthera cf. *tigris*	3	3	1
cf. *Neofelis or Pardofelis*	7	3	2
Viverridae	7	6	1
Canidae	2	2	1
Cuon alpinus	1	1	
Lutrinae	1	1	1
Aonyx cinereus	5	4	2
Phocidae	1	1	1
Sus cf. *scrofa*	50	42	3
Cervidae spp.	298	123	6
Bovinae spp.	378	169	7
Cetacea	1	1	1
Totals	**785**	**387**	**36**

Table 6-14 Comparison of NISP, MNE, MNI for Elasmobranchii, fish, and reptiles.

Taxon	NISP	MNE	MNI
cf. Lamniformes	1	1	1
cf. Alopias spp.	2	2	1
cf. Orectolobiformes	1	1	1
cf. Carcharhiniformes	7	7	1
Myliobatiformes	7	3	1
Siluriformes	4	3	1
Perciformes	7	7	1
Serranidae	4	4	1
Sparidae	4	2	2
Scaridae	1	1	1
Tetraodontiformes	1	1	1
Geoemydidae	398	12	6
Trionychidae	40	2	1
cf. Phasianidae	2	2	1
Ciconiidae	3	3	2
cf. Ardeidae	5	5	2
Totals	**487**	**56**	**24**

6.4.2. Fish and Elasmobranchii

Taxonomic identification and quantification of fish and Elasmobranchii (sharks and rays) from CCN was undertaken, despite not being analysed for MB, as detailed in Chapter five section 5.2.4. Briefly, Sawada et al. (2011) have provided a preliminary analysis of the fish, sharks, and rays from MB. Due to the lack of reference collections in Hanoi and large size of the MB fish, shark and ray assemblage, it was outside the scope of this study to extensively analyse. Basic faunal analysis of fish, sharks, and rays from CCN is covered here – however – this is excluded from Chapter nine for taxonomic comparative purposes.

The majority of the fish remains were unidentifiable but some families, such as, Serranidae, Scaridae, and Sparidae could be identified based on cranial elements. One fragment of Tetradontiformes dentary or premaxilla and four fragments of Siluriformes were identified based on pectoral spines. Although it is difficult to identify families of sharks based on vertebrae or teeth, there are some morphological distinctions that can be used to separate orders or families (Bass et al. 1975; Garrick 1982; Kozuch and Fitzgerald 1989; Purdy 2006). Figure 6-13 displays two vertebrae and two teeth that were classified as cf. Lamniformes and cf. Carcharhiniformes based on morphology (Kozuch and Fitzgerald 1989; Purdy 2006).

Figure 6-13 Vertebrae and teeth identified as shark. Left, vertebrae identified as cf. Lamnidae (left) and cf. Carcharhinidae (right), scale = 2 cm. Right, teeth identified as Lamniformes cf. *Alopias* spp. (thresher shark), scale = 1 cm.

There are a variety of habitats represented by the different taxa including; saltwater, freshwater, and brackish (Table 6-15). Although, many species can inhabit numerous types of environments, some species, such as Scaridae, strictly feed on coral. Ground sharks and rays can be found in brackish waters but carpet and mackerel sharks are strictly saltwater. The range of taxa shows a diverse exploitation strategy.

Table 6-15 The habitats of fish and Elasmobranchii found in the assemblage.

Taxon	Common name	Water type	Habitat
Lamniformes	Mackerel sharks	Salt	Inshore, offshore
Orectolobiformes	Carpet sharks	Salt	Bottom-dwellers
Carcharhiniformes	Ground sharks	Salt & brackish	Offshore, inshore, estuaries
Myliobatiformes	Rays	Salt, brackish, fresh	Inshore, offshore, estuaries
Siluriformes	Catfish	Salt, brackish, fresh	Inshore, estuaries, fresh water
Serranidae	Basses, groupers	Salt & brackish	Coral & rocky reefs, estuaries
Sparidae	Breams, porgies	Salt & brackish	Inshore, estuaries
Scaridae	Parrotfish	Salt	Coral reefs
Tetraodontifomes	Ray-finned fishes	Salt, brackish, fresh	Coral reefs, fresh water streams, estuaries

6.4.3. Reptiles

Reptiles are dominated by Geoemydidae (hardshell turtles), which may be represented by a couple of different species. Since most of the pieces of carapace were quite fragmentary it was difficult to identify further than family. Five fragments of carapace were classified as cf. *Cyclemys dentata* (Asian leaf turtle) and one as cf. *Siebenrockiella crassicollis* (black marsh turtle). Trionychidae (softshell turtles) were also present but fewer in numbers. Only four turtle postcranial elements were identified: two right femora, and right and left humeri. A minimum of seven individuals of Geoemydidae is based on the anterior notch/nuchal part of the carapace.

SEA is incredibly rich and diverse in turtle species. Geoemydidae is one of the most diverse and numerous families with currently 18 recognised genera, while Trionychidae currently have 13 recognised genera (Van Dijk et al. 2012). Turtles are found near still or slow moving shallow bodies of water. The Asian leaf turtle is a widespread species across SEA but the black marsh turtle is currently classified as vulnerable, with a range that extends from south Vietnam, Cambodia, Thailand, Indonesia (Java, Kalimantan, and Sumatra), and eastern and western Malaysia (Asian Turtle Working Group 2016b; 2016a).

Both lizards and snakes were identified in the assemblage (Figure 6-14). Twenty-eight elements of *Varanus* vertebrae were recorded as well as one proximal femur and one right humerus. Twenty-four elements of snake vertebrae were recorded, including two that were unfused (Figure 6-14). There are several different species of *Varanus* and large snakes in SEA and they inhabit a diverse range of environments from woodlands to wetlands. The Asian water monitor (*V. salvator*) is the most common and widespread species of *Varanus* in Asia (Bennett et al. 2010). Although this species inhabits a vast variety of habitats, mangroves, swamps and wetlands are considered to be its most important habitat (Bennett et al. 2010).

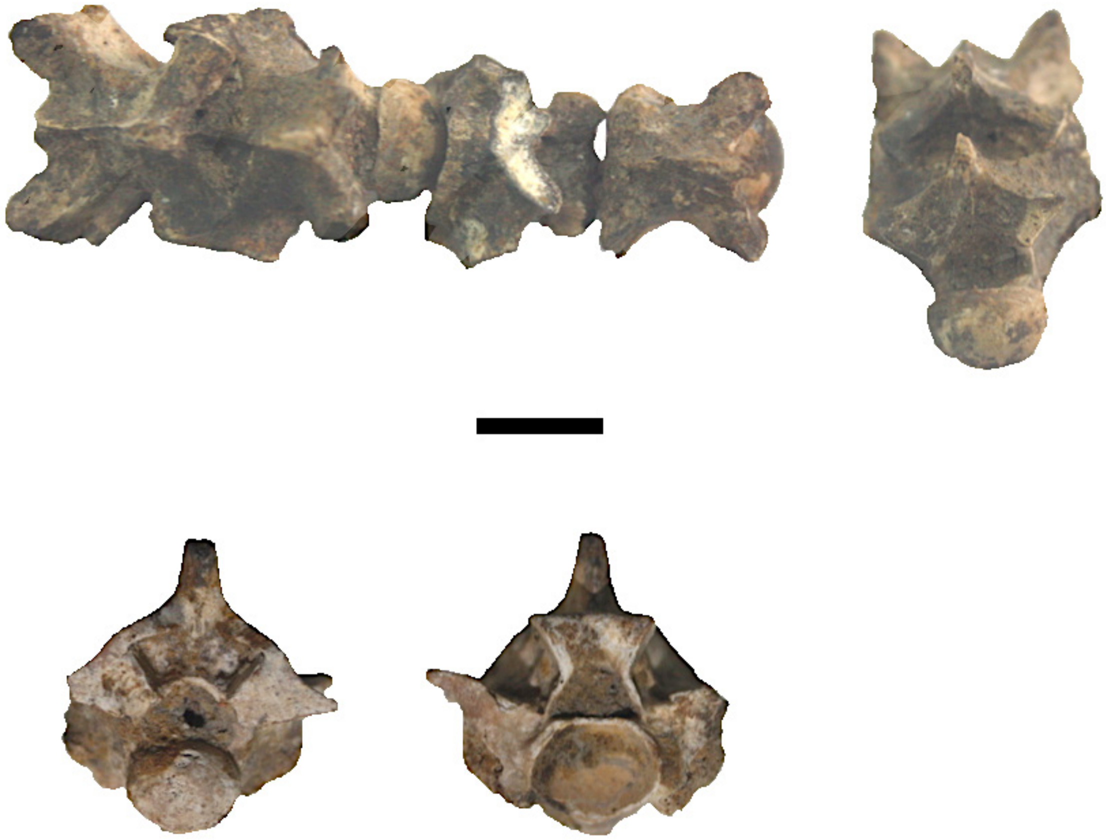


Figure 6-14 Distinguishing between snake and lizard (*Varanus*) vertebrae based on vertebral morphology. Top, *Varanus* vertebral column, partially fused from layer II.3 A10. Below, snake vertebrae from layer III.2. Scale = 1 cm.

6.4.4. Aves

Although birds are few in number (30 NISP), at least three different families are represented including, pheasants and fowls, storks, and herons (Table 6-12). Of particular interest are a proximal left tarsometatarsus and distal right tibiotarsus identified as a male Greater Adjutant (*Leptoptilos dubius*), based on morphology and size (Jones et al. 2016; Figure 6-15). This represents the earliest identification of a giant stork in MSEA (Meijer and Due 2010; Jones et al. 2016). The greater adjutant is described as “the most massive and ugliest of Asian storks, standing at 120–152 cm to the top of the head” (Hancock et al. 2011, 129). The species has a close relationship with humans as they are typically found near rubbish dumps or human habitation and not far from wetlands but are also found in open forests and grasslands (Elliott 1992, 464).

The tarsometatarsus is of particular interest as the shaft has been anthropogenically shaped and shows abrasion marks as well as a carnivore bite mark, which is covered in detail by Jones et al. (2016, Figure 6-16).

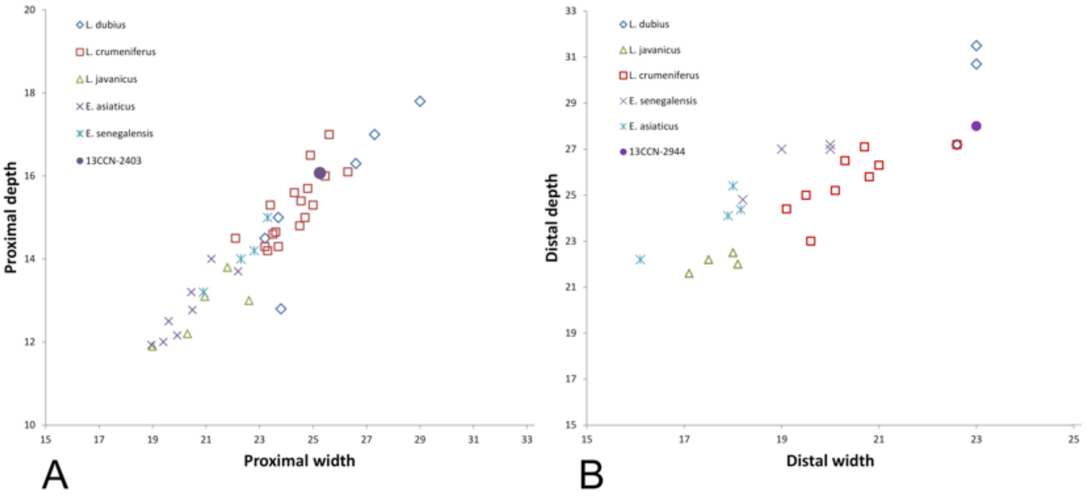


Figure 6-15 Size comparison (in mm) of living Leptoptilini: A, tarsometarsi and B, tibiotarsi. The CCN specimens are indicated by their ID numbers and the blue dot. Graph from Jones et al. (2016 figure 4).

Figure 6-16 Proximal left tarsometatarsus of the Greater Adjutant, showing A, the dorsal and B, the plantar aspects. Arrows point to carnivore puncture mark. Scale = 2 cm. Image from Jones et al. (2016 figure 2).

6.4.5. Primates

Based on dental wear stages there are at least three Cercopithecidae of varying ages in the assemblage. An almost complete left mandible with heavily worn P4, M1–2 and a relatively worn M3, which suggests it is likely from a relatively elderly individual. A right hemi-mandible has slight wear on P4, M1–2, and singular lower left M1/2 displays no dental wear. Other elements include two humeri, two tibiae, one radius, and one axis. There are four genera of Cercopithecidae in Vietnam: *Macaca* (macaque), *Trachypithecus* (leaf monkey), *Pygathrix* (douc langur), and *Rhinopithecus* (snub-nosed monkey).

The majority of the specimens have been classified as macaque or cf. macaque, except a right mandible, which was classified as leaf monkey. There are morphological distinctions between the mandibles of macaques and leaf monkeys, for instance, the lower P3 alveolus extends further in macaques than leaf monkeys (Figures 6-17, 6-18; Philip Piper 2017, pers. comm.).

Figure 6-17 A right mandible identified as a female *Trachypithecus* because of the lack of the extended P3 alveolus, the higher cusps, and general shape of the mandible. Further, the small canine alveolus indicates the individual is female. Scale = 4 cm.

Most macaques are forest-dwelling animals, although, *M. fascicularis* (crab-eating macaque) is tolerant of a range of different habitats including mangroves and swamps (Ong and Richardson 2008). Leaf monkeys and langurs inhabit the forests but numerous species are also associated with karst limestone mountainous areas (Nadler et al. 2008; Xuan Canh et al. 2008b).

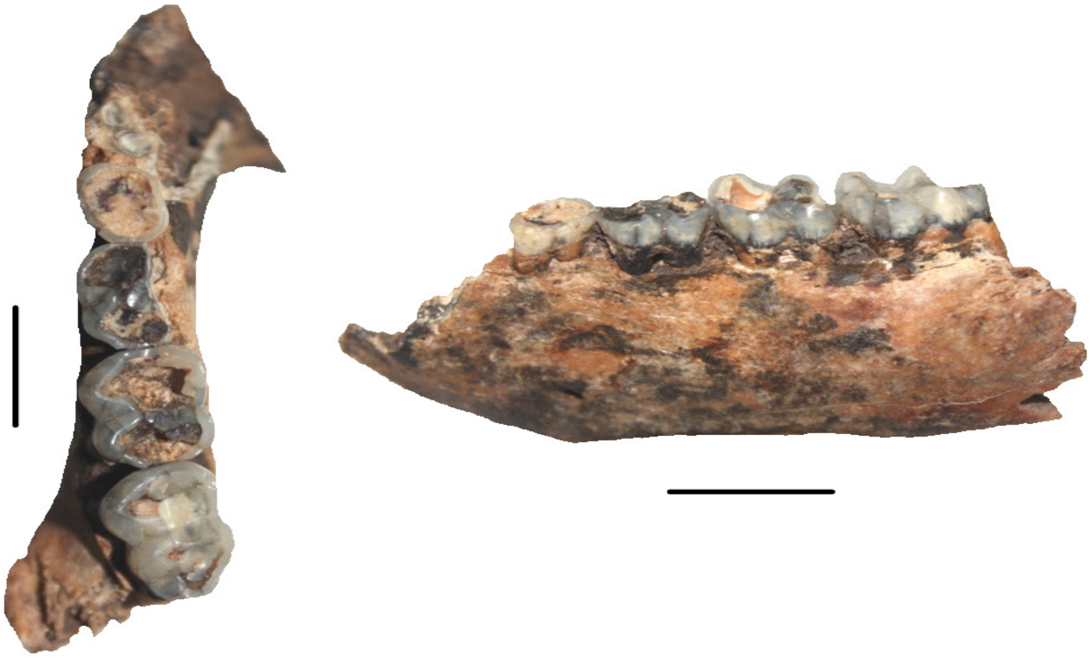


Figure 6-18 A left mandible identified as *Macaca*, as the depth of the mandible is shallower and more elongated than *Trachypithecus*. Scale = 1 cm.

6.4.6. Rodents

Rodents are represented by at least three different families: Hystricidae, Muridae, and Sciuridae. Four elements of Hystricidae (porcupines) were identified including, a mandible, maxilla, singular incisor, and a femur. The mandible has been classified as *Hystrix brachyura* (Malayan porcupine), which is a species common throughout SEA and found in a variety of forest habitats as well as agricultural areas (Lunde et al. 2008; Diedrich 2009). The maxilla has been tentatively identified as cf. *Atherurus macrourus* (Asiatic brush-tailed porcupine) as the morphology of the M2–3 appears dissimilar to *Hystrix*. Specifically, the M2 appears broader and shorter anterior-posteriorly (see Figure 6-19). However, it is possible this is due to subspecies variation within *Hystrix* spp., so this identification remains tentative (compare images in van Weers 1979, 263; van Weers and Montoya 1996, 136).

There are at least three Muridae rat-sized (cf. *Rattus*) rodents represented by postcranial elements including: two femora, three humeri, one tibia, and a fragment of a pelvis. The femora are unfused, as is the tibia. A mandible with a fragmentary incisor but no molars and a tibia was identified as Sciuridae (squirrels) based on size and morphology (Emry and Thorington 1982, 7). However, given there are no molars this identification is cautious.

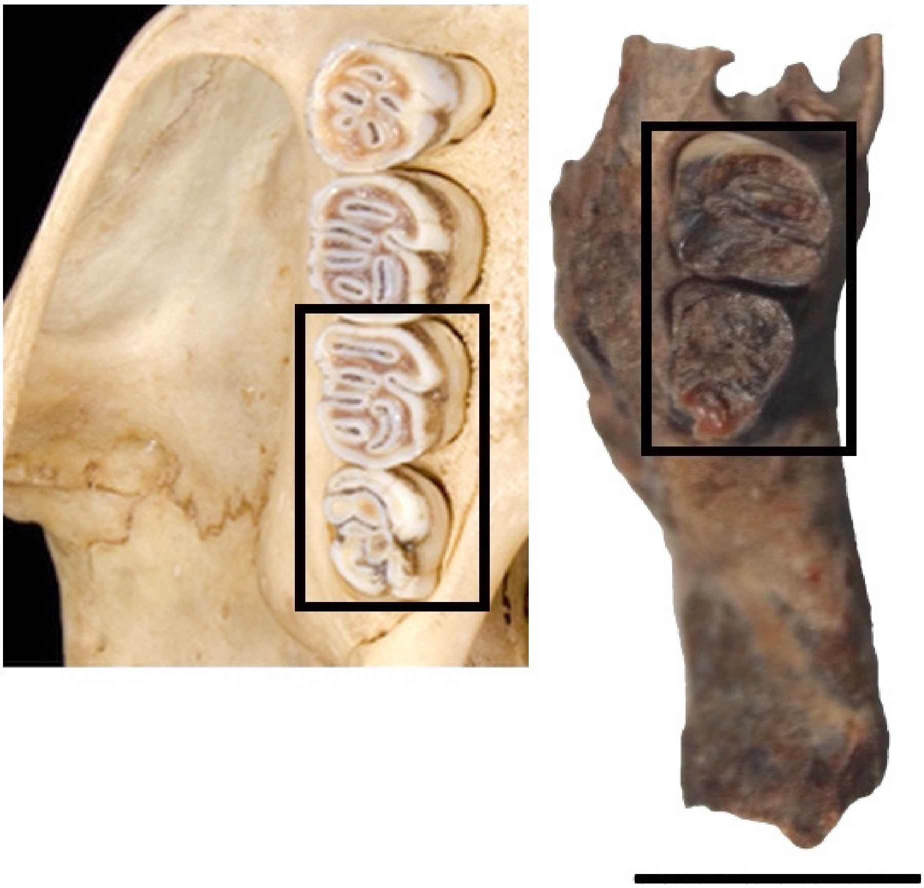


Figure 6-19 Comparison of porcupine maxillae and morphology of dentition. Right: CCN specimen 13CCN-2769, left maxilla with M2–3. Left: *Hystrix indica* left maxilla with P4, M1–3 from Amori et al. (2008). Scale = 1 cm.

6.4.7. Pangolins

Manidae (pangolins) are represented by humeri and ulnae and comprise at least three individuals based on three right humeri (Figure 6-20). There are four species of *Manis* in SEA, *M. culionensis* (Philippine pangolin) is endemic to the Philippines, but *M. javanica* (Sunda pangolin), *M. pentadactyla* (Chinese pangolin), and *M. crassicaudata* (Indian pangolin) inhabit the mainland (IUCN 2016). As the name suggests, the Indian pangolin is found mostly on the Indian sub-continent, and the Chinese pangolin is mostly associated with the Himalayan foothills of Nepal and Bhutan but their range also extends to north Laos and Vietnam (Baillie et al. 2014; Challender et al. 2014a). The Sunda pangolin is the most widespread species, it occurs throughout most of MSEA and parts of Indonesia and Malaysia (Challender et al. 2014b). Their distribution and numbers are limited in recent times because of habitat reduction and poaching as their meat is considered a delicacy. Pangolins are found in a variety of habitats from forests to grasslands, they burrow but are also adept climbers. As mentioned above, there is a small chopmark on a right proximal ulna (Figure 6-20), which shows pangolins were being butchered.

6.4.8. Carnivores

There are at least two species of Felidae represented by mandibles and upper dentition. *Panthera* cf. *tigris* (tiger) elements include almost complete right and left mandibles with no teeth, and a basal phalanx (Figure 6-10). These elements were identified as tiger because of their large size, though it is possible they could be a leopard (*Panthera pardus*). Unfortunately, it is difficult to differentiate between members of the family Felidae as they are morphologically similar and distinction is mainly based on size and geographical boundaries. Nonetheless the mandible and basal phalanx are certainly from a large felid.

Figure 6-20 Pangolin (*Manis* sp.) right ulna (left) with a small cutmark on the lateral shaft, and a right humerus (right). Scale (micro photo) = 50 mm, scale (macro photo) = 2 cm.

A medium-sized felid with an MNI of two is represented by two left mandibles with dentition, a singular upper canine, and upper P3–4 (Figures 6-21). Based on the size and distribution, this felid is probably *Neofelis nebulosa* (clouded leopard), *Pardofelis marmorata* (marbled cat), or *Catopuma temminckii* (Asiatic golden cat). Not much is known about these medium-sized felids given their limited and decreasing numbers but their main habitat is forests (Grassman et al. 2005; Gordon et al. 2007).

Although tigers are currently restricted to forests in tropical Asia, historically they covered a wider range environments and climates (Louys 2014). Their main habitat requirement is the availability of large ungulates as it is estimated they need to kill between 50–60 large prey animals per year (Goodrich et al. 2015). The clouded leopard, marbled cat, and Asiatic golden cat are all strongly associated with forests, especially evergreen tropical rainforests, though little is known about the ecology and behaviour of these medium-sized felids (Grassman et al. 2016; McCarthy et al. 2016; Ross et al. 2016). The

Figure 6-21 Mandible and upper dentition of a medium-sized felid, excavated from burial M22/23 (13CCN-2236-2240). Left mandible with P3-4, M1, and lower left and right canines. Upper: right P3, partial right P4, and right canine. Scale below = 2 cm.

decline of felids, and carnivores in general, during the recent Holocene is largely driven by habitat destruction and severe over-exploitation through hunting (Corlett 2007; Louys 2014).

Body parts of tigers and large felids, particularly skins and teeth, are often used as ornaments for social expressions of wealth (Piper et al. 2007; Piper et al. 2008a). In Borneo, early travellers noted the use of tiger canines as totemic objects by several groups (Piper et al. 2007). There was no perceivable damage to the alveoli on the tiger mandible (Figure 6-10), although it is possible the teeth were deliberately removed and repurposed, though it is interesting there are cutmarks on the lateral surface of the right mandible which are suggestive of skinning (see section 11.6.3. for a discussion of its significance).

Viverridae are represented by several cranial and postcranial elements. One left mandible with P4 and M1 was classified as *Viverra* spp. (civet) (Figure 6-22) and left femur, right ulna, and right calcaneus as cf. *Viverra* spp. It is difficult to further classify taxonomically due to the lack of skeletal comparatives or measurements. Within the genus *Viverra* there are four species, the most common and widespread of these within MSEA is *Viverra zibetha* (large Indian civet; Timmins et al. 2016b). Civets are common in forested areas and wetlands and are mostly nocturnal (Holden et al. 2009; Timmins et al. 2016b).

Figure 6-22 ***Viverra*** **sp. left mandible with P4, M1. Excavated from Layer II.2 A1. Scale = 2 cm.**

Canidae are extremely rare in the assemblage and are only represented by three elements: a right proximal ulna, a right distal femur, and a damaged left lower P4 (Figures 6-23, 6-24). The lower P4 has been attributed to *Cuon alpinus* (dhole/Asiatic wild dog) based on size and biogeographical distribution. It is possible (though less likely), the P4 could be a small *Canis lupus* (grey wolf). Unfortunately, there is not much morphological difference in the lower P4s between *C. lupus* and *Cuon* (Pionnier-Capitan et al. 2011, 2126–7). Conversely, the ulnae of Canidae can be distinguished between *Cuon* and *Canis* but unfortunately the olecranon process is damaged, which makes this distinction not possible (Pionnier-Capitan et al. 2011, 2128). However, both cranial and postcranial elements are more likely to be *Cuon* as the geographic range of *C. lupus* does not extend to Vietnam (Mech and Boitani 2010). Neither the ulna or lower P4 fit the dimensions of domestic dog (see Chapter eight, section 8.5. for biometric comparison).

Figure 6-23 Canid proximal right ulna, either ***Canis lupus*** **or** ***Cuon alpinus*** **(13CCN-2535). Excavated from burial M72. Scale = 1 cm.**

Figure 6-24 Lower P4 that is most likely *Cuon alpinus* (13CCN-3033). Excavated from burial M11. Scale = 1 cm.

Mustelidae are represented by cranial elements, and based on right mandibles there are at least three individuals. There are four species of otters in SEA in two genera, *Aonyx* and *Lutra* (Wright et al. 2008). *Aonyx cinereus* (oriental small-clawed otter) is the smaller species but its teeth are comparatively robust, especially the premolars and molars (Wright et al. 2008, 40). Based on these features it was possible to classify the Mustelidae in the assemblage as *A. cinereus* (Figure 6-25). Although *A. cinereus* and *Lutra* spp. are sympatric within Vietnam, they are behaviourally distinct. *A. cinereus* lives in large family groups and has evolved as a crustacean predator, hence their robust teeth

Figure 6-25 A left mandible identified as *Aonyx cinereus* with P4, M1–2 (13CCN-2704). Excavated from burial M27. Scale = 1 cm.

(Wright et al. 2008, 47). Their preferred environment is shallow water such as swamps, mangroves, and slow moving rivers (Wright et al. 2015).

A few other fragments were also suspected to be seal or sea mammal elements but due to their fragmentary nature and the lack of skeletal or photographic comparatives it was difficult to properly identify them.

6.4.9. Suidae

A NISP of 50 and MNE of 42 skeletal elements of *Sus* cf. *scrofa* (Eurasian wild boar) were identified, largely based on biogeographic distribution (Groves 2007; Groves and Grubb 2011). An MNI of 3 is based on calcanei and lower left canines, and at least two individuals were male based on canine morphology. Groves and Grubb's (2011, 38–9) review of the *Sus scrofa* group divided it geographically into six regions: European, Western/Central/North Asian, Japan, Indochina, and Southeast Asian. The distinction between Indochinese *S.* cf. *scrofa* and SEA pigs was warned to be unclear and liable to change. Further, there are a range of endemic wild pigs to ISEA which complicate the situation (Groves and Grubb 2011, 39; see section 5.7.2. Table 5-4). Wild pigs occupy a wide variety of environments from semi-deserts, tropical rainforests, temperate woodlands, grasslands and farmlands (Oliver and Leus 2008). They roam in groups of various sizes but usually between 6-20 individuals (Oliver and Leus 2008).

Both cranial and postcranial elements are represented at CCN including high and low meat-yielding elements (Figure 6-26, 6-27). The majority of the skeleton is represented, although there is a predominance of extremities (metapodials, carpals, tarsals, and phalanges), and a paucity of elements from the axial skeleton. There were also no fragments of maxillae or crania identified except loose teeth (upper left I1, left canine, and right M2). The reason for the under-representation of maxillary and cranial elements may be related to bone density. In humans, mandibles are on average twice the density of maxillae (Devlin. et al. 1998), as the cortical bone is considerably thicker (Park et al. 2008, 35). Although this has not been tested specifically for pigs, it is possible a similar difference in bone density is resulting in a paucity of maxillae in the CCN assemblage. It is possible the under-representation of maxillae is related to human butchery practices, however there is no clear evidence to support this idea. Interestingly, at MB there is a similar under-representation of mandibles but there is evidence to suggest this may be related to butchery practices (see sections 6.4.13.; 7.4.8.; 11.1.3.; and 11.4.2. for further

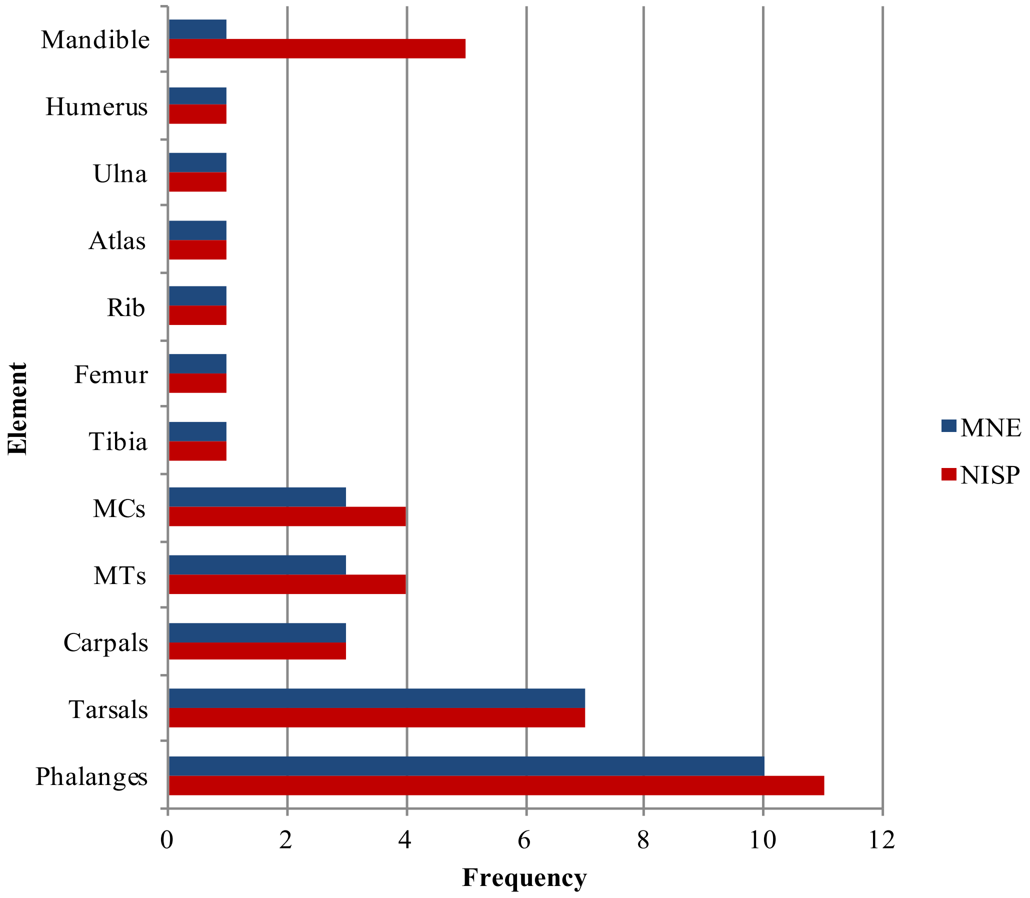
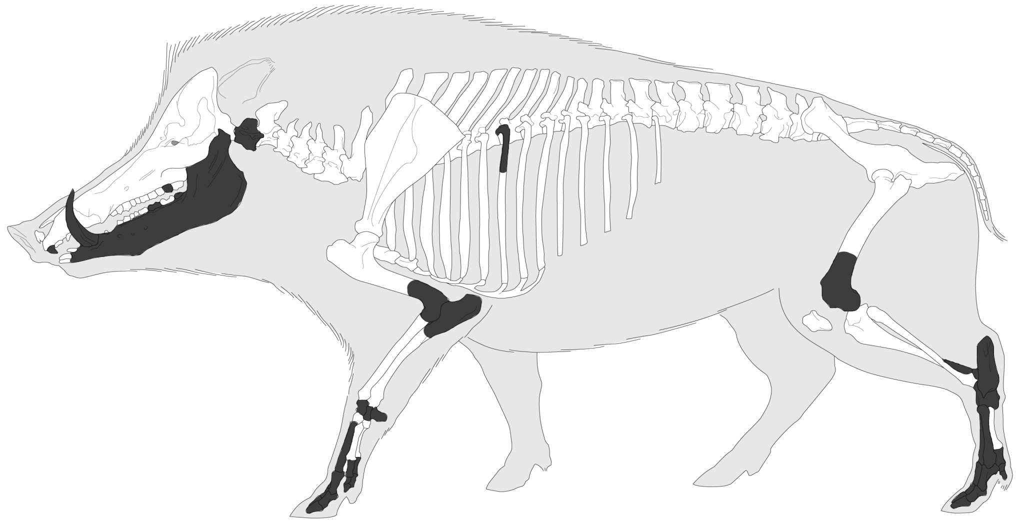


Figure 6-26 BPR of Suidae in the assemblage, a comparison of MNE and NISP values.



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D'après : Léon Pales et Michel A. Garcia, 1981, *Atlas ostéologique pour servir à l'identification des Mammifères du Quaternaire - Herbivores*, Paris : CNRS, pl. 45.

Figure 6-27 Diagram of BPR of Suidae. Note the paucity of axial elements.

discussion and comparison between pig maxillae representation CCN and MB).

Only two molars and 17 postcranial elements could be used for age profiling. The small sample size makes it difficult to determine patterns and the survivorship and mortality scores are not particularly useful. The two molars did not fit into one age category. The upper right M2 using Lemoine et al. (2014) System A would be approximately 8–16 months or 0–52 months using System B, and a lower left M3 is between 18–96 months (System A) or 12–96 months (System B). Postcranially, there was a combination of fused and unfused elements. Based on sub-terminal phalanges at least one individual was between 8–18 months. There were two unfused calcanei but this element has a late fusion stage of between 36–48 months. Thus, there was at least one subadult and one adult individual within the assemblage.

One lower left pig canine was deliberately modified on the occusal edge/lingual surface of the tooth (Figure 6-28). Transverse abrasions are visible as well as a small triangular notch at the apical end, and a small round notch on the coronal end. The tooth has been broken transversely across the apical end, potentially through use. This modified canine was excavated from burial M22/23, but it should be reemphasised that it is difficult to determine whether the faunal elements excavated within the burial context are technically ‘associated’ with the burial. None of the elements appear to have been deliberately included in the burial as a ‘grave good’.

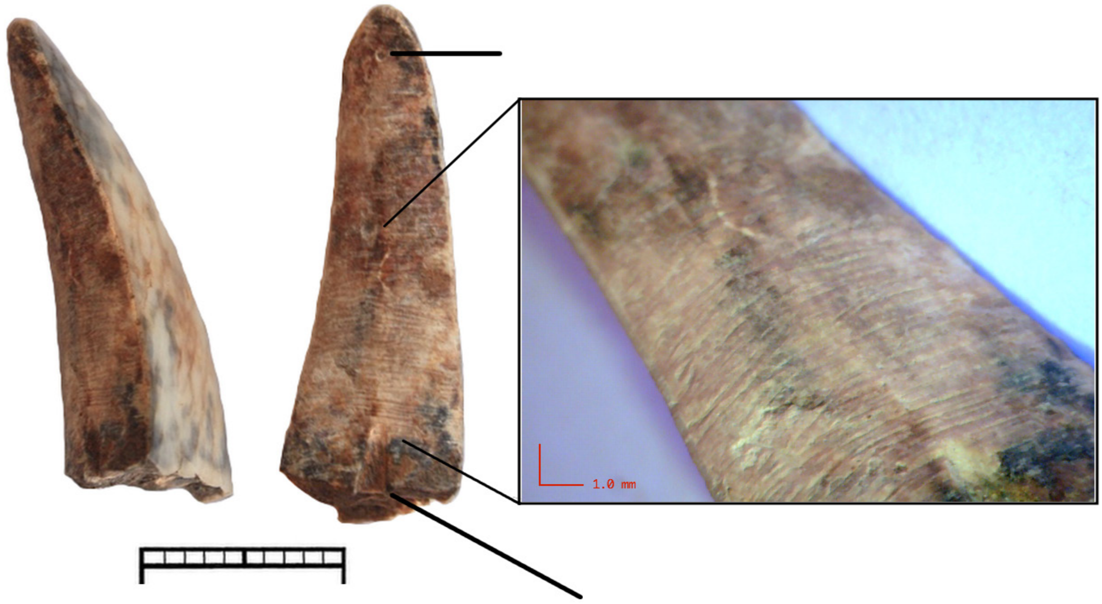


Figure 6-28 A left canine of *Sus* cf. *scrofa* with transverse abrasion marks (see micro image) and a small triangular notch on the apical end and a small round notch of the coronal/crown end (see arrows). Specimen ID 13CCCN-2259, excavated from burial M22/23. Scale on macro photo =1 cm.

6.4.10. Cervidae

Cervidae are the second most common mammal within the assemblage and are represented by at least two different genera, *Cervus* (‘true’ deer) and *Muntiacus* (muntjac/barking deer). This is largely based upon differences in size, as muntjacs are much smaller animals. There are also morphological differences in antlers, although given the fragmented nature of the antlers, size was often the most useful criterion. With the exceptions of the Chinese water deer and caribou (neither of which have any historic presence in this region), within the family Cervidae only males have antlers (Holmes et al. 2011), which confirms that the antlers at CCN belong to male deer. Muntjak antlers are relatively short with long pedicles and they have a smoother surface compared to *Cervus*.

The taxonomic status of the genera and species within Cervidae is in a state of flux as much of the evolution of deer is uncertain (Pitra et al. 2004). The reason for the classification of the larger Cervidae specimens as *Cervus* spp. as opposed to *Cervus*/*Rusa* spp. is that Groves and Grubb (2011) argue against separating *Rusa* into a genus. They classify the Indochinese sambar (*Cervus*/*Rusa unicolor*) as *Cervus equinus*. *Cervus* spp. (elk, red, and sika deer) are widespread across Europe, Asia and North America, while the sambar deer (*Rusa unicolor/Cervus equinus*) is native to SEA (Timmins et al. 2015b). Both deer occupy a variety of forest types, although the sambar deer appears to be more flexible in regards to habitat and diet breadth (Timmins et al. 2015b).

There are between 13–17 recognised species of muntjacs spread across Asia, of which, *M. muntjak* is the most common (Groves and Grubb 2011; Timmins et al. 2016c). These small species of deer inhabit forests and woodlands and are mostly solitary or found in small groups (Timmins et al. 2016c). It is possible that some of the medium-sized deer elements in the CCN assemblage may represent *Axis porcinus* (Hog deer). Historically the hog deer was widespread throughout Asia but is now listed as probably extinct in Vietnam (Timmins et al. 2015a). Their preferred habitat is wet tall grasslands, often in association with rivers (Timmins et al. 2015a).

Some of the antler from the larger species have been deliberately removed, as is apparent from the presence of the pedicle distal to the burr (Figure 6-29). Although many antlers displayed abrasion marks that look remarkably similar to human modifications, a study by Jin and Shipman (2010, 93–4) cautions that abrasion and polish on antlers are often the result of deer rubbing antlers against bark to remove the drying velvet or mark their territories. Thus, caution was applied before assuming modification were the result

Figure 6-29 Above: *Cervus* antler that has been deliberately removed, see presence of the pedicle (B) distal to the burr (A). Context: 13CCN-1685, Layer 2 spits 3-4 B11-A10, under burial M80. Scale = 1 cm.

of human manipulation. However, as mentioned above, the large number of calcined deer antlers in the lower layers around burial M133 is suggestive of an intentional deposit. This shows that deer were not only exploited for their meat (see section 11.6.4. for further discussion).

The NISP for the larger species of deer is higher than muntjacs (99 versus nine). Postcranial remains are more common than dentition. Only one mandible and 18 single teeth were found. Despite the extremely high NISP of Cervidae antler fragments, it is difficult to assess the MNE of fragmentary antler remains. Although the entire skeleton

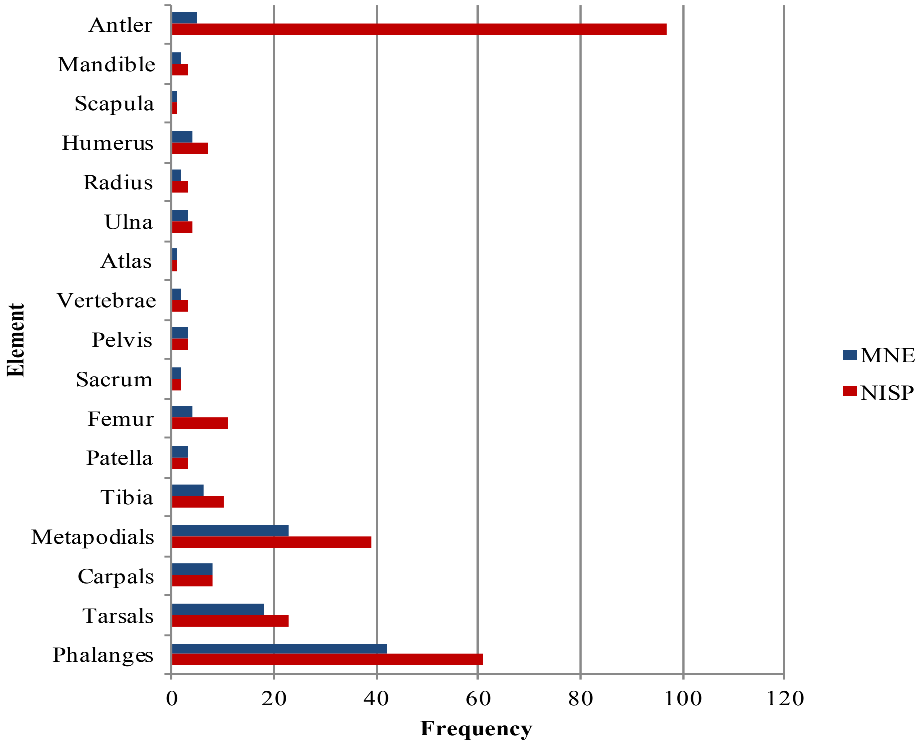
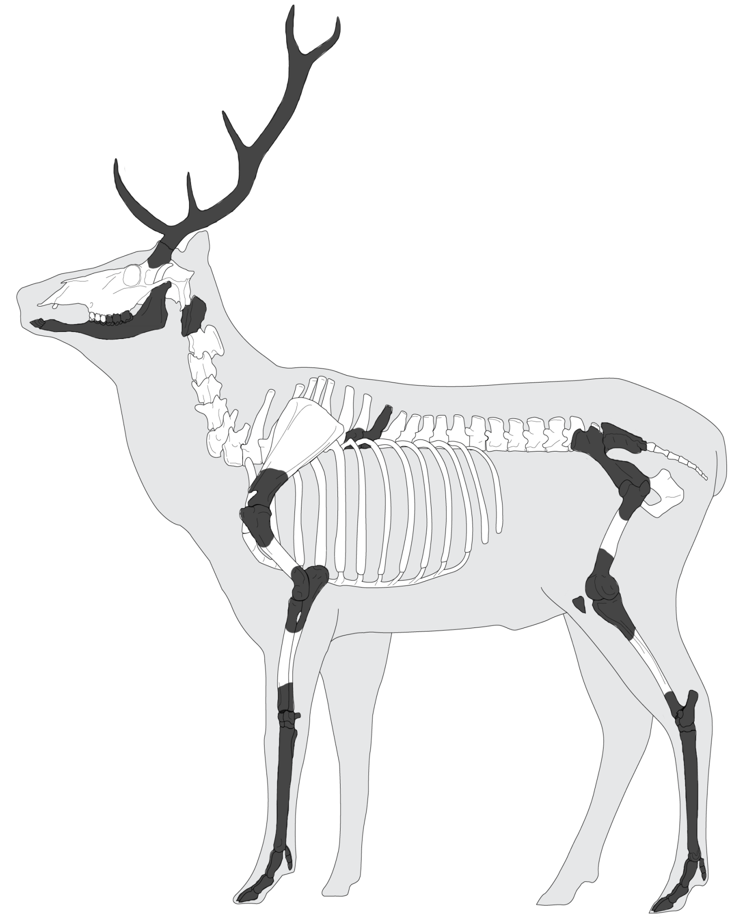


Figure 6-30 BPR for Cervidae spp. (combined total) in the assemblage, a comparison of MNE and NISP values.



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Adapté d'après le squelette de renne dessiné par Cédric Beauval et Michel Coutureau pour ArcheoZoo.org en 2003.

Figure 6-31 Diagram of BPR of Cervidae spp. (combined *Cervus* and *Muntiacus*). Note the paucity of axial elements.

is represented, there is a predominance of extremities (especially phalanges, and antler fragments), and the axial skeleton is under-represented (Figures 6-30, 6-31).

Based on dental wear there is at least one elderly individual, two adults, and one young individual in the assemblage. This is supported by postcranial fusion data (Appendix 3).

6.4.11. Bovinae

Within the tribe Bovini there are two genera in SEA, *Bubalus* and *Bos* (Groves and Grubb 2011). Including the domesticated form, *Bubalus* is represented by five living species, the wild water buffalo (*B. arnee*) is classified as distinct from the domestic form (*B. bubalis*) and the latter is the most common and widespread species (Groves and Grubb 2011, 117). The tamaraw (*B. mindorensis*) and anoa (*B. depressicornsis* and *B. quarlesi*) are both smaller and are endemic to the Philippines and Indonesia respectively (Boyles et al. 2016; Burton et al. 2016a; 2016b). The division of the genus *Bos* is more controversial, with Groves and Grubb (2011, 110–17) dividing the genus into three groups: cattle, gaur-banteng-kouprey, and bison-yak. There are several species of *Bos* within SEA, of which *B. gaurus* (gaur) is the largest, while *B. javanicus* (banteng) is much smaller and similar in size to domestic cattle (Duckworth et al. 2008; Kovarovic and Scott 2014; Gardner et al. 2016). *B. sauveli* (kouprey) is listed critically endangered (possibly extinct), the last absolute confirmed sighting was in 1969/70, and is regionally extinct in Vietnam (Timmins et al. 2016a).

In the CCN assemblage, metacarpals and metatarsals proved to be one of the most useful elements in distinguishing between *Bubalus* and *Bos*. Aside from larger size and greater robusticity in *Bubalus* metatarsals, there are some clear morphological distinctions (Figure 6-32). For example, the distal, middle condyles are more inwardly flaring in *Bubalus* and the proximal facet plateaux extends further laterally and dorsally (Figure 6-32). The majority of the Bovinae that could be further identified were classified as *Bubalus* to due their size, robusticity and morphology (NISP = 96). However, 15 fragments were identified as *Bos* or cf. *Bos*, which included: two terminal phalanges, three sub-terminal phalanges, two basal phalanges, one proximal metacarpal, a left and right proximal metatarsal, a left distal metatarsal, a complete left os-crochu and captio-trapezoid, a distal left tibia, and a complete lower right incisor.

Body part representation of *Bubalus* and cf. *Bubalus* compared to total Bovinae spp.

Figure 6-32 Comparison images of *Bos* (left) and *Bubalus* (right) metatarsals. Left image; see difference in robusticity and flaring of distal condyles in *Bubalus*. Right image; see the extension of the proximal facet laterally and dorsally in *Bubalus*. Photographs courtesy of Philip Piper.

shows a similar pattern (Figures 6-33, 6-34, 6-35). The *Bubalus* carpal BPR is lower in NISP and MNE compared to tarsals but this is probably a product of the difficulty in identifying carpals to specific genera. Caution was employed to carpals and elements that could not confidentially be identified specifically to *Bubalus* were labelled as Bovinae. This is evident when comparing the Bovinae BPR graph as the values for carpals slightly outweigh tarsals, which is probably a result of this caution (compare Figures 6-33 and 6-34).

The overall BPR pattern for Bovinae is similar to Suidae and Cervidae. Though the majority of the skeleton is represented, there is a paucity of axial elements. There is a comparatively high proportion of extremities, but this is probably a product of fragmentation and their frequency within the skeleton. For instance, for an MNI of seven Bovinae the total expected number of phalanges would be 56, and the MNE is 49 (Figure 6-34). The NISP for phalanges is significantly higher than MNE, and this is probably a result of fragmentation.

As their name suggests, water buffalo are reliant on the availability of water. Their preferred habitats are alluvial grasslands, riparian forests and woodlands (Hedges et al. 2008). Conversely, the gaur appears to frequent hilly forest environments (Duckworth et al. 2008) and the range of the banteng overlaps with the gaur but they appear to prefer flatter forested areas (Gardner et al. 2016). Little is known of the habitat and ecology of the kouprey; they seem to have primarily inhabited deciduous forests, especially areas with extensive grasslands (Timmins et al. 2016a).

A total of 35 upper and lower teeth were used in age profiling (Table 6-16). The methodologies of Grigson (1982), Amorosi (1989), and O'Connor (2003) were employed and compared (see Appendix 1.1). Since the ageing of Bovinae teeth is not as refined as for Suidae, especially for single teeth, it was only possible to create categories. In general, the categories between the methods employed agreed with each other. Based on NISP and MNI at least two individuals were subadult, six were adult, and four were elderly (Figures 6-36, 6-37).

Unfused basal and sub-terminal phalanges suggest that at least one individual was less than one year old (O'Connor 2003) or 18–24 months (Amorosi 1989, 64–5). This overlaps with the age profile of an unfused proximal radius (<12–18 months; Amorosi 1989, 63; O'Connor 2003). Fused proximal humeri and tibiae show that at least two individuals were older than 42 months (Amorosi 1989, 62, 69). See Appendix 3 for a summary of the ageing results.

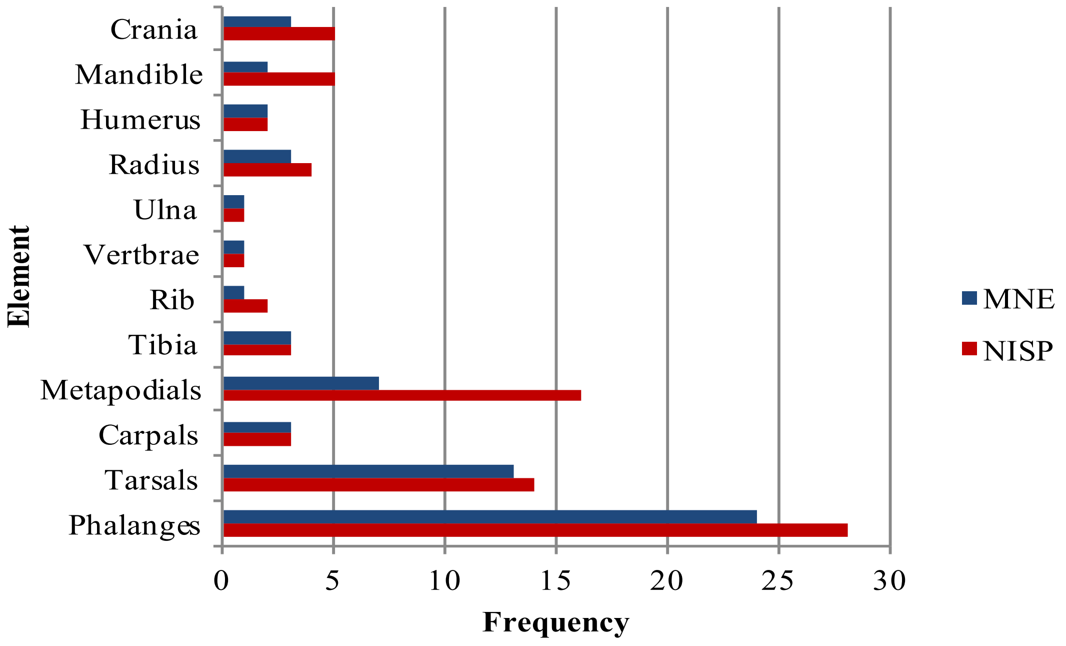


Figure 6-33 A comparison between the MNE and NISP for *Bubalus* and cf. *Bubalus* skeletal elements.

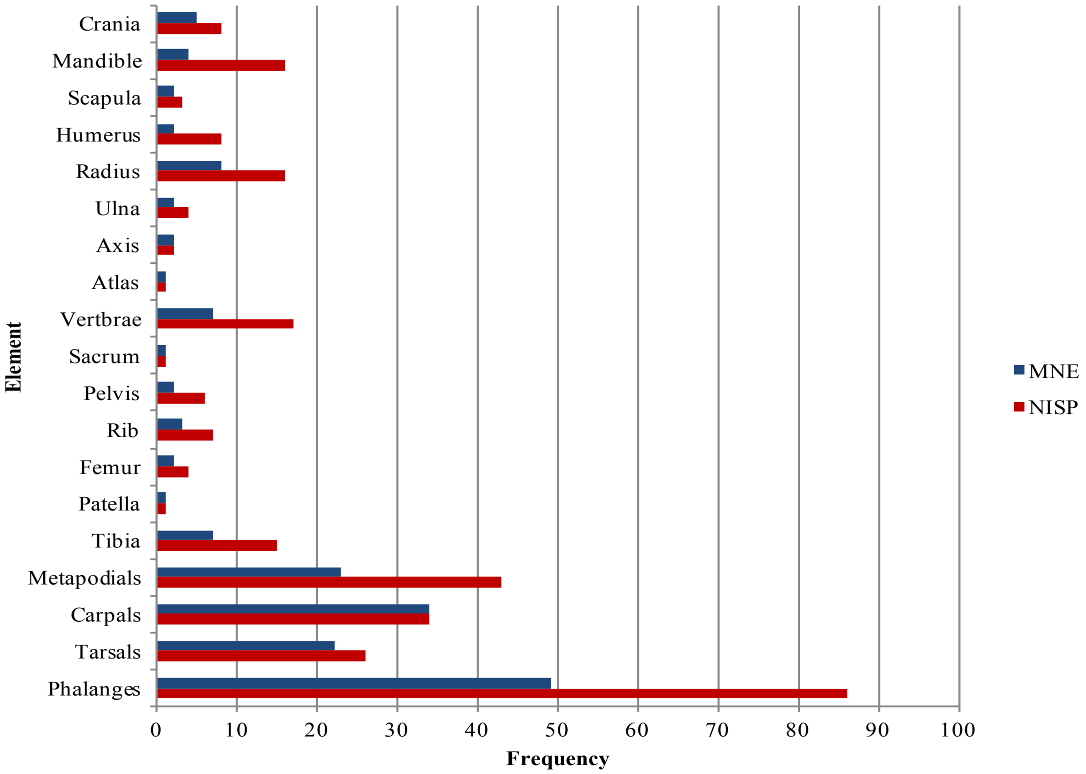
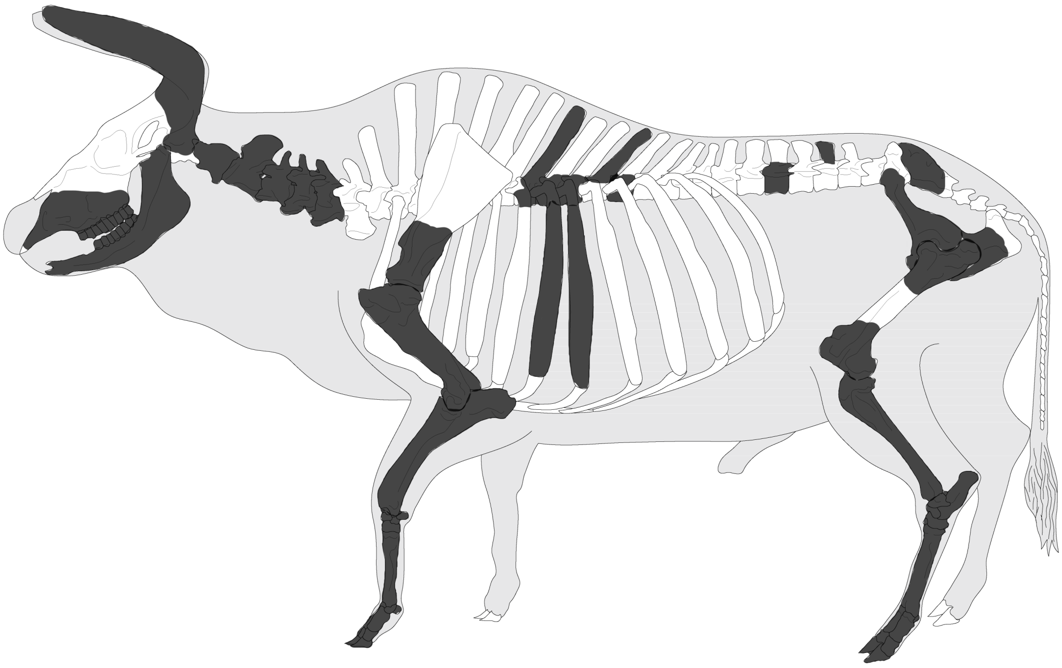


Figure 6-34 A comparison between the MNE and NISP for total Bovinae spp. in the assemblage.



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D'après : Squelette remonté au musée d'Angoulême.

Figure 6-35 Diagram of the BPR of Bovinae.

Table 6-16 Bovinae upper and lower dentition aged to categories. MNI and NISP compared.

Dentition age categories				
Category	**MNI lower**	**NISP lower**	**MNI upper**	**NISP upper**
Subadult	1	3	2	4
Adult	6	10	3	7
Eldery ≥50m	4	7	2	4

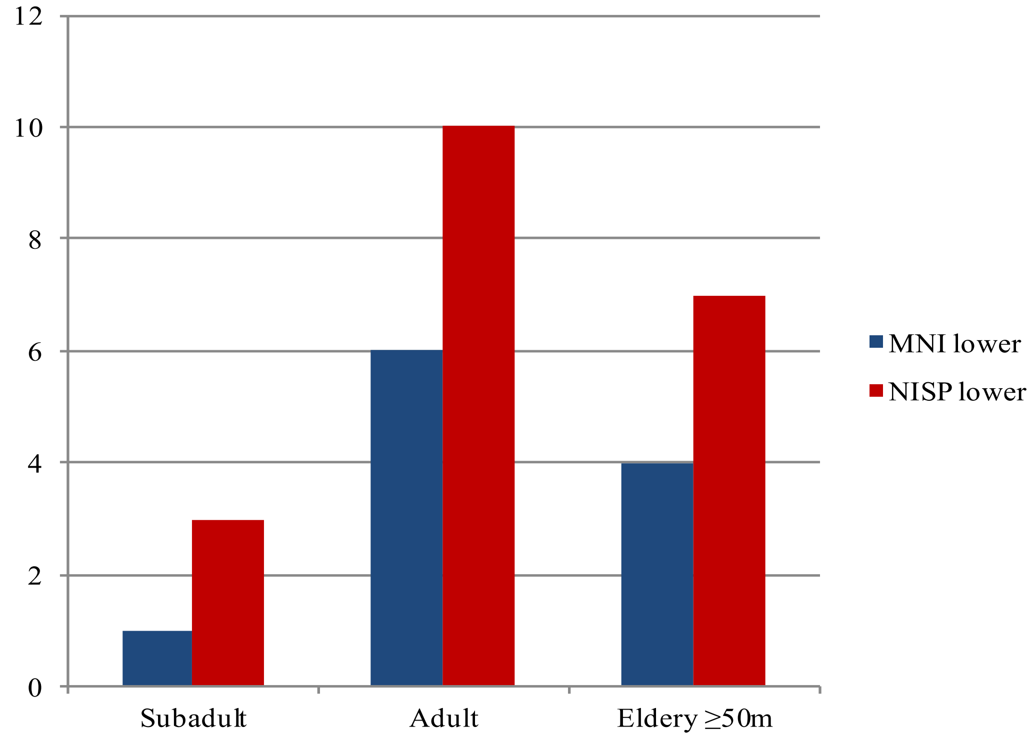


Figure 6-36 Lower dentition of Bovinae aged categories, MNI versus NISP.

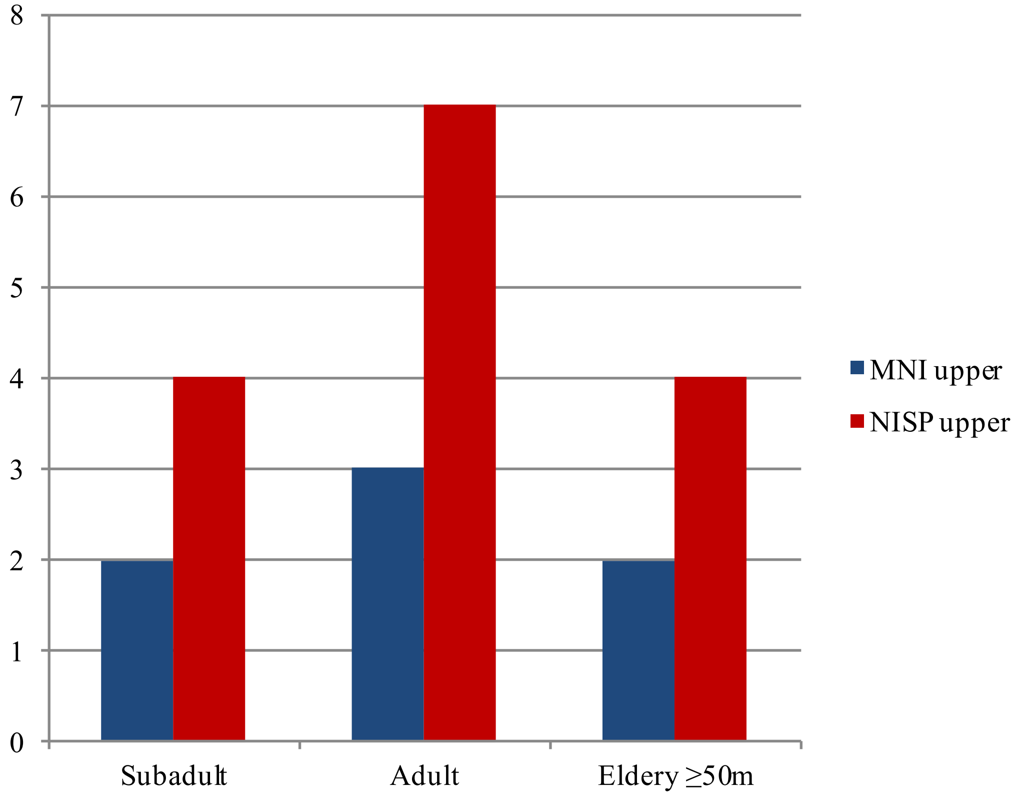


Figure 6-37 Upper dentition of Bovinae aged categories, MNI versus NISP.

6.4.12. Cetacea

Towards the southern edge of the site, the radius of a whale was excavated in square G5, Layer 3. The radius measures 90 cm in length and weighs 16.3 kg. It appears to have been intentionally placed upright in the ground. For a detailed discussion of this bone and its potential significance see Chapter eleven, section 11.6.5.

6.4.13. Summary of taxonomy

The taxonomic species list portrays a variety of taxa, indicating human exploitation of numerous habitats. It is possible some taxa are present in the assemblage simply because it is their natural habitat. However, there are butchery marks on most of the taxa represented in the assemblage and some taxa are outside of their natural environment, which indicates that humans are the primary agent of accumulation. The fish taxa alone portray a variety of water resources including; saltwater, freshwater, and brackish waters. Although, many species can inhabit numerous types of environments, some species, such as Scaridae, strictly feed on coral. Ground sharks and rays can be found in brackish waters but carpet and mackerel sharks are strictly saltwater. The presence of both hardshell and softshell turtles indicate the presence of still or slow moving shallow bodies of water.

The identification of the Greater Adjutant indicates that the species had a wider range that extended to North Vietnam in antiquity. Greater Adjutants are also typically found close to wetlands, open forests and grasslands. However, the unique ‘bone swallower’ behaviour of the stork and close association of the species with humans and human habitation suggests the stork may have been tempted to the site by the presence of middens and, perhaps, human burials. Further, this behaviour indicates that the stork may have influenced the taphonomy of the site as they can swallow small bones or animals whole.

The range of mammalian taxa likewise shows a diverse exploitation strategy, which indicates that a diverse range of environments were in close proximity to the site. The presence of macaques, and several large felids indicates the nearby presence of forest and woodland environments. Large bovids and deer form the major component of the mammalian taxa in the assemblage. The body part representation of the larger mammals (pigs, deer, and bovids) portray a similar pattern, as although all parts of the skeleton are present there is an over-representation of extremities and under-representation of axial elements. This pattern could potentially be related to human behavioural practices or exploitation strategies, such as, discarding these elements elsewhere during the butchery process. However, many researchers usually exclude axial elements or treat them separately in BPR counts because their paucity at sites is ambiguous (Stiner 1991; 2002; Lyman 1994a; 1994b). The vertebral column is particularly susceptible to in-situ destruction because their density is lower on average than the rest of the skeleton, and the projecting processes on vertebrae are more vulnerable to breakage than robust limb bones (Stiner 1991; 2002; Lyman 1994a; 1994b). Thus, the under-representation of axial elements at CCN should be interpreted with caution.

6.5. Conclusion to Chapter six

This chapter covered a detailed analysis of the taphonomic and taxonomic faunal analyses of CCN. Spatial analysis of the distribution of faunal remains suggested that some areas of the site had a higher concentration of bone fragments than others. This was particularly true of the deer antler deposit and the north-western corner of the site. Except this deposit, there was no perceivable difference in taxonomic distribution of the faunal remains.

The taphonomic analysis showed most of the faunal remains were in a robust, well-preserved condition, with minimal evidence for abrasion, rodent gnawing, carnivore activity, or burning. However, manganese surface staining was a very common feature observed, which is probably a product of a wet and decomposing environment. The butchery marks on the faunal remains indicate that a variety of processing stages were occurring at or near the site. The range of skeletal elements suggests whole carcasses processed. Although there is a relative paucity of axial elements, differences in bone density often creates discrepancies in the survival of vertebrae and ribs. Axial elements tend to be susceptible to a higher degree of fragmentation, which means small fragments of these elements may be ‘hidden’ within the unidentified fragments.

The range and diversity of the taxa exploited at CCN suggests the presence of a variety of environmental niches within close proximity to the site including; estuarine, fresh, and salt waters, swamps, forests, woodlands, and grasslands (see section 9.3. for more detail). Although there was a diverse variety of taxa, the majority of the assemblage was dominated by large bovids and deer.

CHAPTER SEVEN
TAPHONOMY AND TAXONOMY: MAN BAC

7.1. Introduction

THIS chapter provides a detailed taphonomic and taxonomic faunal analysis of the 2001, 2004–05, and 2007 excavations of Man Bac. The layout of this chapter follows directly on from Chapter six with an analysis of the spatial and temporal distribution of faunal remains, a detailed taphonomic analysis of post-depositional processes that have affected the assemblage, and finally a taxonomic analysis of the relative proportions of taxa. In particular, this last section includes a detailed analysis of body part representation and ageing profiles for pigs, canids, deer, and bovids. Chapter six already detailed the environmental niches for many of the taxa, so this is only covered for taxa not found in CCN.

7.2. Assemblage count and distribution

A TNF of 4557 bone fragments were analysed from the 2001, 2004–05, and 2007 excavations of MB (Table 7-1). Within this count 1518 fragments could not be identified to taxon or skeletal element (Table 7-2). The number of bones that could be identified to taxa or skeletal element was 3039, or 3013 only counting identifiable taxa. The bulk of the material came from the 2004–05 excavations and from stratigraphic Layer 1 (Table 7-3).

Table 7-1 Summary of the distribution of TNF from three different excavation seasons.

Excavation	TNF	%TNF
2001	558	12.2
2004–05	3176	69.7
2007	823	18.1
Total	**4557**	**100.0**

Table 7-2 Summary of the distribution of TNF from three different excavation seasons.

Totals	Counts	%TNF
TNF	4557	100.00
UNID	1544	33.88
NISP taxa	3013	66.12
NISP taxa & element	3039	66.69

In terms of the distribution of bone fragments, when comparing the TNF per spit for all excavations there appears to be three main concentrations of bone deposition with one or two hiatuses (Table 7-3, Figure 7-1). The spike in concentration in L4.2 (spit 4, Layer 2) is primarily the result of an almost complete skeleton of a very young pig from the 2001 excavation in square A2.

Table 7-3 Distribution of TNF across layers.

Layers	TNF	%TNF
Layer I	3174	70.0
Layer II	999	22.0
Layer I-II	17	0.4
Layer III	251	5.5
Unknown	116	2.5

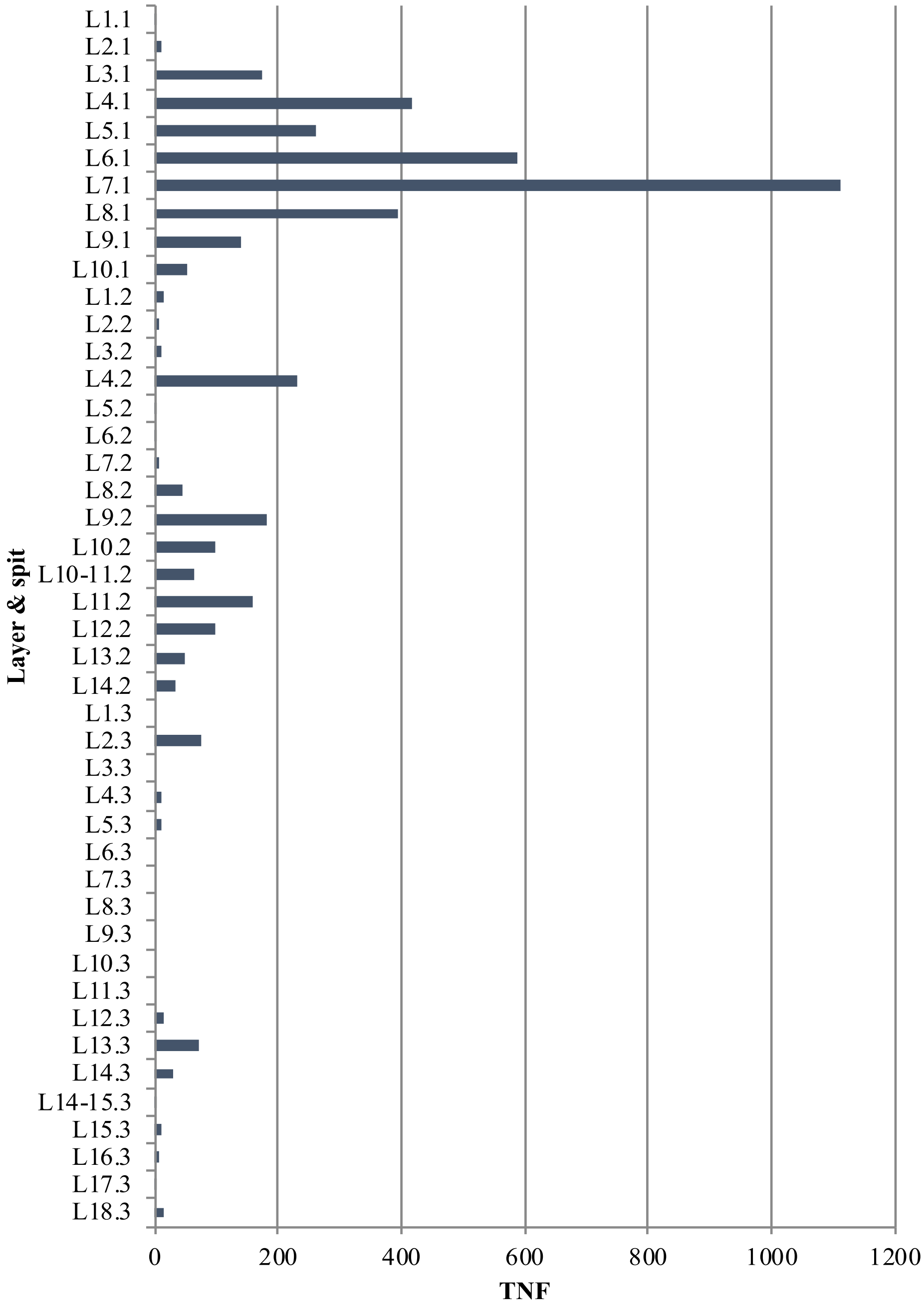
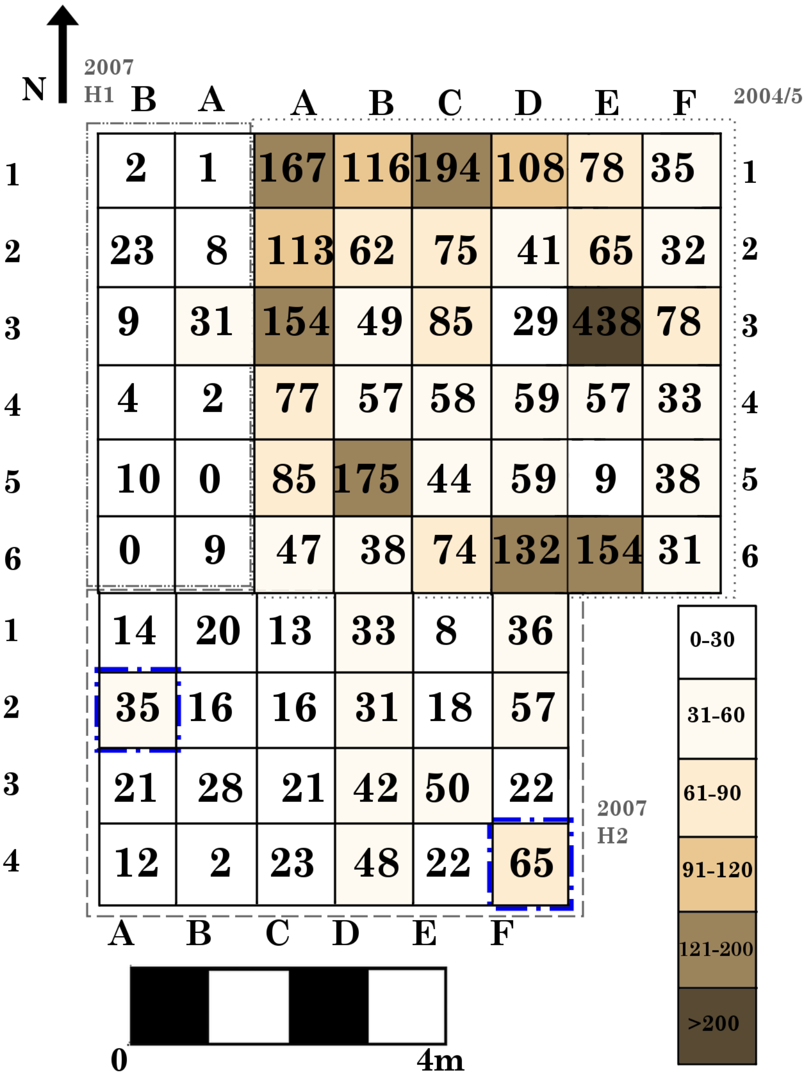


Figure 7-1 TNF per spit in MB assemblage.

7.2.1. Spatial analysis

A spatial analysis comparison of the 2007 and 2004–05 excavations is summarised in Figure 7-2. The 2001 and 1999 excavation seasons were not able to be used in the comparison because there was no available information on square numbers. A total of 653 fragments were excavated from 2007 H2 and 99 from H1. By contrast, 3146 fragments were excavated from the 2004–05 pit. Since the excavation methods were complementary this likely represents real differences in bone fragment distribution, which could potentially relate to site use patterns. When comparing the spatial patterning of the 2007 excavations, the frequency of bone fragments is relatively even between squares. Although squares F4 and A2 (2007, H2 pit) were sieved, this does not appear to have made a significant difference in the amount of material recovered. Whereas, in the 2004–05 square the majority of the bone fragments are located along the northwest side



	B	A	A	B	C	D	E	F	
1	2	1	167	116	194	108	78	35	1
2	23	8	113	62	75	41	65	32	2
3	9	31	154	49	85	29	438	78	3
4	4	2	77	57	58	59	57	33	4
5	10	0	85	175	44	59	9	38	5
6	0	9	47	38	74	132	154	31	6

	A	B	C	D	E	F
1	14	20	13	33	8	36
2	35	16	16	31	18	57
3	21	28	21	42	50	22
4	12	2	23	48	22	65

Figure 7-2 Schematic diagram of the distribution of faunal fragments across the 2007 and 2004–05 excavation squares. The grey dashed lines show the distribution and layout of the excavation squares and the small blue dashed square in H2 were sieved. Refer to Figure 5-2 for complete site diagram.

of the trench (A1–3, B1, C1, D1).

The square with the highest frequency of bone fragments was E3 at 438 in the 2004–05 trench. However, most of these fragments were unidentifiable, so it is difficult to determine whether this represented a 'special deposit'. Nonetheless, there are other areas of the site where 'special deposits' of animal remains were excavated, and many of these deposits are located in the lower layers.[1] Mostly notably, an entire elephant maxilla, 60 cm in length, was carefully buried in Layer 3 (spit 15–16, 2007 H2; Lorna Tilley pers. comm., see sections 7.4.12. and 11.6.2. for more discussion). Also intriguing, was an almost entire juvenile pig skeleton from the 2001 pit in Layer 2 (spit 4, A2). Unfortunately, there are no records or photographs of this juvenile pig in-situ so it is difficult to ascertain whether this was a deliberate burial. The intact survival of a juvenile pig (<6–7 months) with such delicate bones indicates minimal disturbance of the skeleton.

7.3. Taphonomy

Taphonomic analyses discussed below include fragmentation size and preservation of bone, weathering and staining, burning, modifications by carnivores and rodents, and butchery. See Chapter five (section 5.3) for details and discussion on the following methods.

7.3.1. Fragment size and preservation

The majority of the bone fragments were between 0–50 mm in size (91.2%, TNF 4128, Table 7-4). Forty-one fragments were over 10 cm in length, with the largest fragment measuring over 25 cm. The majority of the bones were in a robust state of preservation, especially the pig mandibles and maxillae. The presence of an almost complete young pig skeleton (2001 pit layer two, spit 4, A2) shows that at least in some areas of the site, there was minimal post-depositional disturbance.

Table 7-4 Fragmentation categories in assemblage.

Size (mm)	TNF	%TNF
0-50	4128	91.19
50-100	358	7.91
100-150	31	0.68
150-200	8	0.18
200-250	1	0.02
250-300	1	0.02
Total	**4527**	**100.00**

The fragmentation ratio was determined following Lyman (2008, 251–2). For pigs, femurs and maxillae were the most fragmented elements (Table 7-5). The degree of fragmentation of maxillae is notable (NISP 108,

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[1] For a discussion of the term 'special deposit' and its significance in relation to CCN and MB see Chapter eleven section 11.6.1.

MNE 48, and ratio 2.3:1), compared to mandibles (NISP 30, MNE 18, ratio 1.7:1). Although maxillae are more fragile than mandibles, this difference in NISP and MNE is probably too great to be solely a consequence of bone density (see section 7.4.8 for more details).

Canidae elements were not very fragmented (Table 7-6). For deer, antlers and pelvises were most fragmented (Table 7-7), while ulnae were more fragmented for bovids (Table 7-8).

A comparison of the fragmentation ratios between CCN and MB suggests the deer and bovids from MB are comparatively less fragmented than CCN (see Chapter six, section 6.3.1.). Although the extent of fragmentation with pigs is fairly comparable between sites. The greater extent of fragmentation at CCN could simply be the result of a larger sample as opposed to greater post-depositional taphonomic breakage.

Table 7-5 Fragmentation ratio for Suidae.

Element	NISP	MNE	NISP:MNE
Femur	9	4	2.3:1
Maxilla	108	48	2.3:1
Scapula	17	9	1.9:1
Mandible	30	18	1.7:1
Pelvis	5	3	1.7:1
Radius	7	5	1.4:1
Humerus	21	16	1.3:1
Phalanges	22	17	1.3:1
Tibia	8	7	1.1:1
Metapodials	30	28	1.1:1
Fibula	2	2	1:1

Table 7-6 Fragmentation ratio for Canidae.

Element	NISP	MNE	NISP:MNE
Pelvis	2	1	2:1
Tibia	4	2	2:1
Mandible	2	2	1:1
Maxilla	3	3	1:1
Humerus	1	1	1:1
Ulna	3	3	1:1
Radius	1	1	1:1
Metapodials	4	4	1:1

Table 7-7 Fragmentation ratio for Cervidae.

Element	NISP	MNE	NISP:MNE
Antler	9	3	3:1
Pelvis	6	2	3:1
Mandible	6	3	2:1
Femur	2	1	2:1
Tibia	2	1	2:01
Radius	7	4	1.8:1
Metapodials	11	6	1.8:1
Scapula	4	2	1.3:1
Ulna	6	5	1.2:1
Phalanges	10	9	1.1:1
Humerus	1	1	1:1

Table 7-8 Fragmentation ratio for Bovinae.

Element	NISP	MNE	NISP:MNE
Femur	3	1	3:1
Ulna	3	2	1.5:1
Tibia	1	1	1:1
Metapodials	2	2	1:1
Phalanges	1	1	1:1

7.3.2. Weathering, abrasion, surface staining

The majority of specimens were recorded as weathering Stage 1 (TNF 1773, 89.4%). This pattern is similar across taxa with no difference between identifiable or unidentifiable fragments. Only four unidentifiable fragments were recorded as weathering Stage 4. Two specimens were recorded as having differential weathering stages. One was a muntjac sub-terminal phalange between Stages 1 and 2 (MBANU-1259) and the other was a cf. rhinoceros rib, which was between Stages 2 and 3 (MBANU-1620). This could indicate one surface of the bone was exposed to the elements for a longer duration of time, rather than quickly buried.

Eight samples were recorded as showing evidence of pitting. The majority of the fragments had angular breakage lines (95.4%, TNF 3661), with only 22 fragments being recorded as having rounded edges (0.6%).

In general, the faunal remains were a slightly reddish colour, which is probably related to the colour of the soil and may indicate the presence of iron oxide. The frequency of Mn staining at MB (229 fragments, 5.3%) was considerably less than at CCN. Since Mn staining has been shown to occur in wet and decomposing environments (Shahack-Gross et al. 1997; López-González et al. 2006; Marín Arroyo et al. 2008), this would suggest that MB was comparatively dry and less humic than CCN.

Twenty-six fragments were also recorded as having hard concretions on the surface, similar to breccia. Given the karst limestone environment, these concretions may be related to calcium carbonate precipitation on the bone surface (O’Connor et al. 2017).

7.3.3. Burning

Only 208 (0.5%) fragments showed signs of burning, with a further 16 (0.04%) showing signs of calcination. Unlike CCN, no concentrations of burnt bone were evident.

7.3.4. Rodent and carnivore modifications

Eleven fragments demonstrated modifications consistent with carnivore bites, with another five showing signs of rodent gnawing (Table 7-9). Five skeletal elements with bite marks also showed signs of digestive corrosion (Lyman 1994b, 204–5). Carnivore bite marks and evidence for digestion were mostly recorded on long bones of pigs and medium mammals. Figure 7-3 (A&B) displays a pig sub-terminal phalange with puncture marks probably caused by carnivore canines on the dorsal and plantar surface. This is characteristic of carnivore punctures where either side of the bone has collapsed under the pressure of carnassials leaving an oval depression with flakes of exterior bone pressed into the puncture (Lyman 1994b, 206, Figure 6.20 a). Figure 7-3 (C&D) shows a fragment of mammalian bone that displays carnivore pitting and signs of digestive corrosion (Lyman 1994b, 206, 210, Figure 6.24). This indicates the bone has passed through the digestive

Table 7-9 Details of modifications by rodents and carnivores.

Type	N	Taxa	N	Element	N
Bite	11	*Sus* cf. *scrofa*	6	Extremities	3
Potential bite	3	Bovinae	1	Long bones	6
Digestion	5	Mammal	6	Vertebra	1
Gnaw	5	UNID	2	UNID	5

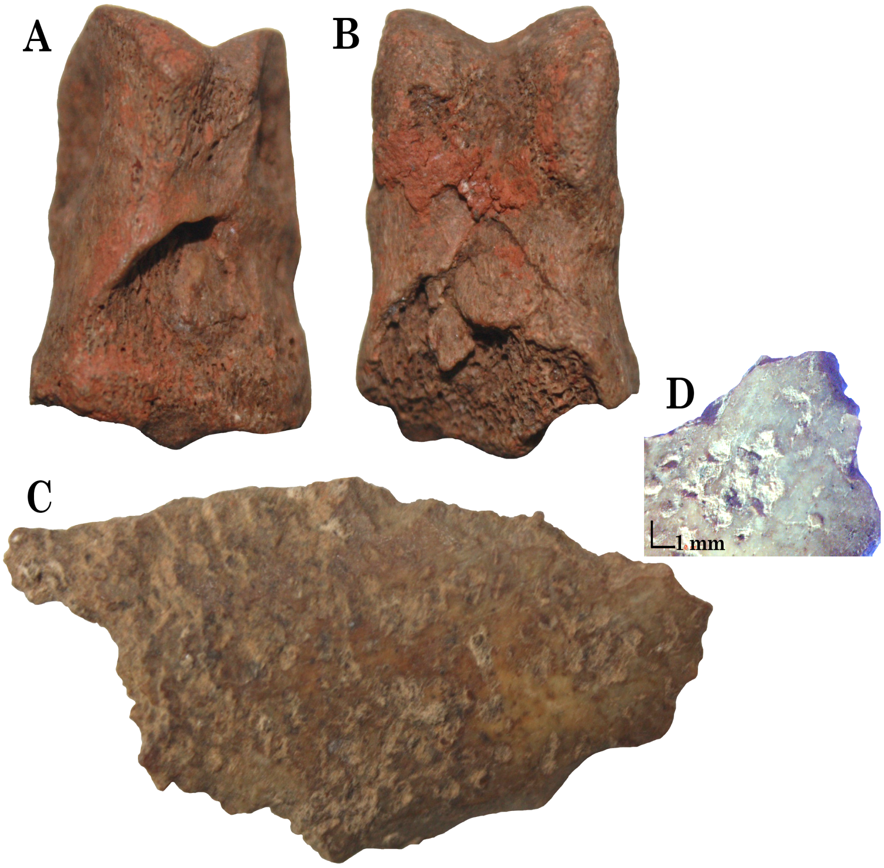

Figure 7-3 Top: sub-terminal pig phalanx with carnivore bite marks (MBANU-004, layer 1 spit 9 C4). A, dorsal surface with carnassial puncture, B, plantar surface with inward bone compression. Below: mammal bone fragment with carnivore bite and digestion marks all over the surface (MBANU-1023, layer 1 spit 7 E6). C, exterior surface of bone fragment, D, microscope detail of acid etching and pitting on surface of bone. Scale of macro images =1 cm; scale of micro image =1 mm.

tract or has been regurgitated after some time in the stomach (Lyman 1994b, 210, 212). The presence of carnivore bite marks and digestion links to the presence of domesticated dog at MB, and indicates that dogs had access to bone scraps, or were at least scavenging (see section 11.4.1. in discussion). Radiocarbon dating of a dog mandible from MB untaken by the author (RKJ) conform to dates previously published, though exactly how this relates to the 'occupation layers' is still unclear (see Chapter ten, section 10.1.5.).

7.3.5. Butchery

There were 15 elements that displayed butchery marks and a further two ambiguous marks (Tables 7-10). Butchery marks are evenly distributed across Layers 1 and 2 and randomly scattered across squares. The deepest cutmarked bone is on a pig basal phalanx in Layer 2 (spit 14). The closest to the surface includes a pig humerus with three parallel, oblique cutmarks on the caudal surface, proximal to the olecranon fossa (Figure 7-4). Cutmarks in this location are consistent with attempts to separate the humerus and the ulna by removing the triceps insertion proximal to the olecranon fossa. A muntjac antler with a chopmark on the pedicle in Layer 1 (spit 5), probably to remove the antler from the skull.

Table 7-10 Frequency of skeletal elements with butchery marks across layers and spits.

Layer 1		
Context	**Spit**	**N**
2004-2005	5	2
2004-2005 & 2007	6	2
2004-2005	7	4
2007	8	1
Layer 2		
Context	**Spit**	**N**
2001	4	3
2001	5	1
2004-5	12	1
2004-5	14	1

Table 7-11 details the species, placement and type of butchery mark. All of the butchered elements were recorded on mammal remains, especially pigs and deer. There was one chopmark on a cf. *Bos* hamate. In terms of more unusual finds, a large carnivore rib had two parallel cutmarks on the proximal end and is also highly polished and smoothed along the shaft. A burnt dog (*Canis familiaris*) right mandible has abrasion marks on the interior/lingual surface. These marks run oblique and transversely to the grain of the bone in line with M1–3. Their location on the lingual surface may represent an attempt to remove the tongue (Rixson 1989, 56–57).

There is evidence for a range of different butchery practices taking place, which indicates that some carcasses were being processed on site. Further, the presence of bone artefacts confirms that the final processing stage was also taking place. Following Amano et al. (2013, 326) and Rixson (1989):

Primary: Evisceration is suggested through cutmarks on the ventral surface of ribs. Skinning is suggested by chopmarks to the base of deer antlers. Removal of the feet is evident through cut and chopmarks on a pig basal phalanx and a bovid os crochu.

Secondary: Gross dismemberment of the carcass is suggested by cutmarks to the pelvis and proximal femur. Disarticulation of units into smaller portions is suggested through cutmarks to the distal humerus, and proximal radius of pig and the proximal ulna of a medium-sized cervid.

Tertiary: The dog mandible with abrasion marks on the lingual surface is suggestive of defleshing. There was also one long bone shaft with a potential percussion mark.

Fifth stage: Working of bone is demonstrated through the presence of bone artefacts at MB. Although it is out of the scope of this thesis to analyse the modified bone elements, there will 11 definite artefacts, three modified elements, and a further four potential artefacts or modified elements (Table 7-12).

Figure 7-4 Left pig humerus (MBANU-007, Layer 1 spit 5, E2) with three parallel, oblique cutmarks on the caudal surface, proximal to the olecranon fossa. Scale on macro photo = 2 cm, micro photo = 1 mm.

Table 7-11 Placement and type of butchery marks in the MB assemblage.

Taxa	Element	Placement	Cutmarks	Chopmarks	Abrasion	Percussion
Muntiacus & *Cervus*	Antler	Burr		2		
Canis familiaris	Mandible	Lingual			1	
Sus cf. *scrofa*	Humerus	Distal	1			
Sus cf. *scrofa*	Radius	Proximal		1		
Sus cf. *scrofa* & Cervidae	Ulna	Proximal	2			
cf. Carnivore	Rib	Proximal	1			
Sus cf. *scrofa*		Distal, ventral	1			
Mammal	Pelvis	Acetabulum, ventral	1			
Cervidae, cf. *Muntiacus*		Ventral	1			
Cervidae	Femur	Proximal	1			
Bovinae, cf. *Bos*	Os crochu	Dorsal		1		
Sus cf. *scrofa*	Phalanx, Basal	Dorsal	1			
Mammal	UNID		1			
Mammal	Long bone	Shaft	1?			1?

7.3.6. Summary of Taphonomy

Analysis of weathering and abrasion shows the fauna material from MB is in robust, well-preserved condition. The fragmentation ratio was relatively lower compared to CCN, although pig maxillae had a higher fragmentation ratio at MB. Signs of burning, rodent, or carnivore modification to bone was minimal, but the presence carnivore bite marks and digestive etching on some bones suggests that dogs had access to some bone scraps.

There was a much lower occurrence of Mn staining compared to CCN. In general, the good preservation, low weathering stage, minimal abrasion, and angular breaks suggests that the majority of the assemblage was relatively quickly deposited with little post-depositional disturbance. Some of the bone fragments displayed a hard breccia crust on the surface, which may be related to the karst limestone landscape.

The butchery marks on the faunal remains indicate a variety of butchery practices were taking place from primary to tertiary, as well as the final processing stage of bone working. However, unlike CCN there was no evidence for the processing for marrow.

Table 7-12 Summary of artefacts and anthropogenically modified elements in the MB assemblage.

ID MBANU-	Exacavation	Context	Taxon	Element	Anth modified	Description
542	2001	L4, spit 2, B2	Mammal	UNID	Artefact	Probably long bone shaft. Bone point with some end shaped into a point. Surface is smoothed and polished. Visible use wear.
602	2001	L4, spit 2, B2	Cervidae cf. *Muntiacus*	Antler, tip	Artefact	Outer surface smoothed and polished. Base of antler has been cut transversely. Two perforated holes approximately 2.35mm in diameter on opposite sides of the beam.
638	2001	L4, spit 2, C2	Mammal	Long bone, shaft frag	Artefact	Bone point. Smoothed along edges and rounded. Pointed end has visible use-wear marks.
986	2004–05	L1, spit 6, D4	UNID		Artefact	Polished and shaped on all sides. Roughly oval/rectangular in shape. Abrasion marks visible on the surface.
1042	2004–05	L1, spit 6, B4	UNID		Artefact	Bone point, shaped and polished on surface. Abrasion marks visible on one surface.
1082	2004–05	L1, spit 6, E4	UNID		Artefact	Rectangular shaped point, polished surface. Abrasion marks visible.
993	2004–05	L1, spit 7, D5	UNID		Artefact	Roughly rectangular shape, coming to a point. Appears rounded and polished. Abrasion marks on one side and point.
1267	2004–05	L1, spit 7, D3	Mammal	UNID	Artefact	Polished and rounded on all surfaces.
1354	2004–05	L2, spit 9, A5	Fish	Spine, 1st dorsal complete	Artefact	Shaped into a point. Smoothed and polished.
730	2004–05	L4, B3	Mammal	Long bone, shaft frag	Artefact	Polished and rounded surface
1412	2007	L2, spit 9, C2	Bovinae	Metapodia, distal frag. Fused.	Artefact	Bone has been split in half longitudinally and transversely. The distal end of the bone has been rounded but appears to be quite pitted- as though it was used to pound something. The surface was heavily concreted so light acetic acid was used to remove this for c5mins which worked extremely well. Showed it to Hallie and Kate and they didn't think it looked like a pathology.
733	2004–05	L1, spit 4, F5	Fish	Spine	Artefact?	Rounded into a sharp point?

1240	2004–05	L2, spit 11, A1	*Sus cf. scrofa*	Phalanx- SubT. Fused.	Artefact?	Damage on distal and proximal facets. Two small round holes on medial and lateral side of shaft.
987	2004–05	L1, spit 6, D4	Mammal cf. Carnivora	Rib, proximal + shaft	Modified	Carnivora cf tiger or bear sized rib? Two cutmarks at the proximal end. Whole rib is very smooth and polished.
1083	2004–05	L1, spit 6, E4	UNID		Modified	Possible artefact debitage, abrasion marks on surface. Looks like attempt was made to shape the bone then abandoned.
097	2004–05	L2, spit 5, D5	*Muntiacus muntjak*	Antler, tip	Modified	Antler is extremely smooth and polished
1355	2004–05	L2, spit 9, A5	Fish	Spine, distal frag	Modified?	Distal end is flattened and polished but this may be natural.
1567	2007	L2, spit 9, F3	Mammal	UNID, shaft frag	Modified?	Possible artefact debitage. Both surfaces are polished. Possible drill hole with groove marks. May be a rhino nasal horn frag?

7.4. Taxonomy

This section follows the outline and methodology used in the previous chapter (section 6.4). For canids, pigs, deer, and bovids body part representation is covered. For canids, and pigs age profiles are discussed. As detailed in section 5.2.4. fish and Elasmobranchii were not part of the analysis for this study.

7.4.1. Taxon representation and quantification

Out of 4557 TNF, 66.1% (3013 NISP) could be identified to taxonomic class. Mammals clearly dominate the assemblage, accounting for 96.1% of identified taxa (2895 NISP; Table 7-13). Reptiles, birds, and Crustacea follow well-behind, accounting for only 3.9% collectively (118 NISP). Table 7-14 (next page) lists the taxa identified in the MB assemblage. Overall, there is considerably less variety in taxa compared to CCN and this does not appear to be a function of sample size (see Chapter nine, section 9.2.1.).

A comparison of NISP, MNE, and MNI values per mammalian taxa shows that pigs clearly dominate all three counts (Table 7-15) while the second most abundant taxon are deer, followed by canids. The MNI values in this table were constructed using conservative estimates by treating the assemblage as one aggregate, i.e., not separating layers or spits (see section 5.5.). Classification of age was taken into account for pigs, based on the presence/absence of dp4 or P4 and M3. Using this method, the MNI of 16 for pigs is represented by 10 juveniles/subadults and six adults. There is at least one male and one female adult pig based on canines.

However, when treating the assemblage layers as separate aggregates, the MNI of pigs increases to 21 (Table 7-16). Of the dentition that could be classified into ages, ten were juvenile/subadults, and nine were adults (in Layer 3 there were three upper M2s that cannot be categorised into ages). This clearly portrays one of the major problems with MNI that Grayson (1984) and Lyman (2008) have discussed in detail, which is that MNI is greatly affected by how aggregates are determined.[2]

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[2] For details on the excavation methods see sections 5.2.3 and 5.2.4., for further discussion of the issues with MNI see section 5.5.1.

7.4.2. Reptiles

Turtles represent the majority of reptiles within the assemblage. The NISP for Geoemydidae and Trionychidae are comparable and fairly low (15 and 20 respectively). The majority of the elements were carapace or plastron fragments. The only postcranial element recorded was a Geoemydidae right scapula. One pleural fragment of a carapace resembled the painted terrapin (*Batagur borneoensis*) or river terrapin (*B. affinis, B. baska*; 2001, L1 spit 3 B1). It is more likely to be the river terrapin as the painted terrapin inhabits Borneo and the Penninsulas of Indonesia, Malaysia, and Thailand (Asian Turtle Trade Working Group 2000a; 2000b; Horne et al. 2016). River terrapins inhabit freshwater rivers when they are juvenile but tend to move towards estuarine areas when they are adults (Kegler 2011). They were once widespread throughout SEA, but are now critically endangered and are regionally extinct in Vietnam (Asian Turtle Trade Working Group 2000a; Kegler 2011).

Only two Chelonioidea (sea turtle) fragments were recorded, one plastron fragment in the 2004–05 tench (L1 spit 9 A3), and one burnt carapace in the 2004–05 trench (L1 spit 7 E6). Six *Varanus* spp. elements were recorded including, four vertebrae (2001 trench L1 spit 3 B1; spit 5 C2; 2004–04 trench L1 spit 7 C5; and B4), one right femur (2007 H2 trench L1 spit 8 E4), and one long bone shaft (2007 H2 trench L2 spit 12 B3).

7.4.3. Birds

Only four elements of birds were recorded; including a proximal right femur (2004–05, L1 spit 6 E4), a proximal carpometacarpus (2004–05, L1 spit 5 E3), a fragment of a metatarsal (2004–05, L1 spit 8 D2), and a long bone shaft (2007, L1 spit 6 D1). Unfortunately, none of the elements could be identified to family.

7.4.4. Primates

Only one element of a primate was recorded in the whole assemblage. This was a distal left humerus of an adult macaque excavated in Layer 2 (spit 4 A2). The bone is in robust condition and the mid-shaft break appears to be a ‘green’ break, indicating it was broken when fresh.

Table 7-13 NISP and %NISP of taxonomic classes, in order of abundance.

Class	NISP	%NISP
Mammal	2895	96.1
Reptile	111	3.7
Aves	4	0.1
Crustacea	3	0.1
Total	**3013**	**100**

Table 7-15 Comparison of NISP, MNE, and MNI of mammalian species.

Taxon	NISP	MNE	MNI
Rodentia spp.	5	5	2
Muridae (cf. *Rattus* spp.)	2	2	1
Hystrix spp.	1	1	1
Macaca spp.	1	1	1
Felidae	1	1	1
Viverridae cf. *Viverra* sp.	3	3	1
Canidae	27	23	4
Aonyx cincereus	2	2	2
Sus cf. *scrofa*	565	327	17
Cervidae spp.	91	51	5
Bovinae	21	15	2
Rhinocerotidae	7	5	1
Totals	**726**	**436**	**37**

Table 7-16 MNI of *Sus* cf. *scrofa* treating layers as separate aggregates.

Layer	NISP	MNI	Juv/ subadult	Adult
L1	276	11	5	6
L2	224	7	4	3
L3	43	3	1	0
Total	**543**	**21**	**10**	**9**

Table 7-14 Species list for MB.

Class	Order	Family	Taxon	Common Name	NISP
Crustacea (Subphylum)					3
Reptilia				Reptiles	2
	Testudines			Turtles	65
		Chelonioidea (Superfamily)		Sea turtles	1
		Geoemydidae		Hardshell turtles	15
			cf. *Batagur borneoensis*	painted Terrapin	1
		Trionychidae		Softshell turtles	20
	Squamata	Varanidae	*Varanus* spp.	Monitor lizard	7
Aves				Birds	4
Mammalia				Mammals	1736
	Rodentia			Rodents	2
		Muridae	*Rattus* spp.	Rats	4
		Hystricidae	*Hystrix* spp.	Porcupine	1
		Large rodent			1
	Primates	Cercopithecidae	*Macaca* spp.	Macaque	1

Mammalia (continued)	Carnivora				24
		Canidae			
				Jackals, wolves, dhole, foxes	18
			Canis sp(p).	Jackals, wolves	3
			Canis familiaris	Dogs (domestic)	6
		Viverridae			
			Viverra spp.	Large Indian civet, large-spotted civet	1
			cf. *Viverra*	Civet cat	2
		Mustelidae	*Aonyx cinereus*	Otter	2
		Small carnivore			2
		Medium-large carnivore			9
	Artiodactyla				55
		Suidae	*Sus* cf. *scrofa*	Eurasian wild boar (domestic)	565
		Cervidae			44
			Cervus	Deer	25
			Muntiacus muntjak	Barking deer	10
			Small Cervid		2
			Medium-large Cervid		10
		Bovinae (subfamily)		Cattle, water buffalo	16
			cf. *Bubalus*	Water buffalo	3
			cf. *Bos*	Cattle	3
		Rhinocerotidae		Rhinoceros	8
			Rhinoceros spp.	Javan or Indian rhino	2
		cf. Rhinocerotidae			3
	Cetacea?			cf. dolphin	1

Mammalia (continued)	**Unordered:**	
	Mammal- small-medium (rodentia, primate)	9
	Mammal- medium (Cervidae, Suidae, Canidae)	177
	Mammal- large (eg Bovinae, large deer)	150
Unidentified		1544
Total		4557

7.4.5. Rodents

Only eight elements of rodents were identified and two families are represented. Muridae (rat-sized) is represented by four postcranial elements, including a left and right femur (2007 trench L1 spit 8 C2; and L2 spit 14 B1), a right tibia (2004–05 trench L2 spit 10 A3), and a pelvic fragment (2007 trench L2 spit 13 F4). A porcupine (*Hystrix* sp.) is represented by a single premolar or molar (2001 trench L2 spit 4 C2). There was also a relatively large proximal right ulna that was not identified, but was consistent in size with that expected of a bamboo rat (*Rhizomys* sp.; 2004–05 trench L1 spit 4 E3).

7.4.6. Carnivores

There were three families of carnivores identified in the assemblage: Canidae, Viverridae, and Mustelidae. Canidae will be detailed separately below. There were four elements of medium-large sized carnivores that could not be further identified. This includes an unfused phalange (2004–05 trench L1 spit 7 D1) and a fused sub-terminal phalange (2007 H2 trench L2 spit 9 E3) both phalanges the size of a medium-large felid. There was also an unidentified carpal bone (2007 H2 trench L1 spit 8 E3) from a medium-large carnivore and a right ulna shaft fragment (2007 H2 trench L1 spit 8 E4) that is probably from a canid. There were four other elements that were categorised as mammal cf. Carnivora including: a polished rib with cutmarks on the proximal dorsal aspect (2004–05 L1 spit 6 D4) mentioned previously, and a fragment of a proximal unfused ulna (2007 H2 M3). The ulna and the rib are relatively large, such as a medium-large felid or bear.

Three viverrid elements were recorded including: a right mandible with M1 categorised as *Viverra* sp. (2007 H2, L1 spit 8 E1), and a left proximal femur (2007 H2, L2 spit 11 D4) and left distal humerus (2007 H2, L3 spit 17 A2) both recorded as cf. *Viverra*.

Mustelid elements include: a left mandible with P2–4, alveoli for P1 and the canine (2007 H2, L1 spit 7 B4), as well as a single lower left P3 (2004–05 L1 spit 7 C2). These elements have been identified as *Aonyx cincereus* and there are at least two individuals present based on lower left P3s.

7.4.7. Identification of dog (*Canis familiaris*)

Canidae were the third most abundant mammal in the assemblage with a NISP of 27, MNE of 23, and MNI of 4 (MNI based on upper left P4s). A total of 18 elements could only be identified as Canidae, three as *Canis*, and six as *Canis familiaris* (Table 7-17). Most of the dentition and cranial elements were recorded as *C. familiaris* except for two fragmentary upper left P4s, a right upper canine, and a lower I3. The wolf and domestic dog can be easily distinguished in size and this is covered in Chapter eight, section 8.5. Distinguishing the dog from *Cuon* (dhole) or *C. aureus* (jackal) is possible using morphological criteria (see section 5.7.3 for details, Table 5-5 gives a summary).

The *C. familiaris* mandible was distinguished from *Cuon* on the basis of two cusps on the talonid of the LM1 (Figure 7-5). Further, the cusp morphology in general is more complex in *Canis* spp. compared to *Cuon* and, the LM1s in jackals have an elongated lingual surface compared to dogs. In upper dentition, again the upper M1s have a more complex morphology in *Canis* compared to *Cuon*, especially in the talonid (Figure 7-6). Compared to the UM1s in jackal, Piper et al. (2012) and Amano (2011, 112) point out that dogs are broader in the labial-lingual direction but the paracone and metacone is elongated in jackals.

A distal humerus and tibia were recorded as *Canis* on the basis of morphological differences between *Cuon* and *C. lupus* (Pionnier-Capitan et al. 2011). For the humerus the angle and extension of the medial epicondyle in the medio-proximal direction matches *C. lupus* compared to *Cuon* (Figure 7-5). In the distal tibia the malleoulus is more prominent and angular, while the distal border is more rounded, which compares more to *C. lupus* than *Cuon* (Figure 7-7). Although the oblique groove on the lateral edge was not visible (as in *C. lupus*), this feature is also not visible in modern domesticated dogs.

In summary, it is most likely that the 27 elements classified as Canidae or *Canis* are domesticated dog but, due to the lack of comparative measurements and/or information on morphological differences caution was exercised.

Table 7-17 Identified Canidae elements in the assemblage, specifying elements identified to *C. familiaris*, and *Canis*.

Element	Portion	Side	NISP	Identified
Maxilla	P3–4, M1–2	L	1	*C. familiaris*
	M1	L	1	*C. familiaris*
	P4	L	2	
	M1	R	1	*C. familiaris*
	M1–2	R	1	*C. familiaris*
	Canine	R	1	
Mandible	I2–3, C, P1–4, M1–2	L	1	Male *C. familiaris*
	Posterior frag	R	1	*C. familiaris*
	I3	L	1	
Humerus	Distal + shaft	R	1	*Canis*
Ulna	Proximal	R + L	3	
Radius	Distal	L	1	
Pelvis	Frag	R	2	
Tibia	Distal	R	2	*Canis*
	Proximal	R	1	
	Shaft	R	1	
Astragalus	Complete	L	1	
Calcaneus	Complete	R	1	
MT2	Proximal	L	1	
MT4	Complete	R	1	
MC2	Complete	L	1	
Metacarpal	Distal		1	
Total			**27**	

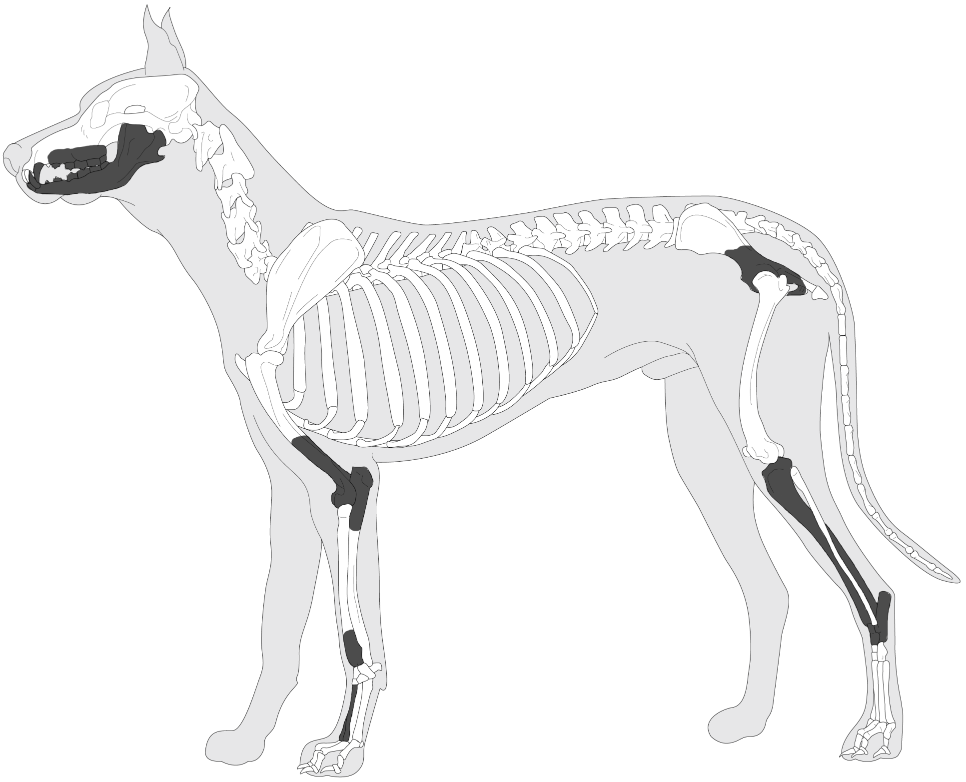
Figure 7-5 Specimen MBANU-044, *C. familiaris* left mandible with C, P1–4, M1–2. Note two cusps on the talonid of LM1 (2007 pit H2, Layer 2 spit 10, F2).

Figure 7-6 Left, MBANU-095, right, MBANU-213, *C. familiaris* right UM1s (from 2004–2005 Layer 2 spit 14 E1, and Layer 1 spit 7 D4). Note the oval shape of the M1 and broader labial-lingual dimension compared to the jackal.

Figure 7-7 Left (MBANU- 1642) *Canis* distal right humerus (left), note the angle and extension of the medial epicondyle and the proximal edge of the trochlea articulation. Right (MBANU-170) *Canis* distal right tibia (right), note the prominent and angular projection of the medial malleolus and round distal border. Excavated from 2007 H2, Layer 1 spit 1, F3 (MBANU-1642), and 2004-5 Layer 1 spit 8, A6 (MBANU-170).

7.4.7.1. Body part representation

The appendicular skeleton is reasonably well represented, as are cranial elements (Figure 7-8). The axial skeleton is lacking, although this may be related to the difficultly of identifying axial elements and they are less likely to survive. The absence of femora is notable since other long bones are present as well as the pelvis.



Référence : Dessin Michel Coutureau (Inrap), en collaboration avec Vianney Forest - © 1996 ArcheoZoo.org
D'après : Robert Barone, 1976. *Anatomie comparée des mammifères domestiques, Tome I Ostéologie - atlas*, Paris : Vigot, p. 25.

Figure 7-8 BPR of Canidae elements in the MB assemblage.

7.4.7.2. Ageing

In terms of ageing the Canidae material, the only element that was unfused was a proximal left ulna, which indicates the individual was less than 15 months (Amorosi 1989, 108). No deciduous teeth were recorded and the wear of the cusps of molar and premolars was present but not excessive. This indicates the canids at MB had reached adulthood but were not elderly individuals. See Appendix 3 for a summary of ageing data.

7.4.7.3. Pathologies

Some of the Canidae elements displayed signs of pathology. A right proximal tibia (MBANU-1054) displays distortion of the tibial plateaux, and a misalignment of the shaft

(Figure 7-9). There were also two calcanei (MBANU-1381, MBANU-1430) with severe pathologies that have resulted in misshaped morphology (Figure 7-10). In particular, the medial facet and process (sustentaculum tali) is misshaped in both calcanei. On the right calcaneus there is a small hole distal to this facet that may be the result of an infection. The lateral surface of the bone is very porous. Due to the distorted morphology it was difficult to confidently identify them as *Canis familiaris*, hence they were recorded as Carnivora cf. Canidae. All three elements were found in different contexts, the tibia (Layer 1, spit 6, D4) was a couple of spits above the left calcaneus (Layer 1, spit 8, E3), but the right calcaneus was found significantly below this (Level 2, spit 14, E1). Either there has been some significant stratigraphic mixing or there may have been two dogs at MB with severe pathologies to their posterior limb. Despite these pathologies these individuals nonetheless managed to survive until adulthood as indicated through epiphyseal fusion.

Figure 7-9 Specimen MBANU-1054, Canidae proximal tibia. The posterior surface (left) and cranial aspect (right) of a proximal right tibia (MBANU-1054) displays a distorted tibial plateaux (right) and a misalignment of the shaft (from 2004–2005 Layer 1 spit 6, D4). The posterior surface is displayed here because the anterior surface has been damaged post-depositionally. Scale = 1 cm.

Figure 7-9 Two calcanei recorded as Carnivora cf. Canidae with pathologies. Both MBANU-1430 left calcaneus (left), and MBANU-1381 right calcaneus (right) display misshaped medial facets and 1381 bone porosity on the lateral surface. MBANU-1430 excavated from 2007 H2 Layer 1 spit 8, E3, and MBANU-1381 from 2004–2005 Layer 2 spit 14, E1. Scale = 1 cm.

7.4.8. Suidae, body part representation

Sus cf. *scrofa* dominated the assemblage with a NISP of 565, MNE of 327, and MNI of 17. The MNI of 17 is based upper right dp4s, P4s and on treating the site as a single aggregate. When the layers are separated and treated as different aggregates the MNI increases to 21, based on upper dentition. In both cases, the presence of a very young pig was also taken into account (2001 excavation, Layer 2 spit 4 A2), this pig had no dentition but represented a different age class. The majority of the elements were found in Layers 1 and 2, and based on canines at least one male and female pig are present. A comparison of MNE% and NISP% values show the whole skeleton is represented including high and low meat-yielding elements (Figures 7-11 and 7-12).

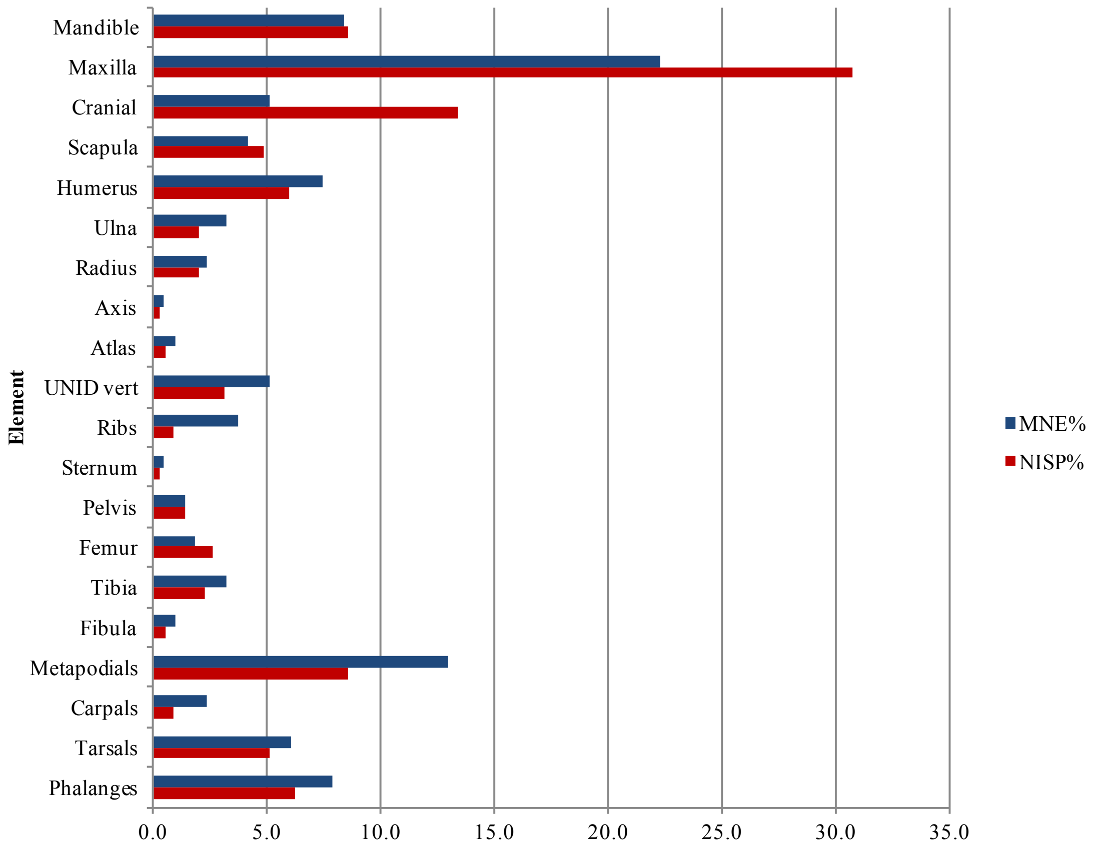
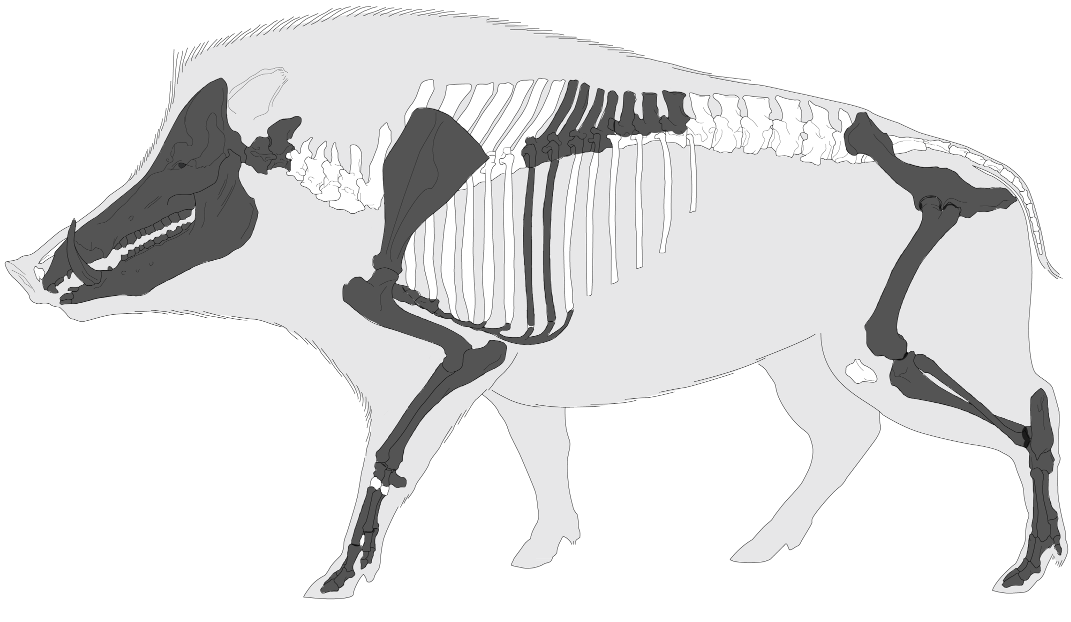


Figure 7-11 *Sus* cf. *scrofa* BPR comparison of %MNE versus %NISP.



Référence : Dessin Michel Coutureau (Inrap) - © 2003 ArcheoZoo.org
D'après : Léon Pales et Michel A. Garcia, 1981, *Atlas ostéologique pour servir à l'identification des Mammifères du Quaternaire - Herbivores*, Paris : CNRS, pl. 45.

Figure 7-12 Graphic representation of *Sus* cf. *scrofa* BPR.

One intriguing pattern is the relatively high proportion of maxillae and upper dentition compared to mandibles. A total MNE of 136 loose teeth were mostly classified as uppers (67 compared to 58).[1] This is unusual as mandibles have a higher density and are usually better preserved than maxillae (Devlin. et al. 1998; Park et al. 2008, 35). In Brain's (1981, 21) study of bone survival patterns in goats, mandibles and the distal end of humeri were the most resistant to destruction. This pattern in the MB assemblage suggests that there was a higher proportion of maxillae than mandibles, which may help to explain the higher fragmentation ratio of maxillae compared to mandibles (section 7.3.1). In other words, difference in bone density alone does not explain the higher fragmentation in maxillae; the greater abundance of maxillae compared to mandibles was probably a contributing factor.

It is possible the over-representation of maxillae relates to butchery practices, such as exploitation of the brain. Brain's (1981, 17–9) ethnoarchaeological research in the Namib desert in Southwest Africa among Hottentot villages found that during the butchery of goats, the brain was usually removed from the skull by smashing the occiput or basal surface of the skull. The palate and maxilla were often broken off as a unit, while the mandible was undamaged or minimally damaged (Brain 1981, 17–9). This type of practice would result in more damage and fragmentation to the maxilla than the mandible, partly because the maxilla is more fragile, but also because the mandible is less obstructive to the brain. At Niah Cave, pig brain exploitation was also suggested through refitted fragments from the squamous part of the temporal bone which displayed characteristic negative flake scars, suggesting the back of the skull had been smashed open to access the brain (Barton et al. 2013, 197, Figure 5.22).

7.4.8.1. Ageing of pigs

Classification of wear stages for dentition followed Lemoine et al. (2014) and Zeder et al. (2015) for fusion of postcranial elements (see Chapter five section 5.6. for detailed discussion). For dentition, three systems of classification were implemented and compared. Using the Specific System, 33 elements were used, while Simplified A had 44 and Simplified B had 56 (Table 7-18). Comparing the three Systems, the overall pattern is similar (Figures, 7-13, 7-14, 7-15). There is a dominance of young pigs, an age gap, followed by a few older pigs. Post-cranial data also supports the dominance of young pigs being slaughtered. The youngest individual was an almost complete juvenile pig skeleton

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[1] Loose teeth were counted separately.

was excavated during the 2001 season (as mentioned in section 7.2.1.). None of its bones had fused and based on the unfused axis and atlas, this pig was less than 6–7 months old when it died. See Appendix 3 for dental and postcranial fusion ageing data.

Table 7-18 Dental samples used per category.

System	Loose Lowers	Mandibles	Loose Uppers	Maxillae	Total used
Specific	3	4	11	15	33
Simplified A	5	5	16	18	44
Simplified B	7	7	21	21	56

Survivorship and mortality profiles were created for dental and postcranial data following Lemoine et al. (2014) and Zeder et al. (2015). The survivorship curve shows the proportion of pigs that survived beyond the age at which elements fused, or is indicated by wear stage. Figure 7-16, shows a sharp decline in survivorship using three systems (Specific, Simplified A and B), with the majority of pigs being slaughtered around 12 months of age (only 35–18% survival past 12 months). Except there is what Zeder at al. (2015, 142–5) refer to as a 'resurrection' between 7–18 months for fusion data. Zeder et al. (2015, 142–5) suggest these upswings are related to taphonomic factors, small sample sizes, or possibly human behaviour. However, I suspect it is also influenced by the methodology employed. The problem is probably partly based on the amount of time represented in each age Class since C and D represent only one month respectively, while E represents 10 months. If Classes C (8–12 months) and D (12–16 months) are combined the profile becomes one of diminishing survivorship, as expected (Figure 7-17).

Comparing Figure 7-17 the methods agree well with one another and demonstrate that the majority of pigs were killed at a young age. Approximately 10% of pigs survived beyond 52 months. However, the dental wear systems have noticeably sharper declining curves than the fusion scores. The reason for this difference is more clearly illustrated in Figure 7-18 which shows there are some classes that fusion scores are revealing that may be capturing pigs that are in-between dental stages. The dental scores portray a drop in survivorship c. 8–12 months, while according to fusion scores there is a dramatic drop in survivorship after 24 months. The combination of the fusion and dental survivorship scores suggest that the vast majority of pigs at MB died either before or shortly after 24 months, and a few individuals lived beyond five years.

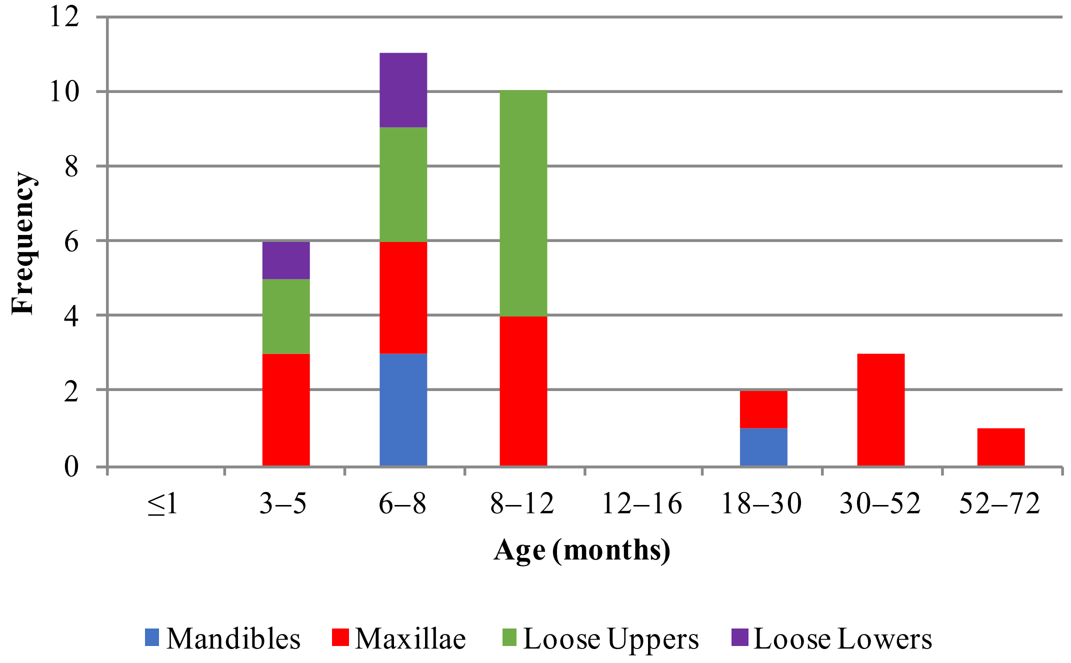


Figure 7-13 Specific ageing system.

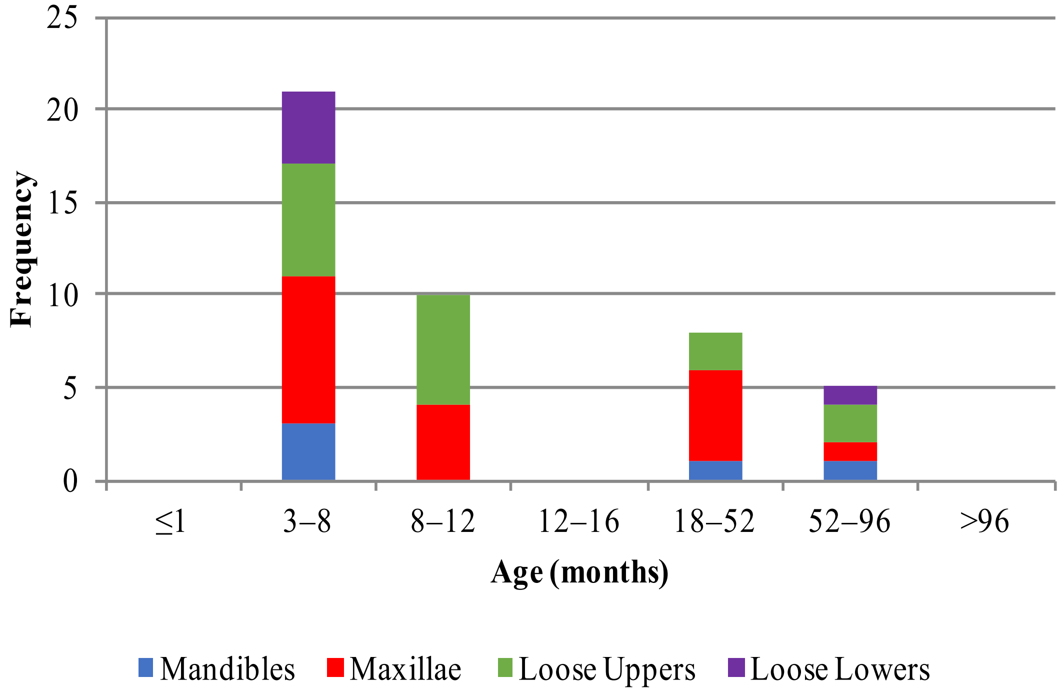


Figure 7-14 Simplified A ageing system.

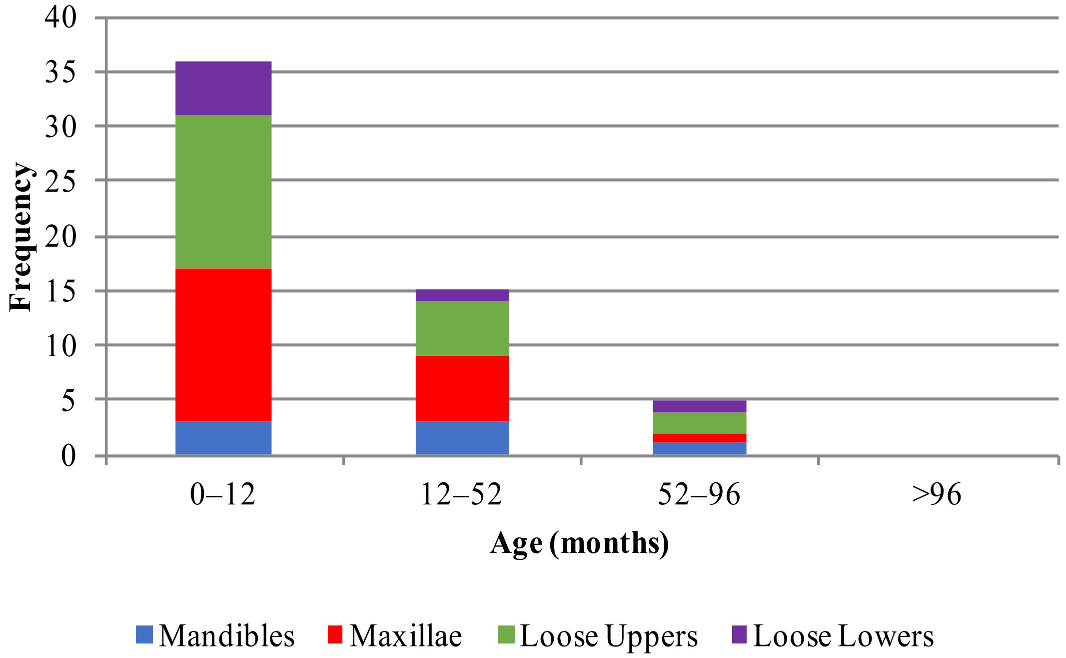


Figure 7-15 Simplified B ageing system.

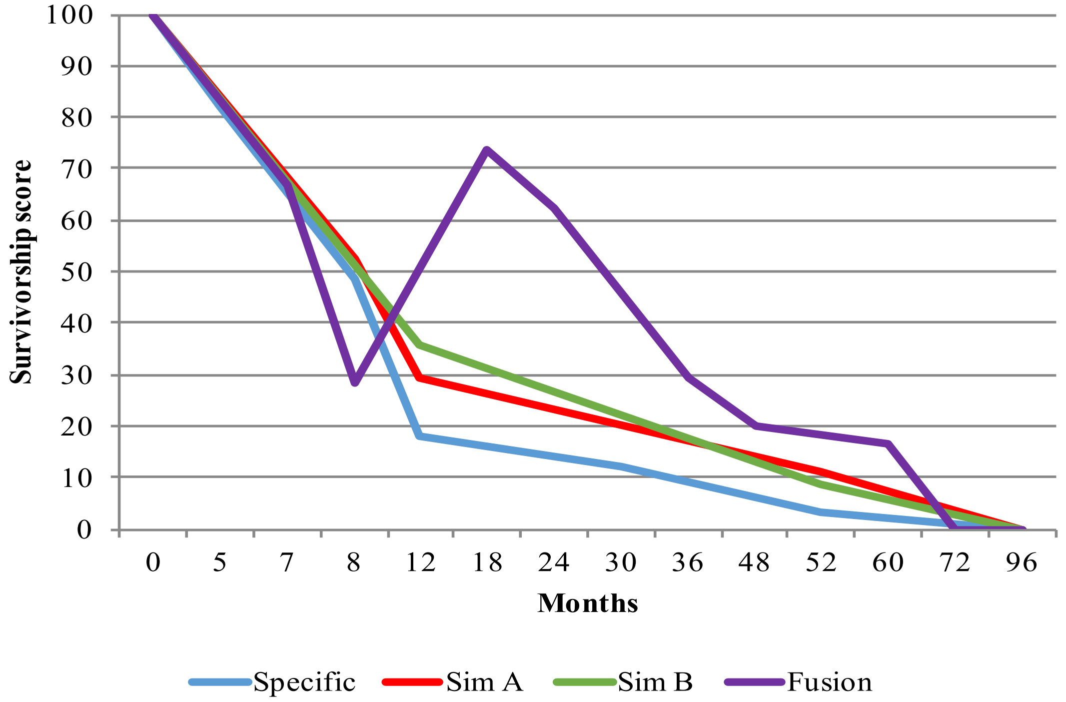


Figure 7-16 Survivorship curves and comparison of ageing systems. Note the “resurrection” in fusion curve between 7–18 months.

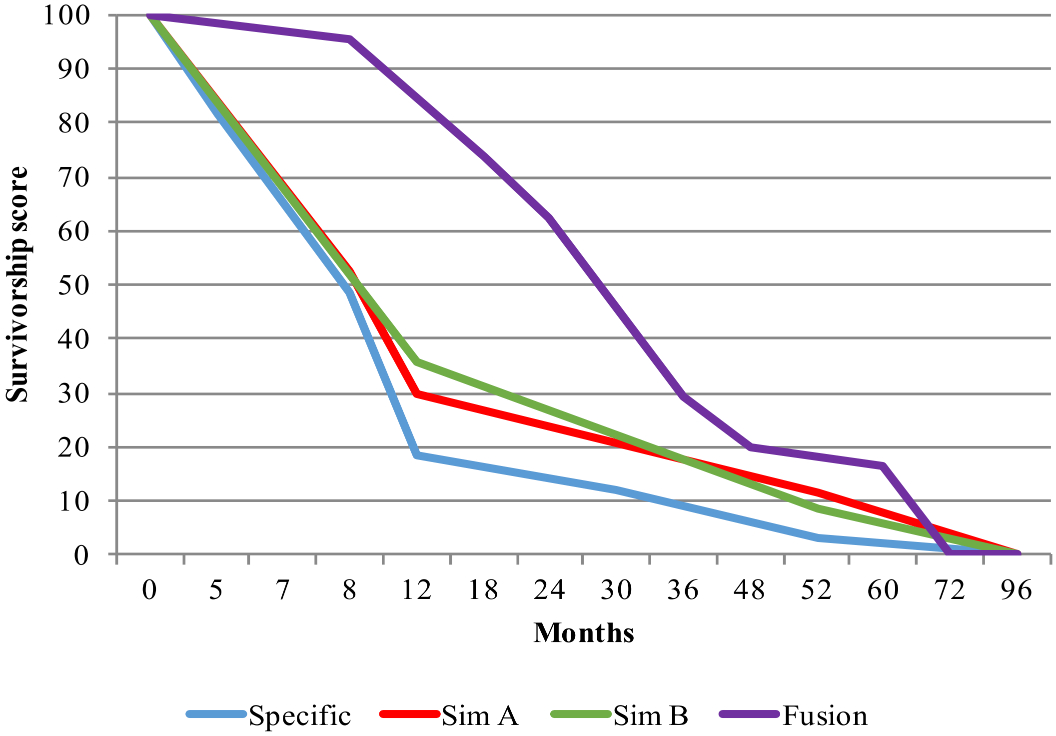


Figure 7-17 Survivorship curves with classes C and D combined for fusion resolves the "resurrection".

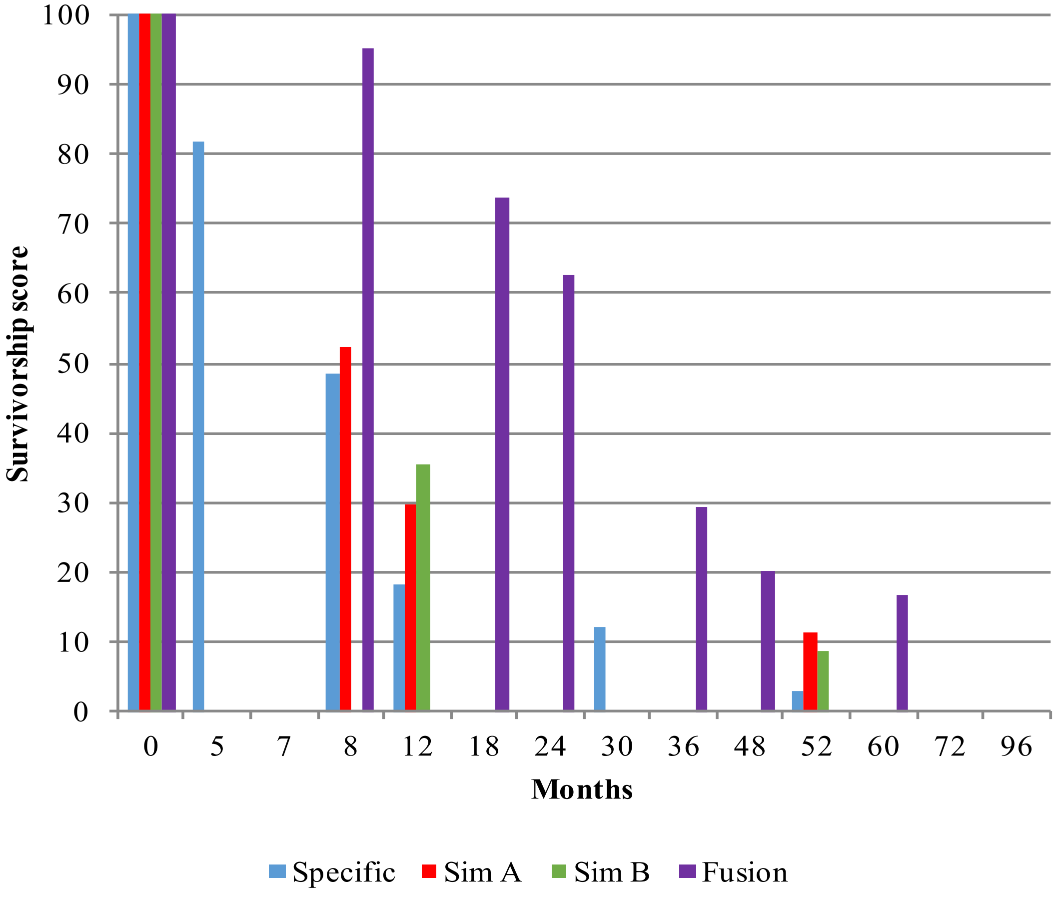


Figure 7-18 Histogram of survivorship scores and comparison of ageing systems.

7.4.9. Cervidae

Cervidae were the second most common mammal found in the assemblage, but with a NISP of 91, MNE of 51, and MNI of 5, they were significantly less abundant than pigs. There are at least two species of deer represented, *Muntiacus* sp. and *Cervus*. Unfortunately, not many elements could be used for defining an age class. There was one *Cervus* dp4 and unfused *Muntiacus* distal metacarpal, as well as a *Cervus* upper and lower M3. Mariezkurenna's (1983, 197) study of *Cervus elaphus* (red deer) suggested that fusion of distal metacarpals is relatively late, over 32 months. Further, the loss of deciduous premolars, and the eruption of M3 is disputed in literature but also seems to be a relatively late, sometime after 20 months (Mariezkurenna 1983, 158–9).

Although most of the skeleton is represented there was slightly more elements of the anterior limb than the posterior, especially the radius and ulna (Figures 7-19, 7-20). Comparatively, there is a high frequency of metapodials and phalanges but this is once again a product of their frequency within the skeleton. Similarly, the high NISP of antlers compared to MNE is related to high fragmentation, but it is also difficult to estimate MNE from antler fragments. Interestingly, post-cranial axial elements are completely absent from the archaeological record (see section 7.4.13 for discussion).

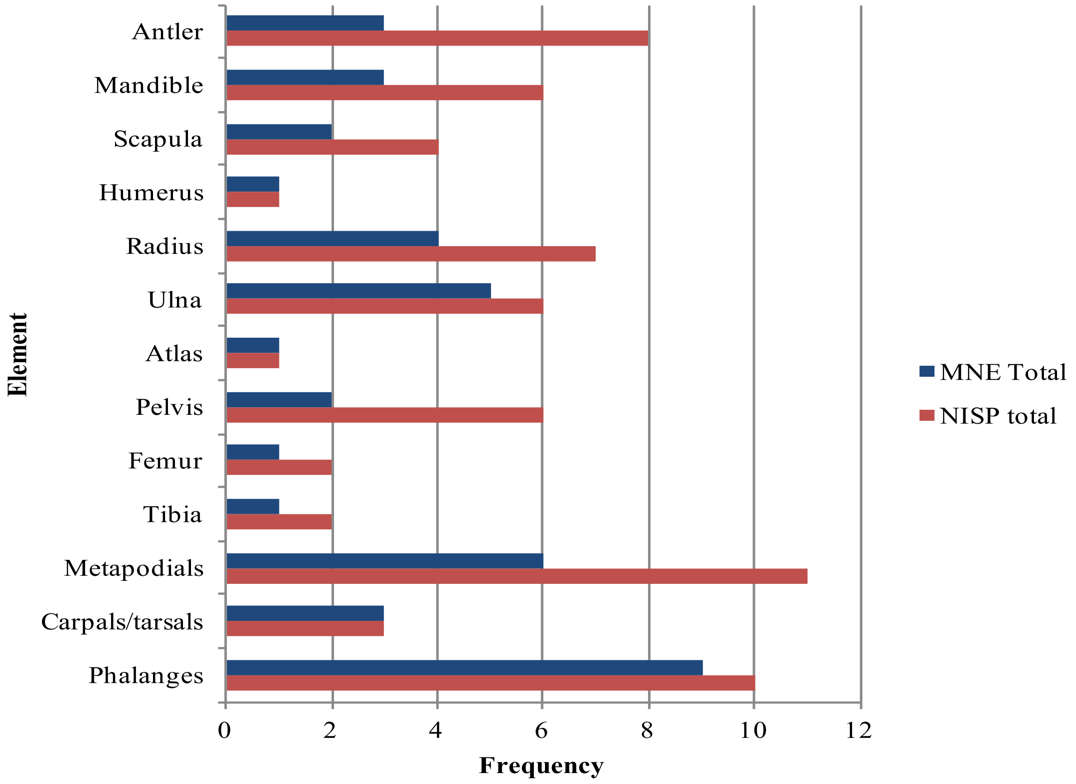
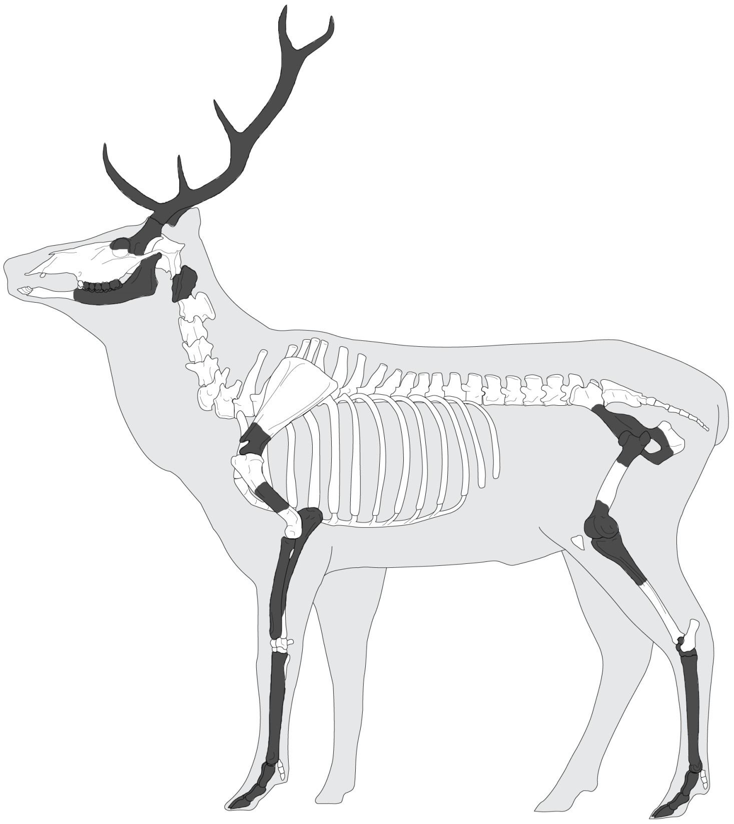


Figure 19 Cervidae BPR, comparison of MNE versus NISP.



Référence : Dessin J.-G. Ferrié - © 2004 ArcheoZoo.org
Adapté d'après le squelette de renne dessiné par Cédric Beauval et Michel Coutureau pour ArcheoZoo.org en 2003.

Figure 7-19 Graphic representation of BPR for Cervidae.

7.4.10. Bovinae

Only 21 elements were identified as Bovinae in the assemblage. The distinction between *Bubalus* and *Bos* can often be made based on morphological and size differences following Higham (1975b). For instance, the proximal ulna facet on the distal aspect of the olecranon curves at a sharper angle in *Bos* than *Bubalus* (Higham 1975b, 32, 34–35). Further, in *Bubalus* calcanei, the facet for the astragalus reaches further down the sustentaculum and the sustenaculum itself is deeper and larger than in *Bos* (Higham 1975b, 28–29). In the astragalus, the lateral proximal trochlea has a sharp, deep fossa in *Bubalus*, and the plantar surface has two main articulating facets that are joined in *Bubalus* but not in *Bos* (Higham 1975b, 29).

Three elements were recorded as cf. *Bubalus* and three as cf. *Bos*, giving an MNI of 1 respectively. *Bubalus* elements include a left unfused calcaneus, a left unfused proximal ulna, and a right astragalus. *Bos* elements include a left semi-lunar, a right os crochu, and a right fused proximal ulna. Unfortunately, there were few very elements that could help to determine an age class. Some elements that were recorded as unfused including a proximal and distal left femur, proximal left and right ulnae, a distal metapodial, and a left calcaneus. However, these elements fuse at a relatively late stage of around 3–4 years (Amorosi 1989). See Appendix 3 for further detail on ageing data.

In terms of body part representation, despite the small number of elements the majority of the body is represented including high and low meat-yielding elements (Figures 7-21, 7-22). Again, there is very little from the axial skeleton represented.

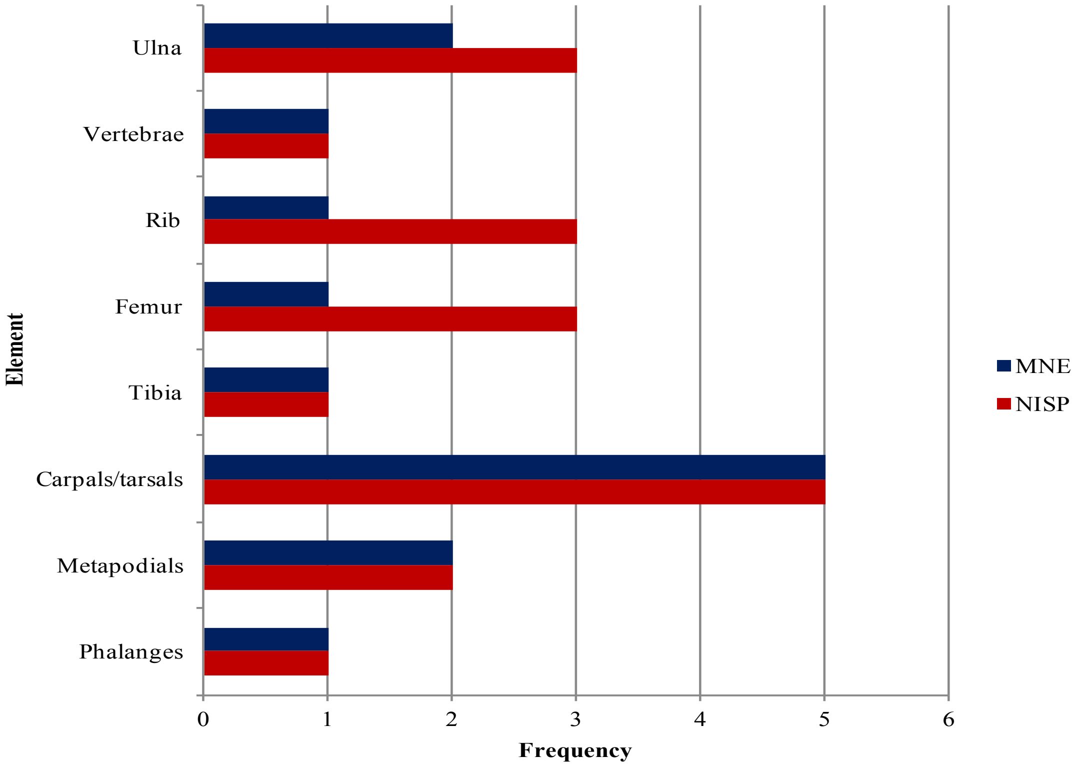
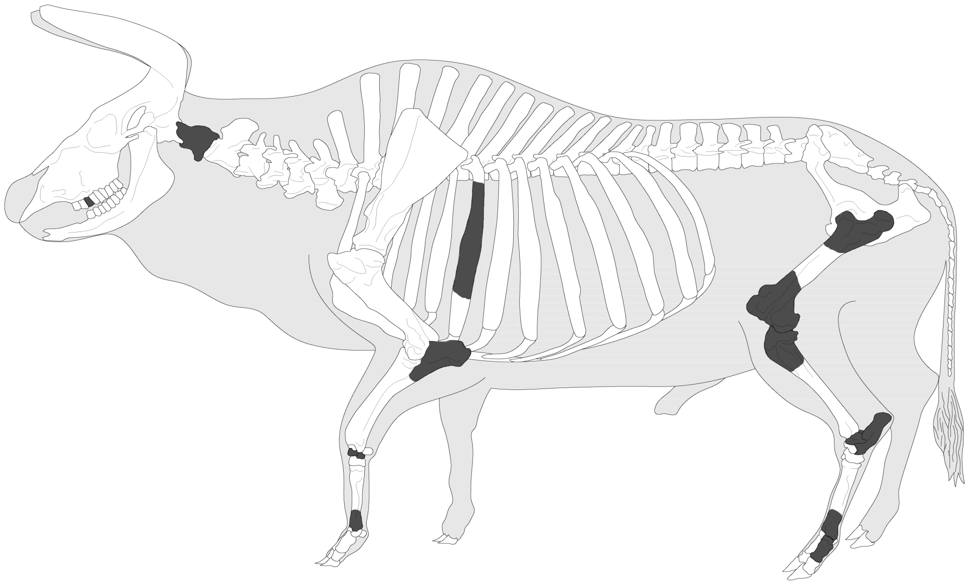


Figure 21 Bovinae BPR, comparison of MNE versus NISP.



Référence : Dessin Michel Coutureau (Inrap) - © 2009 ArcheoZoo.org
D'après : Squelette remonté au musée d'Angoulême.

Figure 7-21 Graphic representation of Bovinae BPR.

7.4.11. Rhinocerotidae

Ten elements were identified as Rhinocerotidae and a further three as cf. Rhinocerotidae. Identification is partly based on size and robusticity but also the presence of four lower molars and premolars. Two of these teeth were lower left molars; MBANU-102 was excavated in Layer 2 spit 14, while MBANU-284 was a surface find (Figure 7-23). Postcranial elements include four rib fragments, a unfused terminal phalanx, a humeral shaft fragment, and a vertebral facet fragment. There are three species of rhinoceros in SEA, which were once widespread but are now vulnerable and critically endangered: *Dicerorhinus sumatrensis* (Sumatran rhino), *Rhinoceros sondaicus* (Javan rhino), *R. unicornis* (Indian rhino) (Talukdar et al. 2008; van Strien et al. 2008a; 2008b).

Based upon the size of the lower molars the Sumatran rhino can probably be ruled out, as it is the smallest species (Yan et al. 2014, 114; Table 7-19). However, discerning between the Indian rhino and the Javan rhino with loose lower molars is difficult because there is overlap in size and the morphology is very similar (Guerin 1980, 70; Yan et al. 2014, 114, 116–7). The habitat range of Javan rhino recorded by early 19th century accounts suggests that the species was more numerous and used a variety of habitats extending from the ocean to summits of mountains (Groves and Leslie 2011, 198). Based on current preferences, it was probably abundant in lowland forests and floodplains where its main diet consists of tree saplings and woody shrubs (Groves and Leslie 2011, 198–99). By contrast, the Indian rhino mostly consumes grasses, which constitute around 70–90% of the dietary intake (Corbet and Hill 1992, 242). The species prefers alluvial grasslands, although it can be found in swamps and forests (Talukdar et al. 2008). Colin Groves (2016, pers. comm.) believes it is more likely the species at MB is the Javan rhino, as the Indian rhino is currently and historically based in India and geographical boundaries between India and Vietnam inhibit movement between the areas (see also Talukdar et al 2008).

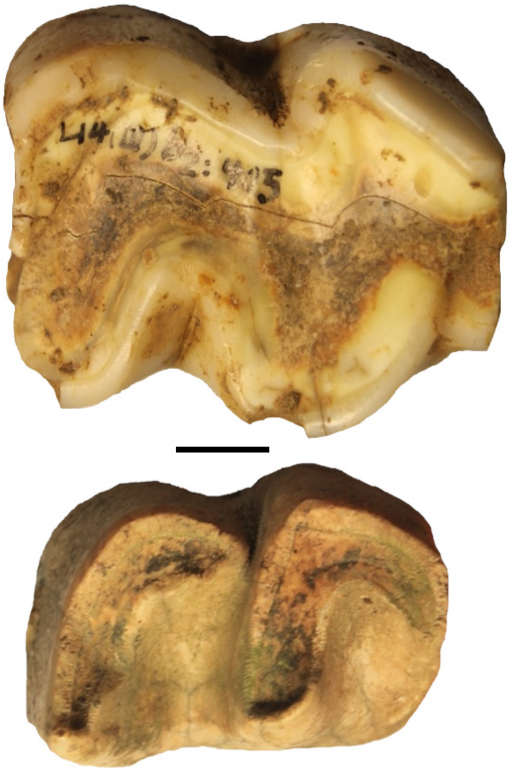


Figure 7-23 Lower left molars identified as *Rhinoceros*, probably *R. sondaicus*. Top: MBANU-102 LM2? (Layer 2 spit 14 B2); below: MBANU-284 LM1? (surface find). Scale = 1 cm.

Table 7-19 Comparison of length of lower molars between *Rhinoceros* spp. and MB specimens, data from Yan et al. (2014, 114), in mm.

	LM1	LM2	LM3
Dicerorhinus	31–40.5	46–48	41–46.5
R. unicornis	39–47.5	52–56.5	40.5–51
R. sondaicus	43–48	49.5–60	41–53
MBANU-102		52 (LM2?)	
MBANU-284		44.7 (LM1?)	

7.4.12. Elephant

An elephant maxilla was excavated in Layer 3, spits 15–17, squares A–B1 and consisted of a tusk and molar (Figure 7-24; Lorna Tilley field notes). The tusk measured approximately 60 cm in length and Lorna Tilley (2015, pers. comm.) notes that the maxilla seems to have been deliberately and carefully buried. There were three human burials to the east and southeast, but they do not appear to be associated with the maxilla (Lorna Tilley field notes).

The species *Elephas maximus* (Asiatic elephant) was once widespread throughout SEA and extended into China as far north as the Yangzte River (Karkala 2016). A very small population of elephants still live in Vietnam, most recent estimates are <100 individuals (Varma et al. 2008). According to Varma et al. (2008), Vietnamese elephant populations suffered heavily in the second half of the 20th when approximately 50% of the forests were lost due to war, logging, conversion to agricultural land, and hunting. Asian elephants generally prefer grasslands with low woody plants and forests. Unlike the African elephant, females do not bear tusks (Karkala 2016), so the individual at MB represents an adult male.

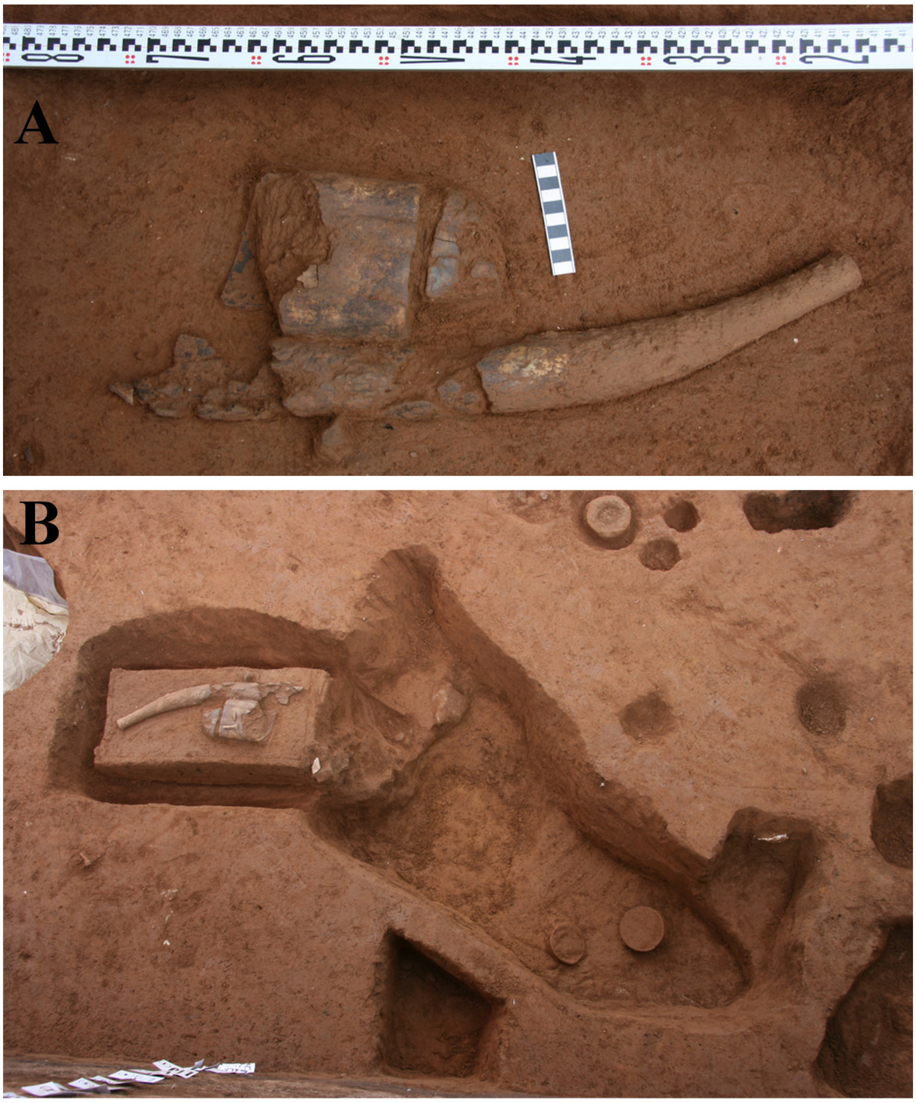


Figure 7-24 Photographs of elephant maxilla in-situ. A: close up of maxilla and tusk with 1m scale along the top. B: showing the wider context of the maxilla within the site. To the right was a human burial from a lower layer that has been lifted. Photos courtesy of Lorna Tilley.

7.4.13. Summary of taxonomy

Mammals were the most abundant taxa represented in the assemblage. Overall, compared to CCN there was less diversity in exploited taxa, and this does not seem to simply be a reflection of sample size (see Chapter nine, section 9.2.1.). In particular, the presence of domesticated dog and the high proportion of pigs at MB is notable, the implications of this are discussed in more detail in Chapters eight, nine, and eleven. Other large taxa include several rhinoceros elements and the deliberate burial of a male elephant maxilla. This creates an intriguing parallel between the deliberate burial of a whale radius at CCN and the continued fascination with megafauna at MB. This is explored in detail in the discussion Chapter eleven section 11.6.

There is also an interesting parallel between CCN and MB in the paucity of axial skeletal elements for deer and bovids. As discussed in the previous chapter (section 6.4.13.), it is difficult to interpret this scarcity as it may purely be a result of differences in bone density and differential preservation. However, when comparing the BPR of pig elements, the axial skeleton is well-represented and there was an intriguing over-representation of maxillae (section 7.4.8.). Thus, differences in bone density do not seem to have affected the representation of the pig elements in the assemblage, which suggests the paucity in axial elements of deer and bovids may reflect real differences in human behaviour. Considering these differences occur between hunted taxa (deer, bovids), and probable domestic taxa (pigs, see Chapter eight), this suggests there were different butchery and deposition practices for wild and domestic animals. This is discussed in more detail in Chapter eleven, sections 11.1.3. and 11.4.2.

7.5. Conclusion to Chapter seven

This chapter provided a taphonomic and taxonomic analysis of the faunal remains from MB. Spatial patterning of the distribution of fauna remains suggests the concentration of skeletal elements were relatively evenly distributed throughout the site. The use of sieving in the 2007 H2 trench does not appear to have made a drastic difference in the amount of small mammals, reptiles, or birds recovered, though it may have increased recovery of fish remains (Sawada et al. 2011).

The taphonomic analysis showed good preservation of faunal material with minimal signs of abrasion, surface staining, burning, or rodent and carnivore modification. Overall, this indicates rapid deposition with limited post-depositional disturbance. One notable taphonomic difference between MB and CCN was a hard breccia crust on the surface of some of the faunal remains, which may have been caused by the seeping of calcium carbonate into the soil. Further, there was minimal Mn staining on the surface of the bone which indicates that MB was a less wet and humic environment compared to CCN.

The butchery marks on the faunal remains indicate a variety of butchery practices were taking place at the site. However, unlike CCN there was no evidence for the processing for marrow. Further, as discussed above (section 7.4.13.) there is a perceivable difference in body part representation of pigs, deer and bovids with a paucity of axial elements in the latter two taxa. It is quite likely this relates to differences in human butchery and deposition practices between wild and domestic taxa, which will be discussed further in

Chapter eleven.

The taxonomic representation of fauna shows a dominance of mammals, especially pig. In terms of NISP, MNE, and MNI deer are the second most-abundant taxa, followed by dog. The implications for the presence of domesticated dog, dominance of pig, and lower diversity of taxa compared to CCN are discussed in depth in Chapters eight, nine and eleven.

CHAPTER EIGHT
Biometrics

8.1. Introduction

This chapter analyses biometric data created for pigs, dogs, and bovids from MB and CCN, addressing one of the main aims of this thesis: whether any domesticated taxa are represented within the archaeological records of CCN and MB (Chapter one section 1.2.). The primary purpose of collecting biometric data for pigs and dogs was to assess and distinguish between domesticated or early managed and wild taxa. For bovids, biometric comparison also potentially helps to distinguish between different genera and species within the sub-family Bovinae. When assessing early cases of domestication biometric analysis should be undertaken alongside a variety of other methods before drawing any conclusions. Within the context of Mid Holocene Vietnam, this is particularly the case for pigs and bovids. However, dogs were domesticated much earlier (Germonpré et al. 2012; Morey 2014), and if they appear in Mid Holocene sites, it should be easily identifiable through morphometric analyses.

The majority of this chapter is concerned with biometric comparison of dentition. Diminution in dentition is one of the first skeletally recognisable features of domesticated species (Zeder 2006a; Zeder et al. 2006; Evin et al. 2013), but also because comparative dental data is much more readily available in publications. Postcranial elements of pigs, dogs and bovids were measured according to the methodology outlined in Driesch (1976). Cranial and postcranial measurements are included in Appendix 4.

8.2. Pig (*Sus* cf. *scrofa*) dental biometrics from Mán Bạc and Cồn Cổ Ngựa

This section provides a biometric analysis of the dental metrics of pigs from MB and CCN and compares this data to other pigs in SEA and China. For a detailed rationale behind the methodology see Chapter five section 5.7.2. Cluster analysis of these samples was performed to assess whether there were observable patterns within the data. ANOVA and post-hoc testing then determined whether these perceived patterns were statistically significant, and specifically what was causing the differences. The results of the cluster analysis are detailed for each lower and upper molar (M1–3; section 8.3.), and these results are interpreted in section 8.4.

8.2.1. Samples used in analyses and expectations

Comparative data of pig dental biometrics were collated from MSEA and ISEA. Samples were intentionally limited to Asia as the size of pig molars can be greatly affected by climate and regionality (Rowley-Conwy et al 2012; see section 5.7.2. for further rationale). The comparative archaeological and modern reference material used in the analysis are summarised in Tables 8-1 and 8-2. A total of 60 pig molars were used, which consisted of one lower M3 from CCN (due to poor representation of pig elements at CCN) and 59 molars from MB (Table 8-3). The majority of the molars were upper M1s and M2s, due to the higher proportion of upper dentition in the assemblage. For specific details on each sample see Appendices 5.2 and 5.3.

Unfortunately, comparative sites from Thailand were unable to be used in this analysis due to either incomplete measurement data (Khok Phanom Di, Non Nok Tha), or unavailable/unpublished data (Ban Non Wat, Non Nok Tha). For instance, Khok Phanom Di and Non Nok Tha only have published molar lengths, but not widths (Higham 1975b, 74; Grant and Higham 1991, 185-6). Initially *Sus barbatus*, the endemic bearded pig to Borneo and the Malay Peninsula, was used as a large size comparison (Kawanishi et al. 2008). However, the size of *S. barbatus* overlapped with many of the medium-large modern *S. scrofa* samples hence, *S. barbatus* samples were eliminated from the cluster analyses for clarity.

A range of different archaeological sites are represented here, some of which almost certainly contain domesticated pigs (Xipo, Prei Khmeng, Phum Lovea), others that are probably wild boars (Dingsishan), while most of the rest are either unknown or potential combinations of both domestic and wild (Table 8-1). Following methodological issues outlined in Chapter four, early domesticated/managed pigs are often difficult to classify purely based on size. Considering the amount of archaeological material used in this analysis it is expected that there will not necessarily be a distinct differentiation between ‘domestic’ and ‘wild’. Further, this type of analysis is largely dependent on previous scholarship and hindered by what is available. Ideally, hundreds of assemblages would be analysed to provide comprehensive results. As such, this analysis should not be seen as the ‘final result’ for pig domestication in SEA, but rather a starting point upon which to ask more questions and perform more analyses.

Table 8-1 Archaeological samples of pig molars used in the analysis. RKJ= data collected by author, PJP= data collected by Philip J Piper.

Archaeological samples			
Site	**Location**	**Date/period**	**Reference**
CCN	Vietnam	See Chapter ten	RKJ
MB		See Chapter ten	
An Son		4410–3010 cal. BP	PJP; Bellwood et al. (2011)
Rach Nui		3555–3265 cal. BP	Piper & Amano (2013, 25 unpub report); Oxenham et al. (2015)
Prei Khmeng	Cambodia	Iron Age	RKJ
Phum Lovea		Iron Age	
Pacung	Indonesia	Iron Age	
Sembiran		Iron Age	
Nagsabaran	Philippines	4000–1350 cal. BP	Amano (2011)
Anaro		3200 cal. BP	Piper et al. (2013a, 180-1)
Savidug		3200 cal. BP	Piper et al. (2013, 191)
Vasino	East Timor	c. 1400 AD	Amano & Piper (2011, 17 unpub report)
Lobang Hangus	Borneo	12,800 ±27 (uncal.) BP; 12,500 ±50 (uncal.) BP	PJP; date Lobang Hangus from Piper & Rabett (2009, 553); date for Gan Kira from Piper et al. (2009, 693)
Gan Kira		~3,200 BP	
Dingsishan	China	Early Holocene	Lu (2010)
Xipo		c. 4000–3500 BC (5950–5450 BP)	Ma (2005)
Cishan		c. 8000 BP	(measurements are means) Yuan & Flad (2002, 725)
Shishanzi		c. 7000 BP	
Shouling		c. 6000–4500 BP	
Jiangzhai		6000–4000 BP	
Banpo		6000–4500 BP	
Yinxu		3400 BP	

Table 8-2 Modern reference material used in the analysis. RKJ= data collected by author, PJP= data collected by Philip J Piper.

Modern reference samples				
Location	**ID**	**Wild/ domestic**	**Collection**	**Reference**
China	MCZ-7952	Wild	Smithsonian Museum of Natural History	PJP
Java	AMNH-42346		American Museum Natural History	
Indochina	AMNH-87595			
Malaysia	AMNH-32655			
Vietnam	AMNH-113754			
Negros	UMMZ-158626	Domestic	Museum of Zoology, Michigan	
Negros	UMMZ-158010			
Sepik Province, PNG	M0434		ANU, Coombs	RKJ
Nam Gnouang, Laos	Laos1		ANU, A&A	
Nam Gnouang, Laos	Laos2			
Shanxi, China	39326		Field Museum of Natural History, Chicago	Amano (2011, 69–70)
Laos, Pong Saly	31799			
Annam, French Indo-China	31791			
Manila, Philippines	A-0067A		UP Archaeological studies program	
Manila, Philippines	A-0067B			
Manila, Philippines	A-0003			
Manila, Philippines	A-0004			
Manila, Philippines	A-0059			

Table 8-3 Summary of pig molars from CCN and MB used in this analysis.

Molar	N
LM1	6
LM2	5
LM3	8
UM1	16
UM2	17
UM3	8
Total	**60**

9.2.2. Explorative phase of cluster analysis

During the explorative phase of cluster analysis, it was discovered that the most optimal variables for comparison are length (mesial-distal), and anterior and posterior (buccal-lingual) breadths examined simultaneously together. When comparing only two variables there was occasionally an inconsistency in which group a sample was assigned to. For example, a molar may have a relatively large anterior breadth but a relatively small posterior breadth. Comparing the anterior breadth and length in this case would assign the molar to a smaller group, while comparison of the posterior breadth and length would assign the molar to a larger group. For this reason, it was decided that comparing all three variables simultaneously in hierarchical and k-means cluster analyses gave the most accurate picture of where a particular sample belonged. Based on these findings, studies that employ only one measurement are questionable and the comparison of length, and anterior and posterior measurements should be encouraged.

Specifically for the lower and upper M3s, it was decided to compare length and anterior breadth as opposed to all three variables, due to the lack of comparative samples. By eliminating the necessity of using posterior breadth in the analysis more than twice as many samples were able to be used. For instance, analysis of LM3s with all three variables included only 36 samples, while comparing length and anterior breadth allowed for 71 samples.[1] This permitted a more meaningful comparison of third molars while at the same time maintaining a degree of caution.

8.2.3. Hierarchical cluster analyses

Hierarchical analyses suggested the presence of three clusters for LM2s, LM3s, UM1s, UM2s, and UM3s was the most appropriate result. For LM1s, four clusters were more appropriate. This difference is likely to be a result of more samples for LM1s, which creates more variability in the data. K-means analysis was then used to place each sample into groups. Since the dendrograms that SPSS creates are large and difficult to display, they have been included in Appendix 5.

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[1] The reason for the large difference in sample size is because much of the reference material did not include a measurement of posterior breadth. This may be due to the difficulty of measuring a partially erupted tooth, breakage to the posterior end, or that simply measuring the posterior breadth was not conducted.

8.2.4. K-means cluster analyses

Based on the results from hierarchical cluster analysis above, k-means cluster analysis was run with four clusters for LM1s and three for LM2, LM3s, UM1s, UM2s, and UM3s. There was some disagreement in the assignment of samples between hierarchical and k-means cluster analyses. This is to be expected, as the methods are slightly different (see Chapter five, section 5.7.2.1.). ANOVA for both hierarchical and k-means analyses were compared to help determine which technique worked best for the samples. It was decided to follow the results of the k-means analysis for the final clustering of groups because this method produces clusters based on the greatest possible distinction between groups (Burns and Burns 2008, 557). Thus, in general this method produces more clarity between clusters.

8.2.5. ANOVA and post-hoc testing

ANOVA was performed to determine whether the clusters were statistically significant. In order to proceed with ANOVA there are a number of assumptions that need to be satisfied. The assumption of homogeneity of variances (Levene's test) was tested and satisfied in some variables but not in others. This is due to the skewed distribution (normality) in some of the variables. For example, in LM1s normality tests showed a normal distribution for length, and relatively normal distribution for posterior breadth, but a skewed distribution for anterior breadth. This affected the Levene's test for anterior breadth, which failed, but both length and posterior breadth passed. However, even if Levene's test fails, Robusticity tests (Welch and Brown Forsythe) are accurate tests that do not assume homogeneity of variance (Field 2012). To be thorough, ANOVA, Welch, and Brown-Forsythe tests were conducted and compared, and these are detailed in Appendix 5.

8.3. Results of cluster analysis

This section covers the k-means cluster results and the results of the ANOVA and robusticity tests per molar. In all cases the results from the ANOVA and Robusticity tests were significant. For results from Levene's test and ANOVA post-hoc tests see Appendix 5. A discussion of the interpretation of the results is provided in the following section (section 8.4).

8.3.1. Lower M1s (4 groups)

A total of 169 LM1 samples were used. K-means using four clusters produced groups that can be characterised as small, narrow, wide, and large (Table 8-4, Table 8-5, Figure 8-1). There is a considerable amount of spread in the modern domestic pigs, a pattern which can be seen in many of the other molar cluster analyses (Table 8-5, see discussion section 8.4). In terms of the archaeological material, the MB samples are spread out across wide, narrow and large groups. Both Xipo (China) and Pre Khmeng (Cambodia) are definite cases of domesticated pigs and the majority of those samples fall into either the small or narrow groups.

ANOVA yielded a statistically significant effect for length and posterior breadth and robusticity tests for anterior breadth also produced significant results. Post-hoc tests suggested the difference between groups was statistically significant (between p = <0.001–0.008). Specifically, Tukey HSD showed significant differences between means in length and posterior breadth. For anterior breadth the wide and large groups were significant but there was some overlap between the small and narrow groups. This can be easily understood when viewing Figure 8-1, as there is some overlap in the anterior breadth between the small and narrow groups. However, overall the statistics support the presence of at least four groups within the data.

Table 8-4 Descriptives for LM1s. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Variables		N	Mean (mm)	sd (mm)
LM1L	Small	36	15.3	0.82
	Wide	30	15.93	0.85
	Large	10	19.02	0.78
	Narrow	93	17.53	0.58
LM1Ba	Small	36	9.96	0.49
	Wide	30	11.42	0.63
	Large	10	12.45	0.94
	Narrow	93	10.34	0.49
LM1Bp	Small	36	10.73	0.57
	Wide	30	12.12	0.56
	Large	10	12.8	0.59
	Narrow	93	11.17	0.59

Table 8-5 Summary of k-means cluster groups for archaeological and modern wild and domestic samples for LM1s.

	Sample	Small	Narrow	Wide	Large	Subtotal
Archaeological	MB		2	2	2	6
	An Son		4	2		6
	Rach Nui	2	2			4
	Prei Khmeng	4				4
	Nagsabaran		1	5		6
	Pacung	4		1		5
	Sembiran	3				3
	Anaro		2	1	1	4
	Savidug	4		1		5
	Lobang Hangus		1		3	4
	Gan Kira		1		3	4
	Dingsishan			4		4
	Xipo	13	76	4		93
Wild				5		5
Domestic		6	4	5	1	16
Subtotal		36	93	30	10	
Total						169

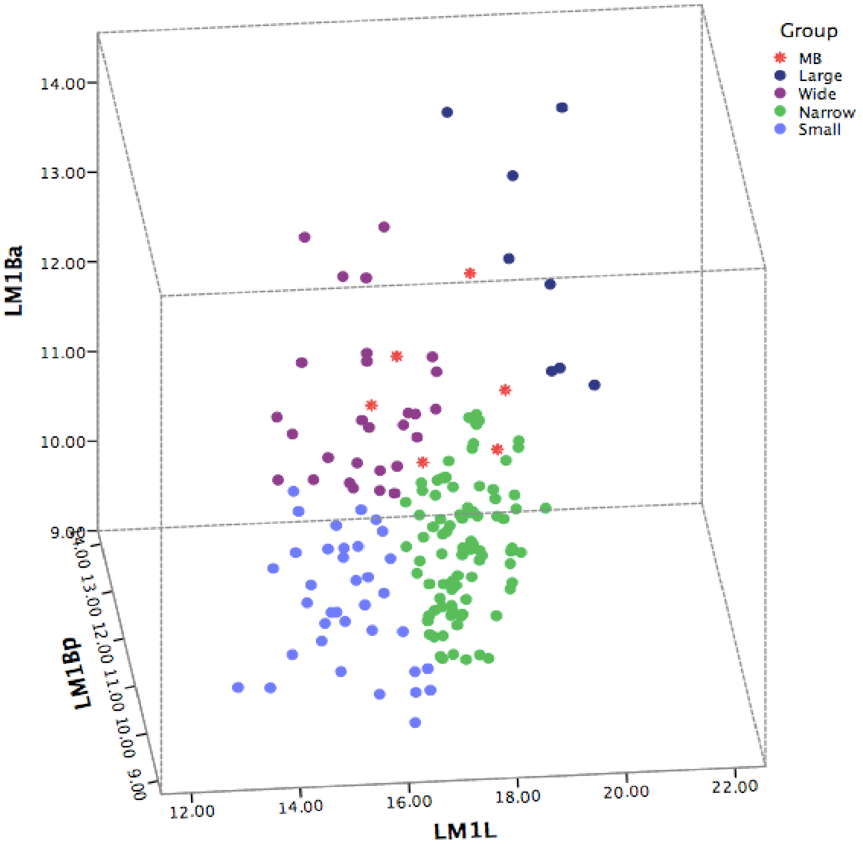

Figure 8-1 Lower M1s 3D graph highlighting the four groups based on K-means results of the 3 variables (L = length, Ba = anterior breadth, Bp = posterior breadth) measured in mm. MB samples are highlighted by red stars. N = 169.

8.3.2. Lower M2s (3 groups)

A total of 114 LM2 samples were used. K-means cluster analysis produced groups corresponding to small, medium, and large sizes (Table 8-6, Table 8-7, Figure 8-2). All of the five MB samples fell into the larger group (Table 8-7, Figure 8-2).

Table 8-6 Descriptives for LM2s. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Variables		N	Mean (mm)	sd (mm)
LM1L	Small	22	18.51	1.09
	Large	25	21.82	1.76
	Medium	67	21.02	0.93
LM1Ba	Small	22	13.34	0.96
	Large	25	16.05	1.16
	Medium	67	13.77	0.91
LM1Bp	Small	22	13.7	0.82
	Large	25	16.64	0.84
	Medium	67	13.89	0.86

Table 8-7 Summary of k-means cluster groups for archaeological and modern wild and domestic samples for LM2s.

	Sample	Small	Medium	Large	Subtotal
Archaeological	MB			5	5
	An Son	3	2	2	7
	Rach Nui	1	4		5
	Prei Khmeng		2		2
	Nagsabaran	1	10	1	12
	Pacung	1		2	3
	Sembiran	2			2
	Anaro	1		1	2
	Savidug	2	1		3
	Vasino	1			1
	Lobang Hangus		1	2	3
	Gan Kira		1	2	3
	Dingsishan		1	2	3
	Xipo	9	41		50
Wild			1	5	6
Domestic		1	3	3	7
Subtotal		22	67	25	
Total					114

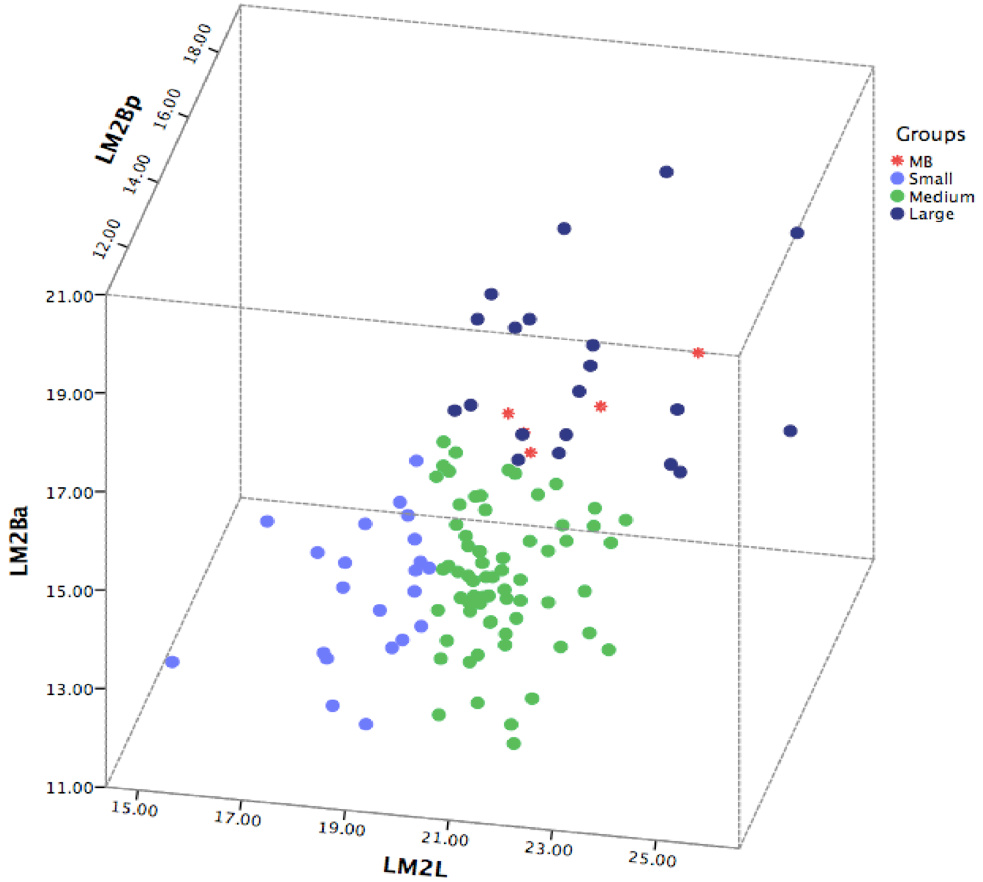

Figure 8-2 Lower M2s 3D graph of the 3 variables (L = length, Ba = anterior breadth, Bp = posterior breadth) measured in mm. MB samples are highlighted by red stars. N=114.

ANOVA yielded a statistically significant effect for anterior and posterior breadth. Robusticity tests for length also produced significant results. Post-hoc tests showed length was the most statistically significant factor influencing the grouping (between p = <0.0001–0.014). Anterior and posterior breadth specifically for the large group was also significant (p = <0.0001). Conversely, there was an overlap in means between small and medium groups in anterior (p = 0.18) and posterior (p = 0.64) breadths. Figure 8-2 shows the overlap in anterior and posterior breadth between small and medium groups, while there is more difference with length between the three groups.

8.3.3. Lower M3s (3 groups)

A total of 71 LM3 samples were used. K-means cluster analysis comparing length and anterior breadth produced three groups corresponding to small, medium/wide, and large (Table 8-8, Table 8-9, Figure 8-3). A total of seven MB samples were used in this analysis, two fell into the medium/wide group and five in the large group (Table 8-9, Figure 8-3). The CCN sample fell into the medium group, but as can be seen from Figure 8-3, it falls into the ‘wide outlier’ group. This indicates the anterior breadth was relatively wide compared to the length of the molar.

ANOVA yielded a statistically significant effect for length and anterior breadth. Post-hoc analysis shows length was the most statistically significant variable influencing all three groups (p = <0.0001). Anterior breadth was significant for the small group (p = <0.001). There was an overlap in means for the anterior breadth in the medium/wide and large groups (p = 0.29).

Figure 8-3 clearly portrays these patterns and illustrates the broad range in anterior breadth of the medium/wide group and overlap with the large group. In particular, there are five samples in the upper part of Figure 8-3 that could be considered outliers to the rest of the medium/wide group (including the CCN sample). To attempt to address this problem, k-means was rerun specifying four groups (instead of three). However, even when four groups are specified these 'wide outliers' did not separate into their own group.[1] This may be partly because there are only five samples in this wide outlier group, which may not be statistically robust enough to warrant another group. Thus, it was decided that three groups gave the clearest outcome for lower M3s. Statistically there are at least three groups within this data but if more samples were included (and/or the posterior breadth), the picture would probably become more complex.

Table 8-8 Descriptives for LM3s. L = length, Ba = anterior (mesial) breath.

Variables		N	Mean (mm)	sd (mm)
LM3L	Medium/ wide	32	35.71	1.45
	Large	29	40.43	1.69
	Medium	10	31.3	2.05
LM3Ba	Medium/ wide	32	17.07	1.56
	Large	29	17.61	1.12
	Medium	10	14.88	1.47

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[1] The wide outliers were an odd combination of sites and museum collections: AMNH-32655 *Sus scrofa vittatus* from Malaysia; Gan Kira, Y/A20; Savidug, C11 50–60 cm; Xipo; and CCN.

Table 8-9 Summary of k-means cluster groups for archaeological and modern wild and domestic samples for LM3s. *average measurement

	Sample	Small	Medium/ wide	Large	Subtotal
Archaeological	MB		2	5	7
	CCN		1		1
	An Son			2	2
	Rach Nui		5		5
	Prei Khmeng				0
	Nagsabaran	1	2	2	5
	Pacung		1	2	3
	Sembiran				0
	Anaro		1		1
	Savidug		1	1	2
	Vasino				0
	Lobang Hangus			4	4
	Gan Kira	1	1	1	3
	Dingsishan		2	1	3
	Xipo	7	11	3	21
	Cishan*			1	1
	Shishanzi*			1	1
	Shouling*		1		1
	Jiangzhai*		1		1
	Banpo*		1		1
	Yinxu*	1			1
Wild			2	4	6
Domestic				2	2
Subtotal		10	32	29	
Total					71

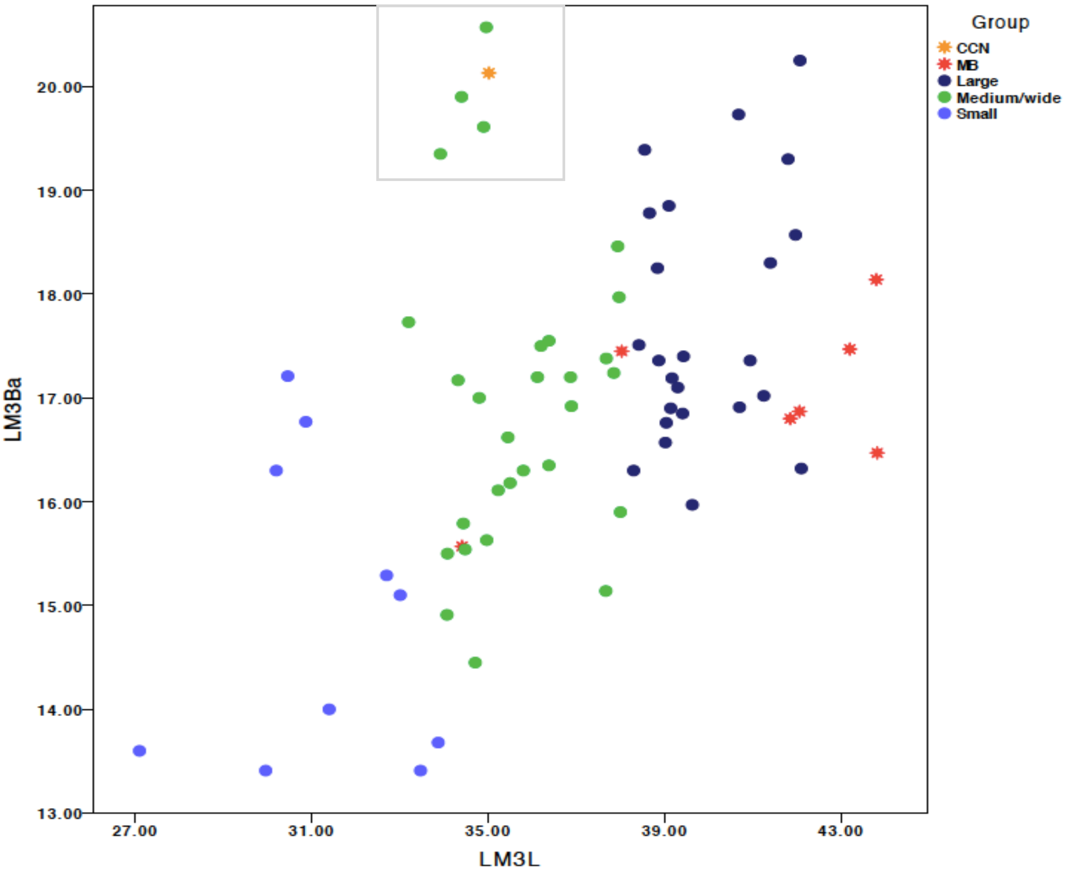

Figure 8-3 Lower M3s biplot of the 2 variables (L = length, Ba = anterior breadth) measured in mm. MB samples are highlighted by red stars and the CCN sample by a yellow star. The wide outliers are highlighted with a square. N = 71.

8.3.4. Upper M1s (3 groups)

A total of 139 UM1 samples were used. K-means cluster analysis produced three groups that corresponded to small, wide, and large (Table 8-10, 8-11, Figure 8-4). At a total of 16 samples from MB, this analysis had the second largest number of molars from the site that could be used in the biometric analyses. Most of the samples (n = 13) were classified into the 'wide' group, while three were characterised as 'large' (Table 8-11, Figure 8-4).

ANOVA and robusticity tests yielded a statistically significant effect for length. Post-hoc analysis suggested that posterior breadth was overall the most significant contributing variable to group clustering ($p = <0.0001–0.001$). For length there was an overlap between the small and wide groups ($p = 0.23$), though not for the large group ($p = <0.0001$). For anterior breadth there was some overlap in the large and wide groups ($p = 0.02$), but not for the small group ($p = <0.0001$). These patterns can be seen in Figure 8-4.

Table 8-10 Descriptive for UM1s. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Variables		N	Mean (mm)	sd (mm)
UM1L	Large	83	17.99	1
	Small	15	14.88	1.24
	Wide	41	15.42	1.13
UM1Ba	Large	83	14.01	0.85
	Small	15	11.69	1.13
	Wide	41	14.52	1.11
UM1Bp	Large	83	14.14	0.93
	Small	15	11.7	1.04
	Wide	41	14.83	1.17

Table 8-11 Summary of k-means cluster groups for archaeological and modern wild and domestic samples for UM1s.

	Sample	Small	Wide	Large	Subtotal
Archaeological	MB		13	3	16
	An Son		1	1	2
	Rach Nui	1	1	1	3
	Prei Khmeng	3			3
	Phum Lovea	1	2		3
	Nagsabaran		1	3	4
	Pacung	2	2		4
	Anaro	1		6	7
	Savidug		5	1	6
	Vasino	3			3
	Lobang Hangus			2	2
	Gan Kira		2	8	10
	Dingsishan			5	5
	Xipo	4	5	53	62
Wild			4		4
Domestic			5		5
Subtotal		15	41	83	
Total					139

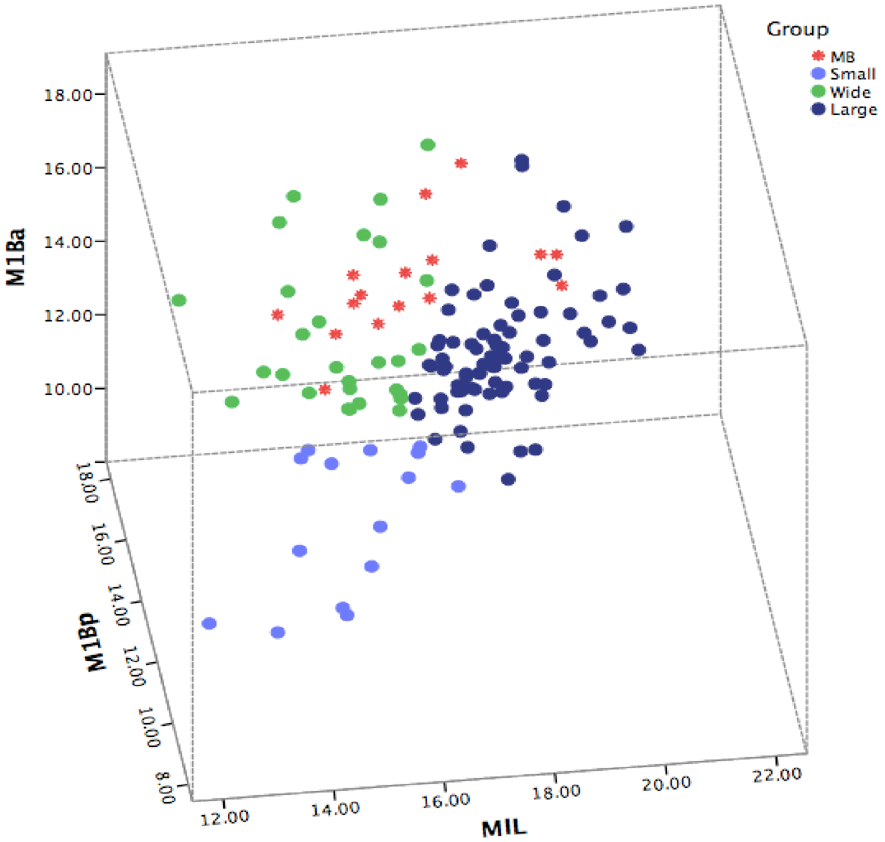

Figure 8-4 Upper M1s 3D graph of the 3 variables (L = length, Ba = anterior breadth, Bp = posterior breadth) measured in mm. MB samples are highlighted by red stars. N = 139.

8.3.5. Upper M2s (3 groups)

A total of 96 UM2 samples were used. K-means cluster analysis produced three groups that corresponded to small, medium/wide, and large (Table 8-12, Table 8-13, Figure 8-5). This analysis had the largest number of molars from MB at 17 samples. A total of 14 of these samples were placed into the medium/wide group and the other three into the large group (Table 8-13; Figure 8-5).

ANOVA yielded a statistically significant effect for all three variables. Post-hoc analysis shows a mixture of results for each variable. For length, the medium/wide and small groups overlap (p = 0.8), while the large group is significant (p = <0.0001). Anterior and posterior breadths of the large and medium/wide groups overlap (p = 0.73, 0.76 respectively), while the small group is significant for both breadths (p = <0.0001). This suggests that although statistically there are at least three significant groups within the data, there is also some overlap in the means in each variable. This overlap in size between groups can be seen in Figure 8-5.

Table 8-12 Descriptives for UM2s. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Variables		N	Mean (mm)	sd (mm)
UM2L	Small	41	20.48	1.52
	Large	28	23.48	1.34
	Medium/ wide	27	20.26	1.26
UM2Ba	Small	41	15.94	1.15
	Large	28	18.66	1.14
	Medium/ wide	27	18.88	1.02
UM2Bp	Small	41	15.72	1.22
	Large	28	18.52	1.55
	Medium/ wide	27	18.79	1.4

Table 8-13 Summary of k-means cluster groups for archaeological and modern wild and domestic samples for UM2s.

	Sample	Small	Medium/ Wide	Large	Subtotal
Archaeological	MB		14	3	17
	An Son		1	2	3
	Rach Nui	2			2
	Prei Khmeng	1			1
	Phum Lovea	1			1
	Nagsabaran	1	1	1	3
	Pacung	2		1	3
	Anaro	1		2	3
	Savidug		4		4
	Vasino	2			2
	Lobang Hangus			2	2
	Gan Kira	2		5	7
	Dingsishan	1	1	2	4
	Xipo	27	1	8	36
Wild			4	1	5
Domestic		1	1	1	3
Subtotal		41	27	28	
Total					96

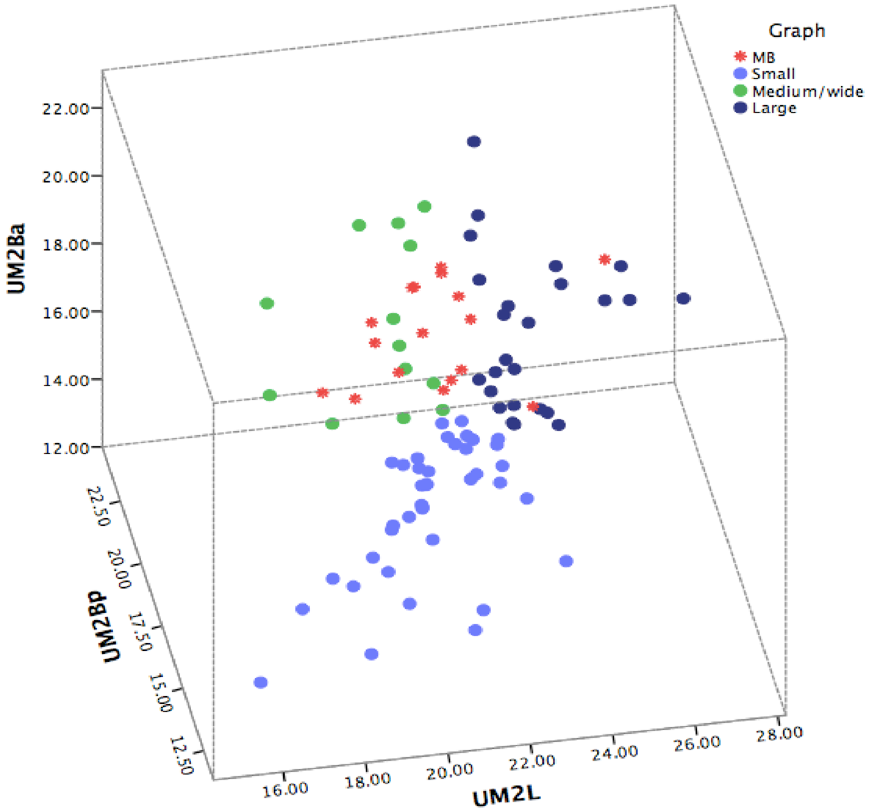

Figure 8-5 Upper M2s 3D graph of the 3 variables (L = length, Ba = anterior breadth, Bp = posterior breadth) measured in mm. MB samples are highlighted by red stars. N = 96.

8.3.6. UM3s (3 groups, using length and Ba)

A total of 56 UM3 samples were used. K-means cluster analysis comparing length and anterior breadth produced three groups corresponding to small, medium, and large (Table 8-14, Table 8-15, Figure 8-6). There were eight MB samples used in this analysis, three were placed into the small group, four into the medium group, and one into the large group (Table 8-15, Figure 8-6).

ANOVA yielded a statistically significant effect for both length and anterior breadth. Post-hoc analysis showed that both length and anterior breadth were significant contributing factors to the group clusters (between p = <0.0001-0.003). These three groups are displayed in the biplot below (Figure 8-6).

Table 8-14 Descriptives for UM3s. L = length, Ba = anterior (mesial) breath.

Variables		N	Mean (mm)	sd (mm)
UM3L	Small	13	31.28	2.04
	Large	14	39.99	1.39
	Medium	29	36.44	1.41
UM3Ba	Small	13	18.65	1.08
	Large	14	22.04	1.67
	Medium	29	20.39	1.54

Table 8-15 Summary of k-means cluster groups for archaeological and modern wild and domestic samples for UM3s.

	Sample	Small	Medium	Large	Subtotal
Archaeological	MB	3	4	1	8
	An Son		1		1
	Rach Nui	1			1
	Nagsabaran		2		2
	Sembiran	1			1
	Anaro			1	1
	Savidug		1		1
	Lobang Hangus		10	4	14
	Gan Kira	2	5	2	9
	Dingsishan		2	4	6
	Xipo	4	2		6
Wild			2	2	4
Domestic		2			2
Subtotal		13	29	14	
Total					56

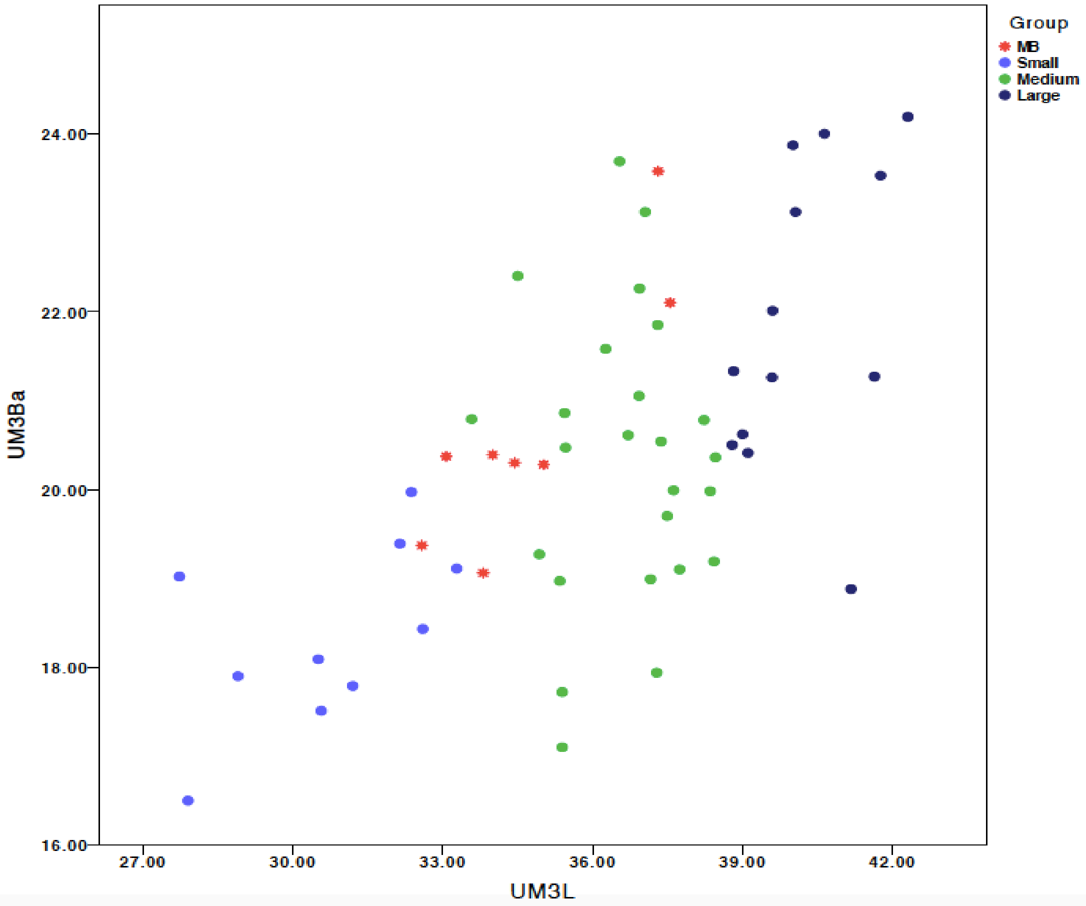

Figure 8-6 Upper M3s biplot of the 2 variables (L = length, Ba = anterior breadth) measured in mm. MB samples are highlighted by red stars. N = 56.

8.4. Discussion and interpretation of cluster results

ANOVA and Robusticity tests produced statistically significant results for all molars, which indicates there are at least three groups of pigs within the biometric dataset that can be generally classified as small, medium, and large. The most difficult aspect of cluster analysis is determining the optimal number of clusters in the data because this is largely subjective (Burns and Burns 2008, 557–8). The more clusters there are, the increasingly artificial the classification becomes (Burns and Burns 2008, 557–8). In this case, the majority of samples that were used in the analysis were archaeological material where the 'domestic status' of the pig is unknown or in the 'early' process of domestication. Hence, as expected there was some overlap in the means of groups. Assemblages of pigs that are in the early phases of domestication or management are not going to yield clear 'domestic clusters'. This is because it can take thousands of years for the full suite of domestic traits to become skeletally apparent, as was discussed in Chapter four (section 4.2.2.; also see Zeder (2001; 2008; 2012b; 2015a) who has discussed this in detail).

Table 8-16 summarises the total number of molars classified into each group arranged into time period for simplicity. For a summary of each site see Appendix 5.3. Overall, the subtotal for each group is relatively similar, though the medium/wide group leads (n = 226). Most of the MB samples were classified into the medium/wide group, followed by large, with a few samples falling into the small and narrow groups. Other archaeological sites also show a spread in size – though notably – generally older sites contain a higher

Table 8-16 Summary of all the samples analysed in k-means cluster analysis.

Sample	**Small**	**Narrow**	**Medium &/or Wide**	**Large**	**Subtotal**
Terminal Pleistocene/ Early Holocene[1]	1	1	21	32	55
CCN			**1**		**1**
Mid-Holocene China[2]	65	76	67	65	273
MB	**3**	**2**	**35**	**19**	**59**
Mid– Late Holocene SEA[3]	58	10	70	54	192
Wild			18	12	30
Domestic	10	4	14	7	35
Subtotal	**137**	**93**	**226**	**189**	
Total					**645**

[1] Lobang Hangus, Dingsishan, Cishan

[2] Xipo, Shishanzi, Shouling, Jiangzhai, Banpo, Yinxu

[3] Pre Khmeng, Phum Lovea, Pacung, Sembiran, Nagsabaran, An Son, Rach Nui, Savidug, Vasino, Gan Kira

number of large samples (Lobang Hangus, Dingsishan). Conversely, Mid–Late Holocene sites show a broad spread in size and tend to fall within the medium/wide group.

Particularly interesting is the comparison of MB and Xipo, a Mid Holocene site in the middle Yellow River that clearly has an intense pig-management system (Ma 2004; 2005). There is a spread in molar size within the Xipo assemblage, with 64 samples falling into the larger group (Appendix 5). However, there is a narrowing of molars (n = 117) and a fair proportion fall into the small group (n = 64). At MB, the spread in molar size is more asymmetrically leaning towards wide and larger groups. However, the pigs at Xipo were clearly in an intense management system. If the pigs at MB were in an early phase of management and/or are interbreeding and being supplemented with wild boars, the more asymmetrical spread in size is understandable. This is what Larson and Fuller (2014) term ‘introgressive capture’, and is discussed further in Chapter eleven section 11.2.1.2.

The relatively late sites of Pacung and Sembiran (Bali, Indonesia) show a much clearer distinction in size (Appendix 5.3). This could relate to domestic versus wild pigs, or potentially the exploitation of a larger species (such as *Sus barbatus*). Conversely, both Lobang Hangus and Gan Kira (Borneo) have long sequences, and the pig assemblage has been argued to show a transition in size that may be related to the introduction of domestic pigs (Piper et al. 2009, 693). This appears to be particularly the case for Gan Kira (appendix 5.3), although another possibility is there may be more than one species of pig in the assemblages.

In regards to the modern reference collections, there are clearly some issues with the spread of data, which did not create a distinct division between wild and domestic pigs as anticipated (Table 8-16). This is particularly the case for the modern ‘domestic’ samples which are spread out across small, narrow, medium/wide, and large groups. The broad range in size may be related to interbreeding, regionality, and/or may reflect that modern wild boars have undergone a change in size since the Pleistocene/Early Holocene. For future research it would be beneficial to compare Pleistocene/Early Holocene wild boars with archaeological material, as opposed to modern wild boars. Further, a more regionally specific comparison would potentially help to eliminate such a spread in the data. These factors may offer a more realistic and representative analysis of size reduction related to domestication of pigs in SEA. This is discussed further in the concluding chapter.

8.4.1. Comparison of molar assignment grouping

One of the ways to further explore the patterns within the data is to examine which group each molar was assigned to within a mandible or maxilla. For instance, within a mandible all of the teeth may fall into the ‘small’ group, or the M1 may fall into the ‘small’ group, while the M2 may fall into the ‘medium’ group. There are nine MB mandibles and maxillae where this could be examined; three of these samples had molars that ‘disagreed’ between their assigned groups while the other six ‘agreed’ (Table 8-17). In all cases this ‘disagreement’ was between the ‘medium/wide’ and ‘large groups’. This indicates there is a fair amount of overlap between the medium/wide and large groups. As discussed above, this could be related to the ‘transitory/early’ phase of management/domestication of the pigs from MB and/or interbreeding with wild populations. See appendix 5.2 for a list of all MB samples and which group they were assigned to.

Table 8-17 Comparison of the assigned groups of individual molars in nine MB mandibles and maxillae. * indicates samples that ‘disagreed’ in molar assignment grouping.

Sample	**Assigned Group**	
ID	**Medium/Wide**	**Large**
MBANU-052	UM 1, 2	
MBANU-059*	UM 1	UM 2
MBANU-060*	LM 3	LM 2
MBANU-061	UM 1, 2, 3	
MBANU-070	UM 1, 2, 3	
MBANU-091	UM 1, 2	UM 3
MBANU-225*	UM 1	UM 2
MBANU-265		LM 1, 2
MBANU-416		LM 2, 3

8.4.2. Coefficient of variation

Rowley-Conwy et al. (2012) suggest a coefficient of variation (CV) over 5 indicates there is more than one population of pigs within the assemblage. When comparing the CV between the measured variables in the MB samples the majority of variables have values that are higher than 5 (12 out of 18), and a further 3 variables are very close to a CV of 5 (Table 8-18). Thus, it is not surprising the cluster analysis indicated there were at least three groups within the data set. Following Rowley-Conwy et al.’s (2012) suggestion, it is likely there is more than one group of pigs at MB.

Table 8-18 Summary of Mean, SD, and CV of the lengths, anterior and posterior breadths for all MB molars used in analysis. Measurements in mm. *indicates CV values that are higher than 5.

Lower M1s				Upper M1s			
	Mean	**SD**	**CV**		**Mean**	**SD**	**CV**
LM1L	17.43	1.02	5.87*	UM1L	16.52	1.53	9.25*
LM1Ba	11.38	0.59	5.21*	UM1Ba	14.98	0.92	6.12*
LM1Bp	12.44	0.42	3.39	UM1Bp	15.13	0.72	4.77
Lower M2s				**Upper M2s**			
	Mean	**SD**	**CV**		**Mean**	**SD**	**CV**
LM2L	21.68	1.38	6.37*	UM2L	21.14	1.64	7.74*
LM2Ba	15.48	0.55	3.55	UM2Ba	18.81	0.77	4.09
LM2Bp	16.43	0.62	3.77	UM2Bp	18.62	1.07	5.76*
Lower M3s				**Upper M3s**			
	Mean	**SD**	**CV**		**Mean**	**SD**	**CV**
LM3L	41.02	3.53	8.61*	UM3L	34.72	1.83	5.28*
LM3Ba	16.97	0.83	4.89	UM3Ba	20.68	1.48	7.14*
LM3Bp	17.16	0.88	5.13*	UM3Bp	18.45	1.19	6.48*

8.4.3. Summary

All of the analyses used suggest that there is more than one population of pigs within the MB sample. The cluster analysis indicates at least three statistically significant groupings. The molars fell into a range of categories from small to large. Defining the reason for this spread in molar size, or what the groupings mean, is the challenging aspect of cluster analysis. However, the analogous spread in molar size of other Mid–Late Holocene assemblages indicate this variety in pig biometrics could be related to early phases of domestication or management (i.e. not displaying the full traits of domestication). Additionally, the particularly large samples in the MB assemblage may indicate occasional hunting of wild boar and/or potentially interbreeding with wild populations, this is further discussed in section 11.2.1.2.

8.5. Dog biometrics (*Canis familiaris*) from Mán Bạc

This section discusses the Canidae dental measurements. Only ten postcranial elements were measured, they are detailed in Appendix 4. As discussed in Chapter six section 6.4.8., the Canidae elements found at CCN are most likely *Cuon alpinus* (dhole). However, for MB *Canis aureus* (golden jackal) and the dhole were ruled out based on dental morphology (see Chapter seven section 7.4.7. for specific details). Purely in terms of size the golden jackal and the dhole overlap with the range for modern domesticated and archaeological dogs. In general, the UP4s, UM1s, and LM1s of the dhole are more elongated compared to domestic canids or the golden jackal. For a detailed description of the morphological distinction between the dhole, the golden jackal, and domestic dog see Chapters five section 5.7.3.

For dental biometric analysis, lower M1–2s and upper P4s–M1s of modern domestic dogs, canids from several archaeological sites in SEA, and recent and Palaeolithic wolves were compared (Table 8-19). Modern dingoes were also added to the comparison as they represent the larger size range of domestic/feral dogs. The dhole and the jackal were also included for size comparison.

A quick comparison of size difference displays a clear separation between *Canis lupus* (grey wolf) and the smaller Canidae (Figures 8-7 to 8-11). The Chinese grey wolf (*C. l. chanco*) is relatively small compared to the European grey wolf, nonetheless, the distinction in size between wolves and other canids is clearly evident. The individuals from MB fit closely with archaeological samples from An Son (south Vietnam), Nagsabaran (Philippines), Non Nok Tha and Ban Chiang (Thailand), Sembiran and Pacung (Bali, Indonesia), as well as modern domestic dogs (Figures 8-7 to 8-11).

8.5.1. Summary

Based on morphology of the canids from MB, both the golden jackal and the dhole can be ruled out (Chapter seven, section 7.4.7.), and based on dental metrics the grey wolf can be eliminated. In summary, the canids from MB were almost certainly domesticated dogs.

Table 8-19 List of samples used for Canidae dental biometric analyses. ANU= Australian National University, UPASP= University of the Philippines Archaeological Studies Program, NMNH= National Museum of Natural History, CSIRO= Commonwealth Scientific and Industrial Research Organisation, NHML= Natural History Museum of London, FMNH= Field Museum Natural History. RKJ= data collected by author, PJP= data collected by Philip J Piper.

Species	Site	Region	Collection	Age	Reference
Archaeological samples	Man Bac	Vietnam		3836–3083 cal. BP	RKJ
	An Son	Vietnam		4410–3010 cal. BP	Piper et al. (2010, 10)
	Pacung/Sembiran	Indonesia		Iron Age	RKJ
	Ban Chiang	Thailand		Neolithic	Higham et al. (1980, 161)
	Non Nok Tha	Thailand		Neolithic	Higham et al. (1980, 161)
	Ban Tong	Thailand		Neolithic	Higham et al. (1980, 161)
	Ban Phak Top	Thailand		Neolithic	Higham et al. (1980, 161)
	Ban Lum Khao	Thailand		Neolithic	Higham and Thosarat (2004a, 162)
	Nagsabaran	Philippines		Neolithic–Iron Age	Amano (2011, 153); PJP
	Kamikuroiwa	Japan		Early Jōmon, 7400–7200 cal. BP	Komiya et al. (2015, 78)
Canis familiaris (domestic dog)			ANU	Modern	RKJ
			UPASP	Modern	Amano (2011, 153); PJP
Canis lupus dingo (dingo)			NMNH	Modern	Amano (2011, 153); PJP
			FMNH	Modern	Amano (2011, 153); PJP
			CSIRO	Modern	Amano (2011, 153); PJP
Canis lupus (grey wolf)	Kesslerloch	Switzerland		Magdalenian, Late Palaeolithic	Napierala and Uerpmann (2012, 131)
				Modern	Ripoll et al. (2010, 443–44)

Canis lupus chanco (Tibetan wolf)		China	NHML	Modern	Higham et al. (1980, 153)
Canis aureus (golden jackal)			NHML	Modern	Higham et al. (1980, 152) NB: **MEANS**
Cuon alpinus (cuon, dhole)	Parpallo, La Riera, Gabasa, B Zafarraya, Amalda IV	Iberian Peninsula		Upper Pleistocene	Ripoll et al. (2010, 443)
			NHML	Modern	Higham et al. (1980, 153) NB: **MEANS**
		Nepal, Vietnam, China, India, Laos	FMNH	Modern	PJP

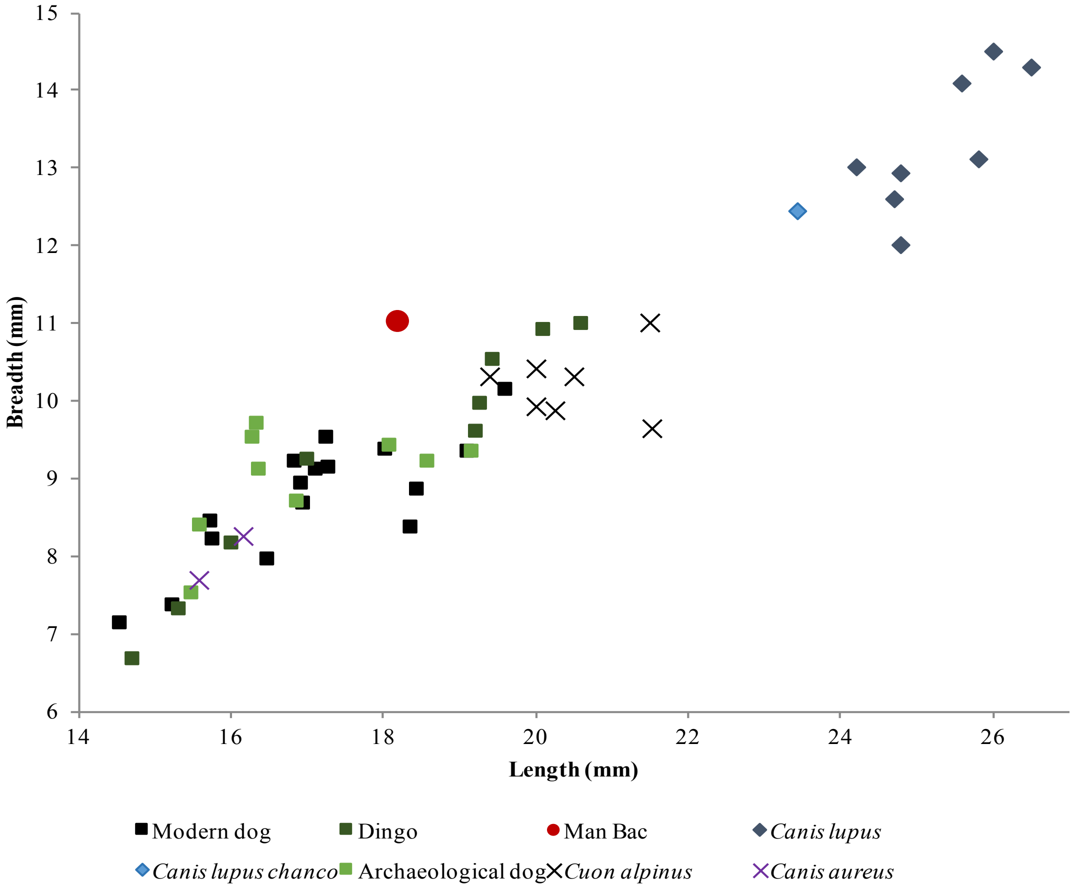

Figure 8-7 Comparison of upper P4s of *Canis* spp. and *Cuon alpinus*.

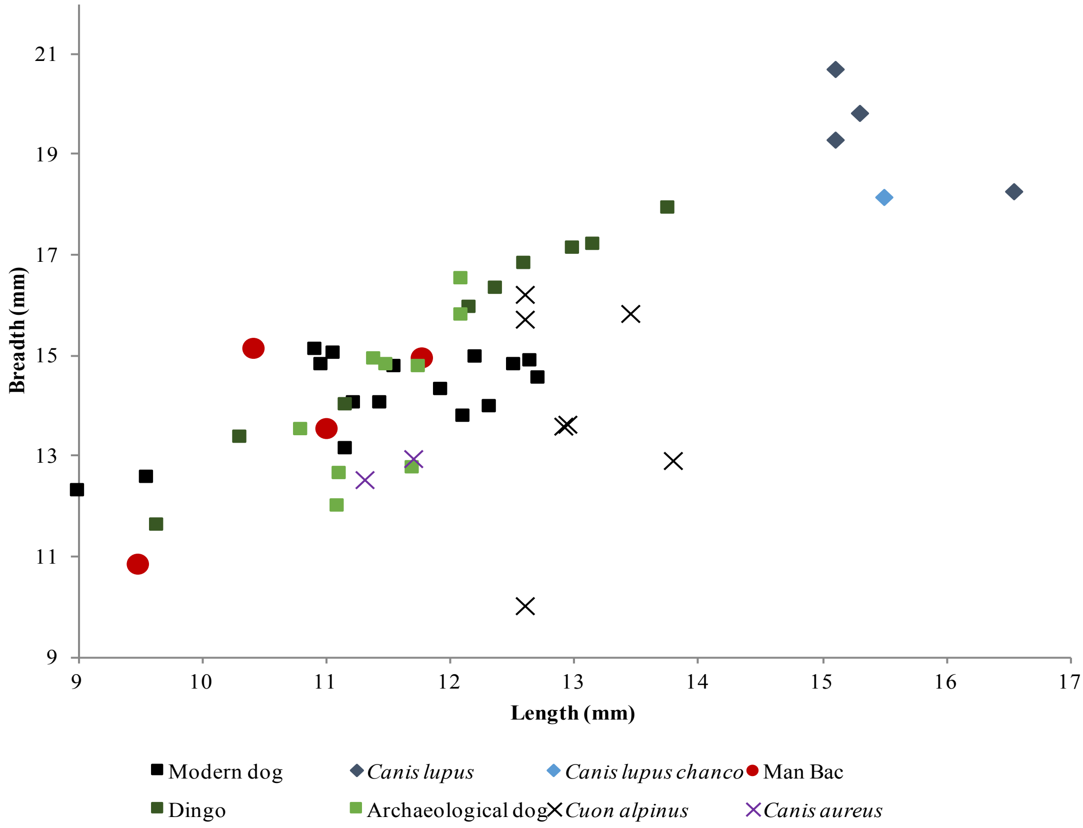

Figure 8-8 Comparison of upper M1s of *Canis* spp. and *Cuon alpinus*.

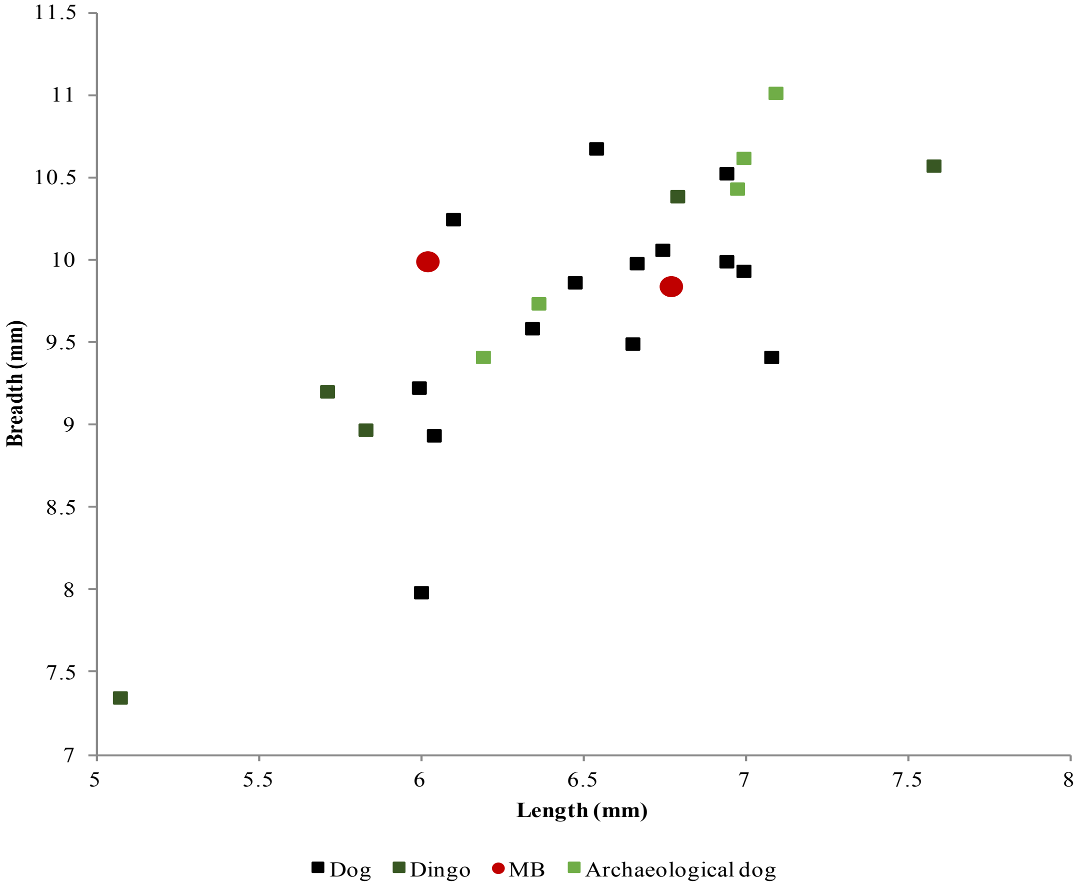

Figure 8-9 Comparison of upper M2s of *Canis familiaris* and archaeological samples. Comparative measurements of *Canis lupus*, *Canis aureus*, or *Cuon alpinus* were not found.

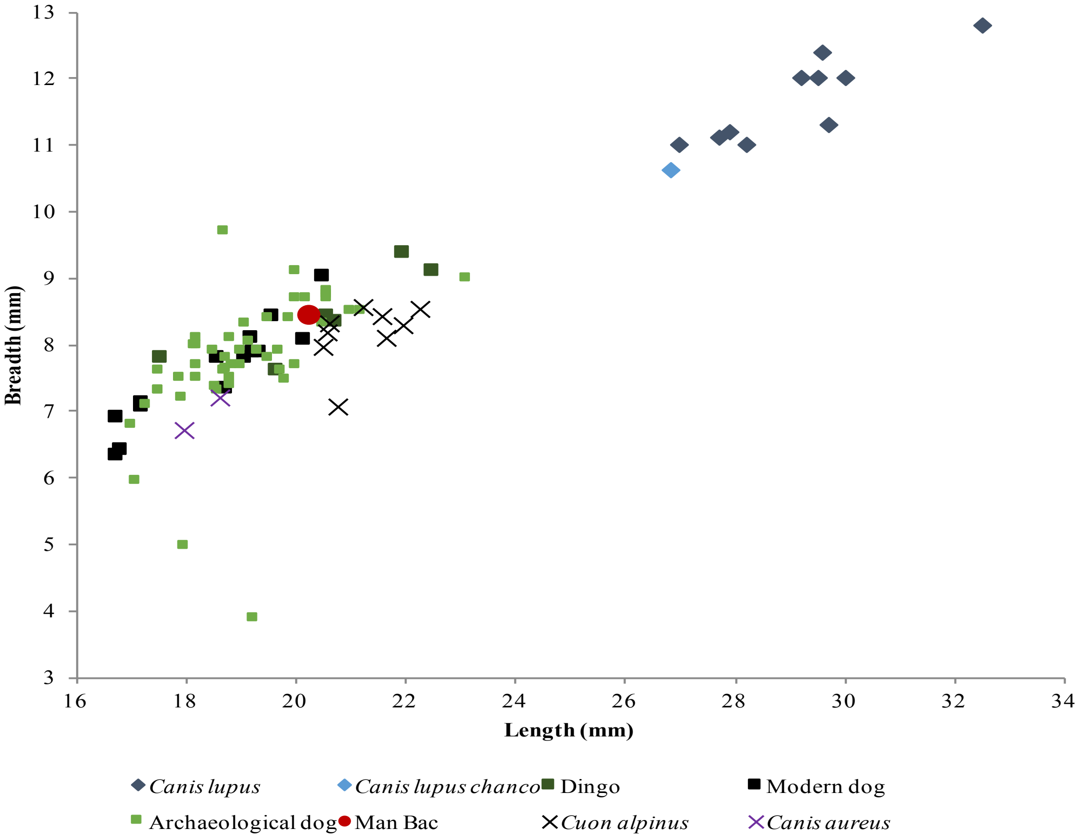

Figure 8-10 Comparison of lower M1s of *Canis* spp. and *Cuon alpinus*.

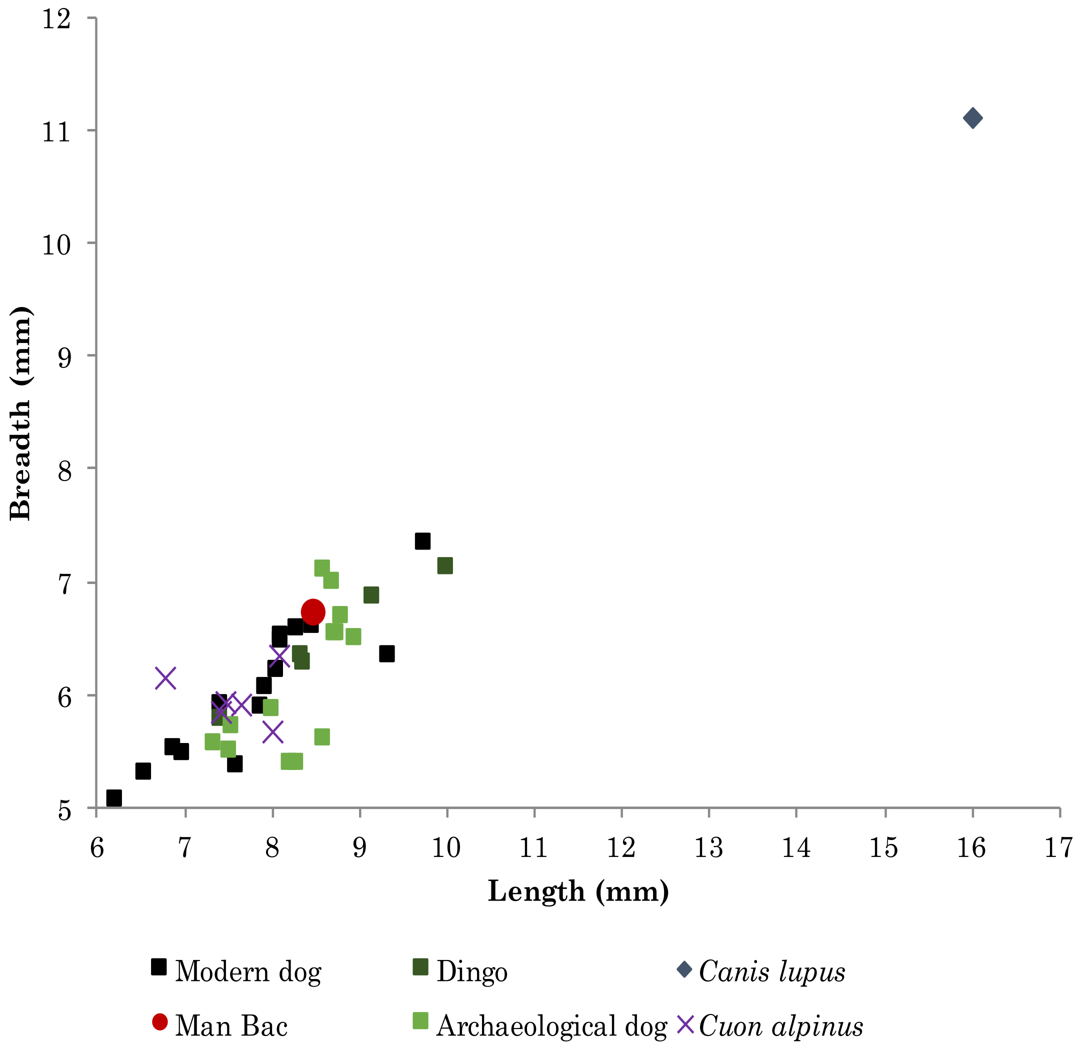

Figure 8-11 Comparison of lower M2s of *Canis* spp. and *Cuon alpinus*. The *Canis lupus* measurement is an average measurement, from Napierala and Uerpmann (2012, 131).

8.6. Bovinae biometrics from Cồn Cổ Ngựa

Biometric data of the Bovinae from CCN were collected for two main purposes. Firstly, there are a variety of species of Bovinae in SEA and comparison of size can help to distinguish within these genera. Morphological criteria can also assist in distinguishing between these genera, as outlined in Chapters six, 6.4.11. and seven, 7.4.10. Secondly, a size comparison could help to determine whether any of the bovids were domesticated. As with other domesticated animals, it is hypothesised that domesticated bovids will be smaller than their wild counterparts. However, little is known about the domestication of water buffalo in SEA (Flad et al. 2007; Yuan 2010, and see Chapter three, section 3.5.3.3.). This is further compounded by the scarcity of published comparative measurements of Bovinae, which makes it difficult to properly test either of these main aims. Nonetheless, postcranial and dental measurements were taken of Bovinae skeletal elements (Appendix 4). The most well published comparative material are phalanges and dentition (see Tables 8-20 and 8-21), thus, discussion will be limited to these two skeletal areas. Due to the difficulty in obtaining useful comparison material these results are provisional. Further, this analysis is restricted primarily to CCN due to the limited bovid remains from MB.

8.6.1. Phalanges

Sub-terminal phalanges (intermediate, 2nd phalanx) and basal phalanges (proximal, 1st phalanx) measurements were collated from archaeological and modern reference collections (Table 8-20). Higham's (1975a; 1975b) measurements of Non Nok Tha (NNT) in Thailand were a particularly useful comparison, and the Aceramic site of Santhli was also used for comparison (Patel and Meadow 1998). Two Pleistocene samples from China and India were added for a large-size comparison (Badam and Jain 1988; Mead et al. 2014). Modern measurements of a variety of species were obtained from published material and measurements were collected at the Australian Museum (Table 8-32).

For sub-terminal phalanges, ten CCN samples are well on the larger side of the graph while one falls in with the smaller NNT samples (Figure 8-12). Intriguingly, the CCN samples are much larger than the Pleistocene species *Leptobos* or modern *Bos gaurus*, which are both large animals. For basal phalanges, three CCN samples fall within the larger group, close to Pleistocene species *Bos namadicus* and *Leptobos* (Figure 8-13).

Table 8-20 Samples used for comparison of sub-terminal and basal phalanges of Bovinae.

Site	Species	Age	Location	Reference
Archaeological				
CCN	cf. *Bubalus*		Vietnam	RKJ
NNT	cf. *Bos and* cf. *Bubalus*		Thailand	Higham (1975a; 1975b)
Santhli	cf. *Bubalus arnee*	Aceramic	India	Patel & Meadow (1998, 189)
Pleistocene				
	Bos namadicus (extinct)	Mid–Late Pleistocene	India	Badam & Jain (1998, 100)
Renzidong Cave	*Leptobos* (extinct)	Pleistocene	China	Mead et al. (2014, 5)
Modern				
Species	**Common name**	**Collection**	**Notes**	**Reference**
Bubalus bubalis	Water buffalo			Higham (1975a, 42)
			Means	Patel & Meadow (1998, 198–99)
			Means	Nourinezhad et al. (2012, 231)
Bos taurus	Cattle		Means of 24 females	Higham (1975a, 274)
Bos javanicus	Banteng			Higham (1975b, 49)
Bos gaurus	Gaur			Higham (1975a, 274)
Bos grunniens	Yak	Australian Museum		RKJ
Bos indicus	Zebu cattle	Australian Museum		RKJ

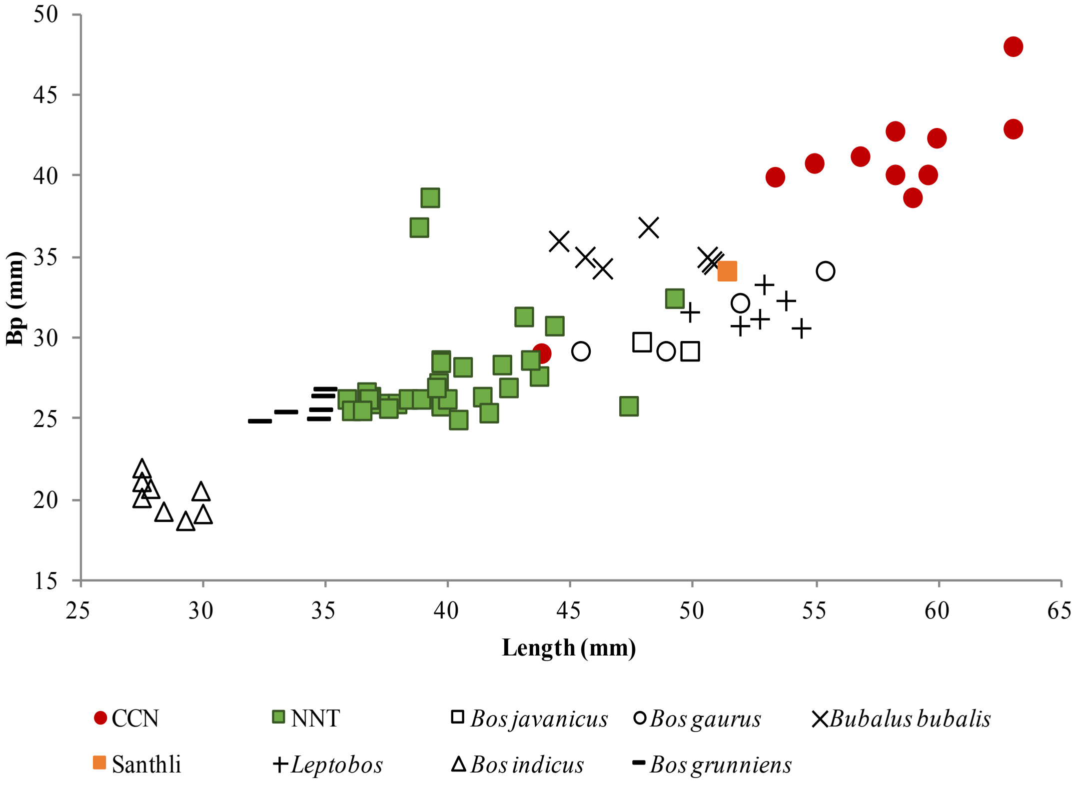

Figure 8-12 Length and proximal breadth of sub-terminal phalanges.

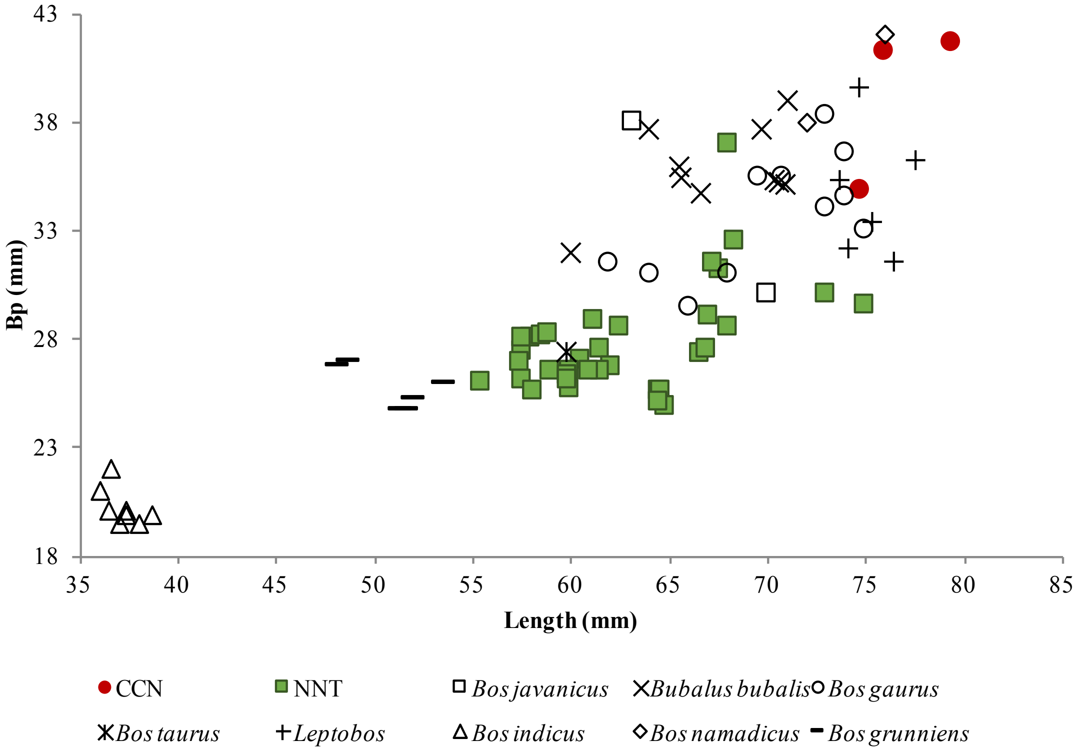

Figure 8-13 Length and proximal breadth of basal phalanges.

8.6.2. Dentition

Measurements of Bovinae dentition were collated from archaeological and modern collections for comparison (Table 8-21). One of the major issues was that many publications only give length and no breadth measurements, which makes comparison difficult. Archaeological samples include two Iron Age sites in Cambodia, the Early Holocene site Dingsishan (China), and the Aceramic period site Sathli (India). As before, Pleistocene samples from the Asian region were included for large comparatives. Unfortunately, there were no upper M1s from CCN.

The CCN samples generally fall into the larger side of the graph and are fairly similar in size to Dingsishan (Early–Mid Holocene), Tatrot, and Tam Hang South (THS; Mid Pleistocene; Figures 8-14, 8-15, 8-16). The two Iron Age cf. *Bubalus* samples from Cambodia overlap with the smaller CCN samples. The Pleistocene Illford samples of *Bos primigenius* lower and upper M3s generally fall into the largest part of the graph (upper right).

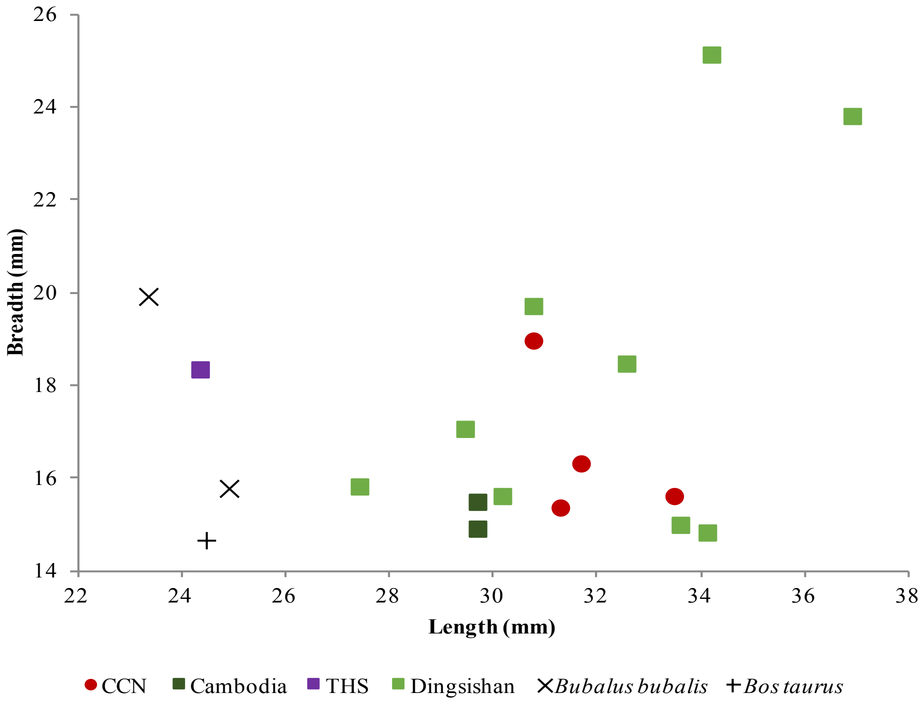

Figure 8-14 Length and breadth of lower M1s.

Table 8-21 Samples used for biometric comparison of Bovinae molars.

Site/collection	**Location**	**Age**	**Species**	**Reference**
Archaeological				
CCN	Vietnam		cf. *Bubalus*	RKJ
Prei Khmeng	Cambodia	Iron Age	cf. *Bubalus*	RKJ
Phum Lovea	Cambodia	Iron Age	cf. *Bubalus*	RKJ
Dingsishan	China	Early–Mid Holocene	*Bubalus* spp.	Lu (2010)
Santhli	India	Aceramic	*Bubalus* spp.	Patel & Meadow (1998)
Pleistocene				
Tam Hang South	Laos	Mid Pleistocene		Bacon et al. (2010)
Tatrot	Pakistan	3.3-2.6 Ma	cf. *Bison sivalensis*	Khan et al. (2011; 2010)
Modern				
Australian Museum			*Bubalus bubalis*	RKJ
			Bos taurus	
Australian National University			*Bos taurus*	

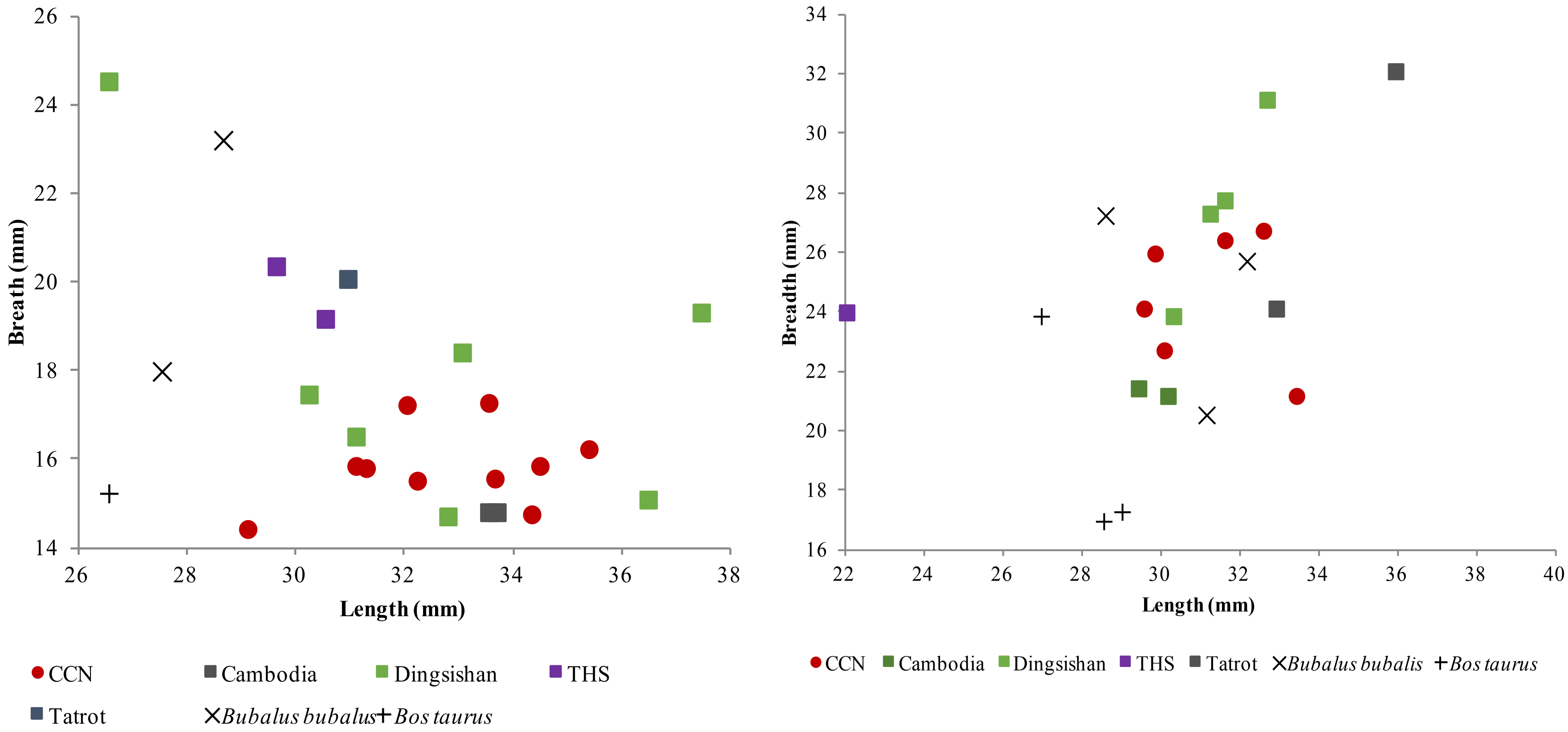

Figure 8-15 Length and breadth comparison of lower (left) and upper (right) M2s.

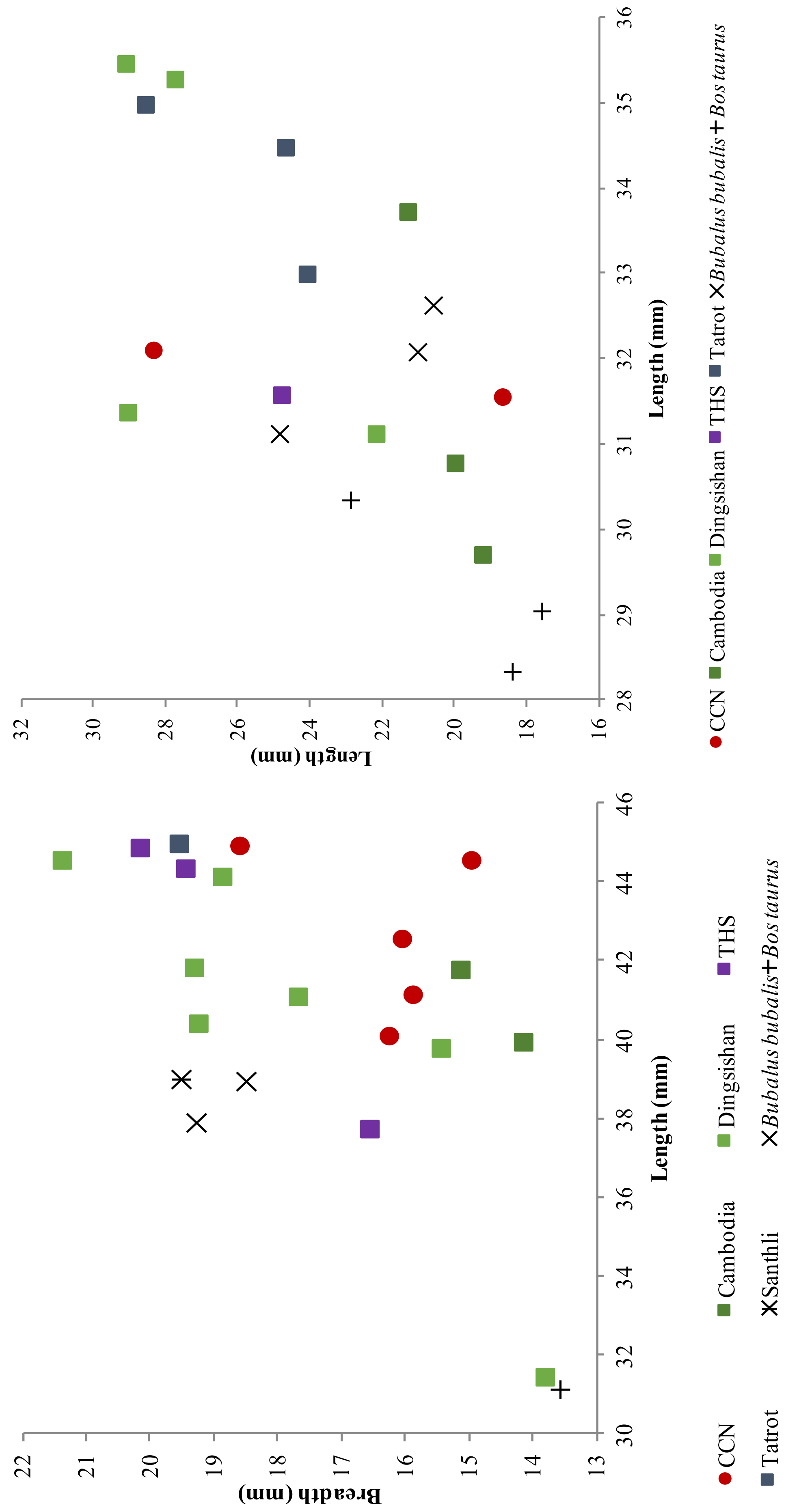

Figure 8-16 Length and breadth comparison of lower (left) and upper (right) M3s.

8.6.3. Summary of Bovinae dentition and phalange biometrics

The limited comparative material makes it difficult to draw any definite conclusions. However, the CCN samples are generally quite large in comparison to modern domestic *Bubalus bubalis* or *Bos* spp. They are also relatively large compared to NNT in Thailand and Prei Khmeng and Phum Lovea in Cambodia. The CCN samples are most similar in size to Dingsishan, although the smaller samples overlap with the Cambodian samples (Figures 8-14 to 8-16). Overall, based on the above comparative data the majority of the CCN samples probably represent wild *Bubalus* spp. (water buffalo), potentially *Bubalus arnee*.

On the basis of biometrics, Higham (1975a; 1975b) argued there were at least two species of bovids at NNT, the larger species probably representing *Bubalus* and the smaller *Bos*. A comparison of the sub-terminal phalange measurements supports this theory for CCN (Figure 8-12). One sub-terminal phalanx falls within the NNT range of measurements and is far smaller in size to the rest of the CCN samples. Along with morphological criteria, this supports the presence of at least one *Bos* sp. within the assemblage (see Chapter six, section 6.4.11. for morphological criteria).

8.7. Conclusion to Chapter eight

The aims of this chapter were to distinguish between wild and domestic taxa of pigs, dogs, and bovids at CCN and MB, and to help differentiate between different Bovinae genera. Based on the above biometric analyses there are three main conclusions that can be drawn:

1. The pig statistical analyses suggested the presence of at least three groups of pigs at MB with all of the molars generally falling into ‘small’, ‘medium’, ‘narrow’, ‘wide’ and ‘large’ categories. This pattern is similar to all of the archaeological material from Mid–Late Holocene, which displayed a spread in molar size. It was argued this variety in size may indicate the pigs at MB were in an early stage of management or domestication. This may have been supplemented with occasional hunting of wild boar. This patterning is is agreement with what Sawada et al. (2011) originally hypothesised.

2. The dogs at MB can be confidently identified as domestic dog (*Canis familiaris*) based on the morphometric analyses. All the MB dog elements fall comfortably within the domestic dog range and are similar in size and morphology to other Mid Holocene

archaeological dogs across SEA and Asia, especially An Son (Vietnam), Nagsabaran (Philippines), Bang Chiang and Non Nok Tha (Thailand), and Kamikuroiwa (Japan).

3. The Bovinae from CCN were probably wild water buffalo (*Bubalus arnee*). The presence of at least one wild cattle (*Bos* spp.) at CCN is suggested through morphological and metrical differences to *Bubalus* (see Chapter, section 6.4.11.). For instance, the comparison of sub-terminal phalanges shows a distinct separation between the majority of CCN samples, which are extremely large, and one much smaller phalange from CCN that clusters close to the NNT samples (Figure 8-12).

The statistical analysis of pig dentition in this chapter suggests the pigs from MB may have been in an early phase of management as their molar size has reduced, but is still variable. This complements the ageing analysis in Chapter seven (section 7.4.8.1.), which strongly suggested a management strategy focusing on meat production. Further, the definite presence of domesticated dog at MB adds further weight to the hypothesis of the pigs being domesticated, as the two-layer hypothesis stipulates that domestic dogs and pigs were probably introduced into northern Vietnam together (Chapter two, see section 2.3.11.). These conclusions are effectively what Sawada et al. (2011) orginally suggested, and this analysis supports those hypotheses. Conversely, the absence of domesticated taxa at CCN throws doubt on the claims of some scholars (Bui Vinh 1991; Nguyen Viet 2005) who argued the Đa Bút period shows the first evidence for agriculture and domestication in Vietnam. The broader implications of the presence or absence of domesticated taxa at MB and CCN will be discussed in Chapter eleven.

Lastly, it is worth restating that this type of comparative biometric analysis is only as good as its comparative reference material. Although SEA zooarchaeology has come a long way, it is hoped that as the field continues to develop, more quantitative data will be published to allow for more in-depth comparison. One of the findings to come out of the pig dental comparison was that modern wild boar reference material may not be an entirely appropriate analogy for Late Pleistocene/Early Holocene wild boar. Further, more regionally specific measurements of boar and pigs would be beneficial, as some of the difference in size may be related to regionally-specific morphology. The same critiques apply to analyses of other domestic taxa, particularly of Bovinae, which is lagging behind. For a further discussion of these issues see the concluding chapter.

CHAPTER NINE
Taxonomic comparison

9.1. Introduction

This chapter is divided into two main components: a taxonomic comparison specifically of CCN and MB, and a multivariate regional analysis comparing fauna assemblages across SEA. The comparison between CCN and MB is based on the methods outlined in methodology Chapter five section 5.8., and it is largely based on taxonomic indices outlined in Lyman (2008). The multivariate analysis is based on methods outlined in thesis methodology section 5.9.

The purpose of undertaking these methods of analysis relates to the main aims of this thesis (Chapter one section 1.2.). Namely, to compare the faunal assemblages of CCN and MB and understand and account for any perceivable similarities or differences in composition or abundance of taxa. Since CCN and MB sit on either side of the proposed ‘Neolithic boundary’ in Vietnam, differences in the faunal assemblage could potentially relate to changing subsistence economies and domestication. The multivariate analysis is aimed at addressing wider regional patterns within SEA faunal assemblages. Effectively, this chapter provides both a micro and macro image of CCN and MB by specifically comparing fauna identified at each site, and contextualising how this compares to other sites within SEA.

9.2. Taxonomic structure and composition of Cồn Cổ Ngựa and Mán Bạc

This section specifically compares the faunal assemblages of CCN and MB. Analyses undertaken include: NTAXA/richness, measures of taxonomic composition, taxonomic heterogeneity, and χ^2 analysis.

9.2.1. NTAXA / richness and sample size influence

The number of taxa within an assemblage is one of the most basic forms of comparing assemblages. However, as Lyman (2008) and Grayson (1984) warn it can be affected by sample size. This can be easily checked by comparing the NTAXA to NISP values.

Lyman (2008, 192, 194) log transforms NISP values and places them on a biplot with a linear trendline for simple comparison. In order to test whether sample size was affecting the assemblages, the NTAXA of CCN and MB were compared to other sites in Thailand, China, Vietnam, and ISEA (Table 9-1). NTAXA was calculated to a genus level for mammals, birds, and reptiles. Fish and Elasmobranchii were excluded to enable inter-site comparability as they were not part of the analysis of MB and are often not included in other comparative literature.

Table 9-1 NTAXA and NISP comparison between sites and log transformed values.

Region	Site	NTAXA	NISP	Log transformed	
				NTAXA	NISP
Vietnam	CCN	20	3095	1.3	3.49
	MB	14	2581	1.15	3.41
	An Son	11	275	1.04	2.44
	Rach Nui	17	847	1.23	2.93
	Lang Trang	25	3250	1.4	3.51
	Hang Boi	23	139	1.36	2.14
Thailand	Khok Phanom Di	46	6816	1.66	3.83
	Ban Non Wat	15	2903	1.18	3.46
	Non Nok Tha	11	178	1.04	2.25
	Ban Lum Khao	6	425	0.78	2.63
	Ban Chiang	22	364	1.34	2.56
ISEA	Pacung & Sembiran	8	628	0.9	2.8
	Nagsabaran	5	980	0.7	2.99
	Niah: Lobang Hangus	49	2018	1.69	3.3
	Niah: West Mouth	50	1338	1.7	3.13
	Braholo Cave	33	1658	1.52	3.22
China	Xipo	19	3001	1.28	3.48
	Dingsishan	21	35065	1.32	4.54
	Wayaogou	23	6094	1.36	3.78

Based on the statistically insignificant R^2 value there is no correlation between sample size and NTAXA (Table 9-1, Figure 9-1). This indicates that some degree of caution should be applied when making inferences about taxonomic composition. However, since this correlation is relatively weak it is acceptable to proceed with statistical analyses.

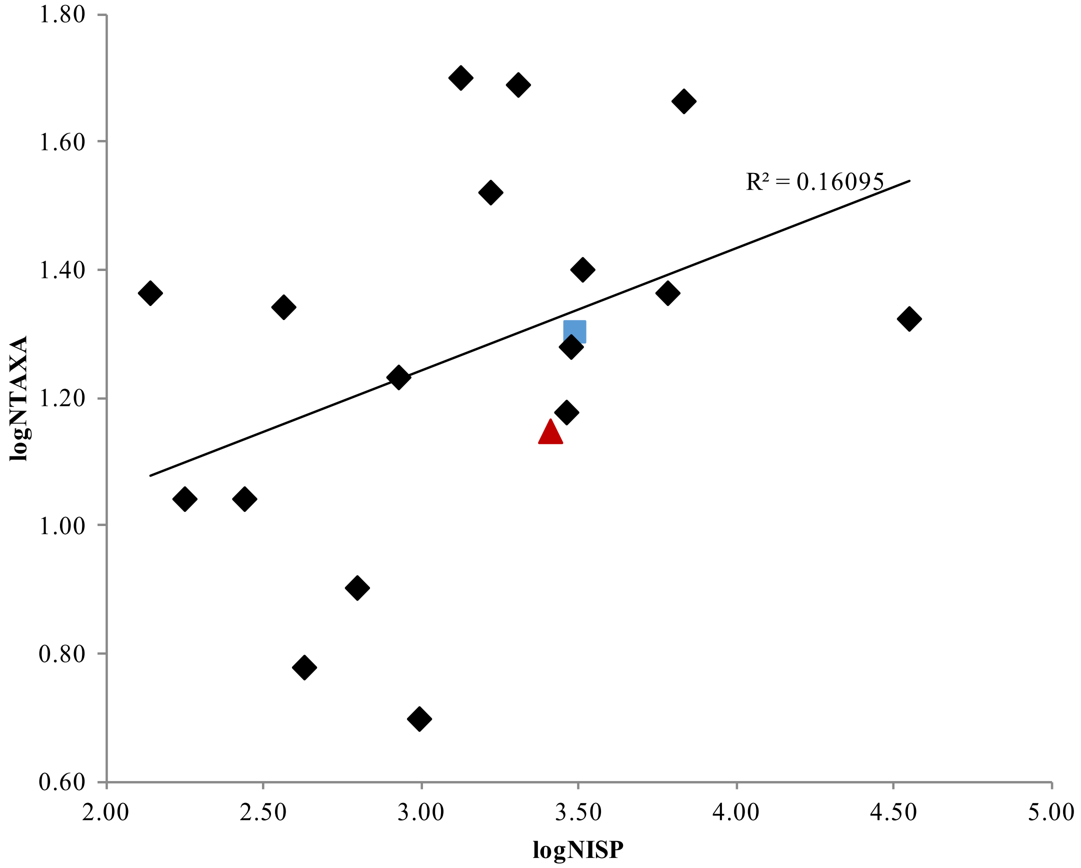

Figure 9-1 Log transformed NISP and NTAXA based on values in table 7-1. CCN is represented by blue square and MB by the red triangle.

9.2.2. Taxonomic composition

For this section the NTAXA and NISP of CCN and MB were specifically compared. As before, this comparison includes mammals, reptiles, and birds and excludes fish, sharks, and rays. The statistical methods applied here are Jaccard and Sorenson indices. The Jaccard index emphasises differences between fauna and the Sorenson index emphasises similarities (see Chapter five, section 5.8.2. for discussion).

The Jaccard (J) and Sorenson (S) indices were compared at the genera level using NTAXA:

$$\begin{aligned} J &= 100C / (A + B - C) \\ &= 100*11 / (20 + 14 - 11) \\ &= \mathbf{47.83} \end{aligned}$$

$$\begin{aligned} S &= 100(2C) / (A + B) \\ &= 100(2*11) / (20 + 14) \\ &= \mathbf{64.71} \end{aligned}$$

In both the above equations:
A = NTAXA in CCN
B = NTAXA in MB
C = NTAXA in common to both assemblages

A Jaccard index of 47.83 and a Sorenson index of 64.71 is modest, suggesting the assemblages are slightly similar (64.71), but there is also a fair amount of difference (47.83). However, the issue with these indices is that they do not take into account taxonomic abundance (Chapter five, 5.8.2.) Thus, to explore this pattern taking into account taxonomic abundance, the adjusted Sorenson index (Sq) was calculated with NISP using the mammalian genera only:

$$\begin{aligned} Sq &= 2CN / (AN + BN) \\ &= 2*101 / (341 + 627) \\ &= \mathbf{0.2087 \text{ or } 20.87\%} \end{aligned}$$

Where;
AN = ∑ of NISP in CCN (Table 9-2)
BN = ∑ of NISP in MB (Table 9-2)
CN = ∑ of the lesser of the two abundances of taxa shared between assemblages (Table 9-3)

Table 9-2 Total NISP of mammalian genera in CCN and MB assemblages.

Total NISP mammal genera			
CCN	**NISP**	**MB**	**NISP**
Macaca	6	*Macaca*	1
Trachypithecus	1	*Rattus*	4
Rattus	7	*Hystrix*	1
Hystrix brachyura	1	*Canis familiaris*	8
Atherurus macrourus	1	*Viverra*	3
Manis	5	*Aonyx cinereus*	2
Panthera tigris	3	*Sus* cf. *scrofa*	565
Neofelis/Pardofelis	7	*Cervus*	25
Viverra	4	*Muntiacus*	10
Cuon alpinus	1	*Bubalus*	3
Aonyx cinerus	5	*Bos*	3
Sus cf. *scrofa*	50	*Rhinoceros*	2
Cervus	99		
Muntiacus	9		
Bubalus	126		
Bos	16		
Total	**341**	**Total**	**627**

Table 9-3 Method for determining CN value based on the sum of the lesser of the two abundances of taxa shared between assemblages (highlighted in bold). For an explanation of the method see section 5.8.2.

Shared taxa					
CCN	**NISP**	**CN value**	**MB**	**NISP**	**CN value**
Macaca	6		*Macaca*	**1**	**1**
Rattus	7		*Rattus*	**4**	**4**
Hystrix	1		*Hystrix*	**1**	**1**
Viverra	4		*Viverra*	**3**	**3**
Aonyx	5		*Aonyx*	**2**	**2**
Sus cf. *scrofa*	**50**	**50**	*Sus* cf. *scrofa*	565	
Cervus	99		*Cervus*	**25**	**25**
Muntiacus	**9**	**9**	*Muntiacus*	10	
Bubalus	126		*Bubalus*	**3**	**3**
Bos	16		*Bos*	**3**	**3**
Subtotal		**59**	**Subtotal**		**42**
CN value (59+42) = 101					

The differences in the assemblages indicated by the Jaccard and Sorenson indices become increasingly emphasised when taking taxa abundance into account with the adjusted Sorenson index: 20.87. Although CCN has more NTAXA, MB has a far higher NISP of genera (Tables 9-2 and 9-3). This is because *Sus scrofa* dominate the identified genera in the MB assemblage. Thus, according to the adjusted Sorenson index CCN and MB have very different assemblages when considering taxonomic abundance.

Another simple way to show similarities and differences between two faunal assemblage is to create a bivariate scatterplot using relative (percentage) abundances of taxa (Lyman 2008, 189–90; Figure 9-2). Only taxa with values <100 are displayed (not including *Sus*, *Bubalus*, and *Cervus*) in order to plot the values. If the relative abundances of taxa were equivalent between sites the points would fall close to the linear trendline. The points that fall further on the MB side suggest that taxa are relatively more abundant at that site, and vice versa. Thus, Figure 9-2 suggests that among the taxa that are less abundant (<100 NISP), there are some clear differences in relative taxonomic abundance. For instance, MB has comparatively more dogs (*Canis familiaris*) and muntjacs (*Muntiacus*), while CCN has comparatively more wild cattle (*Bos*) and felids (*Panthera tigris*, *Neofelis*/*Pardofelis*). Conversely, the relative proportion of otters (*Aonxy cinereus*) at each site is very similar. Overall, Figure 9-2 suggests that even when removing the most abundant taxa there are still distinct differences in faunal composition between MB and CCN. In terms of taxa that are particularly archaeologically interesting, the absence of dogs at CCN compared to their (relatively) high presence at MB is intriguing.

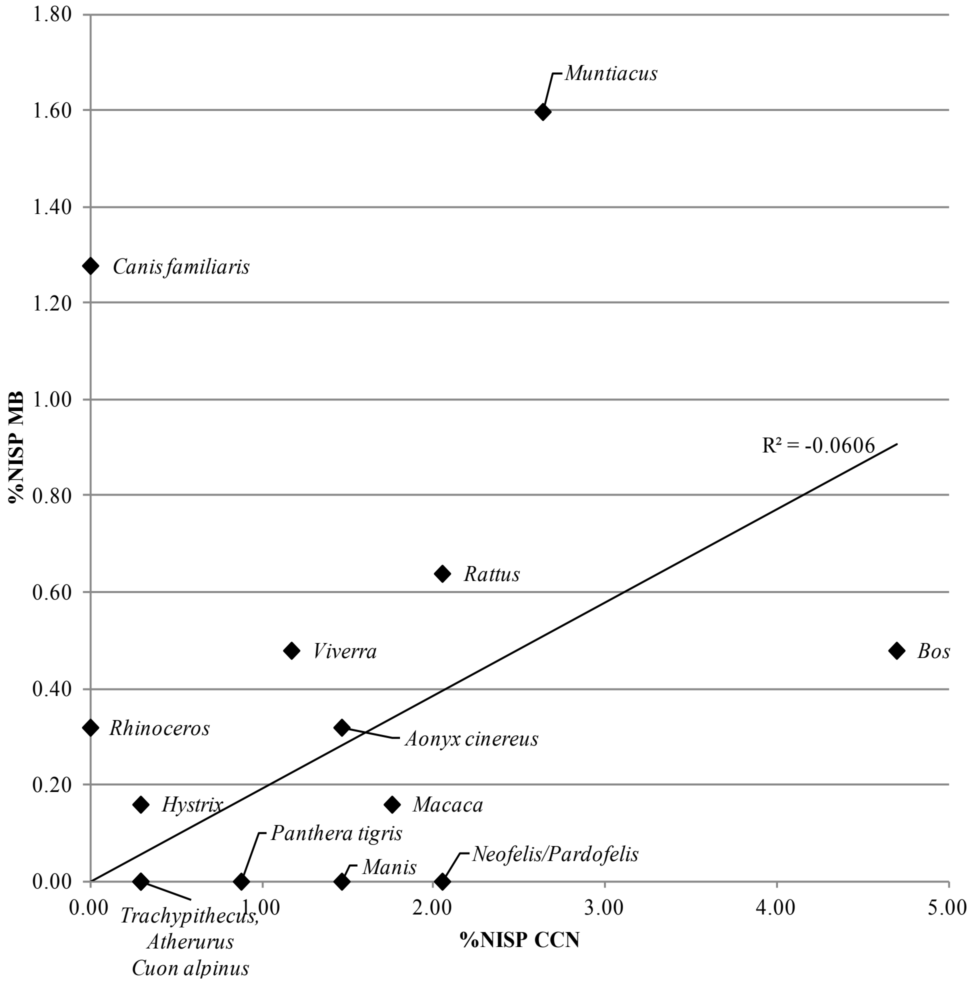

Figure 9-2 Bivariate scatterplot of relative (percentage) abundances of mammalian genera at CCN and MB. Only genera with a NISP <100 were plotted.

8.2.3. Taxonomic heterogeneity

The Shannon-Wiener index (H) is a measure of the relative (proportional) abundances of taxa (Lyman 2008, 192). The greater the value, the greater the heterogeneity (see Chapter five, section 5.8.3.). The equation is as follows:

$$H = - \sum [(P_i) * \ln(P_i)]$$

Where;

P_i = proportion (P) of a particular taxon/species (i) in the assemblage
ln = natural log
$-\sum$ = (minus) total NISP

The methodology for working out the Shannon-Wiener indices of CCN and MB are detailed below (Tables 9-4 and 9-5). The Shannon-Wiener index for CCN is 1.76, and

0.51 for MB. This suggests that CCN is more heterogeneous in taxonomic composition than MB.

Table 9-4 Method for determining Shannon-Wiener index for CCN based on mammalian taxa.

Taxon	NISP	P_i (taxon / total NISP)	ln(P_i)	P_i*ln(P_i)
Macaca	6	0.02	-4.04	-0.07
Trachypithecus	1	0.00	-5.83	-0.02
Rattus	7	0.02	-3.89	-0.08
Hystrix	1	0.00	-5.83	-0.02
Atherurus macrourus	1	0.00	-5.83	-0.02
Manis	5	0.01	-4.22	-0.06
Panthera tigris	3	0.01	-4.73	-0.04
Neofelis/Pardofelis	7	0.02	-3.89	-0.08
Viverra	4	0.01	-4.45	-0.05
Cuon alpinus	1	0.00	-5.83	-0.02
Aonyx cinerus	5	0.01	-4.22	-0.06
Sus cf. *scrofa*	50	0.15	-1.92	-0.28
Cervus	99	0.29	-1.24	-0.36
Muntiacus	9	0.03	-3.63	-0.10
Bubalus	126	0.37	-1.00	-0.37
Bos	16	0.05	-3.06	-0.14
Total	**341**			**-1.76**
Shannon-Wiener				**1.76**

Table 9-5 Method for determining Shannon-Wiener index for MB based on mammalian taxa.

Taxon	NISP	P_i (taxon / total NISP)	ln(P_i)	P_i*ln(P_i)
Macaca	1	0.00	-6.44	-0.01
Rattus	4	0.01	-5.05	-0.03
Hystrix	1	0.00	-6.44	-0.01
Canis lupus familiaris	8	0.01	-4.36	-0.06
Viverra	3	0.00	-5.34	-0.03
Aonyx cinereus	2	0.00	-5.75	-0.02
Sus cf. *scrofa*	565	0.90	-0.10	-0.09
Cervus	25	0.04	-3.22	-0.13
Muntiacus	10	0.02	-4.14	-0.07
Bubalus	3	0.00	-5.34	-0.03
Bos	3	0.00	-5.34	-0.03
Rhinoceros	2	0.00	-5.75	-0.02
Total	**627**			**-0.51**

To determine whether this difference in heterogeneity is caused by a difference in taxonomic evenness, this was calculated using the index for evenness (e) (Lyman 2008, 195). The lower the value, the less evenly distributed the assemblage. The equation for evenness is:

$$e = H / \ln S$$

Where;

H = Shannon-Wiener index
ln = natural log
S = NTAXA

$$\text{CCN evenness} = 1.76 / \ln{*}18$$
$$= \mathbf{0.61}$$

$$\text{MB evenness} = 0.51 / \ln{*}12$$
$$= \mathbf{0.21}$$

The evenness for CCN is 0.61 and for MB is 0.21. This suggests that MB is not very evenly distributed because the assemblage is dominated by *Sus* cf. *scrofa*, whereas CCN is relatively more evenly distributed between taxa. This can be easily seen in Figure 9-3, which captures the uneven distribution of taxa between sites and the stark difference in NISP values.

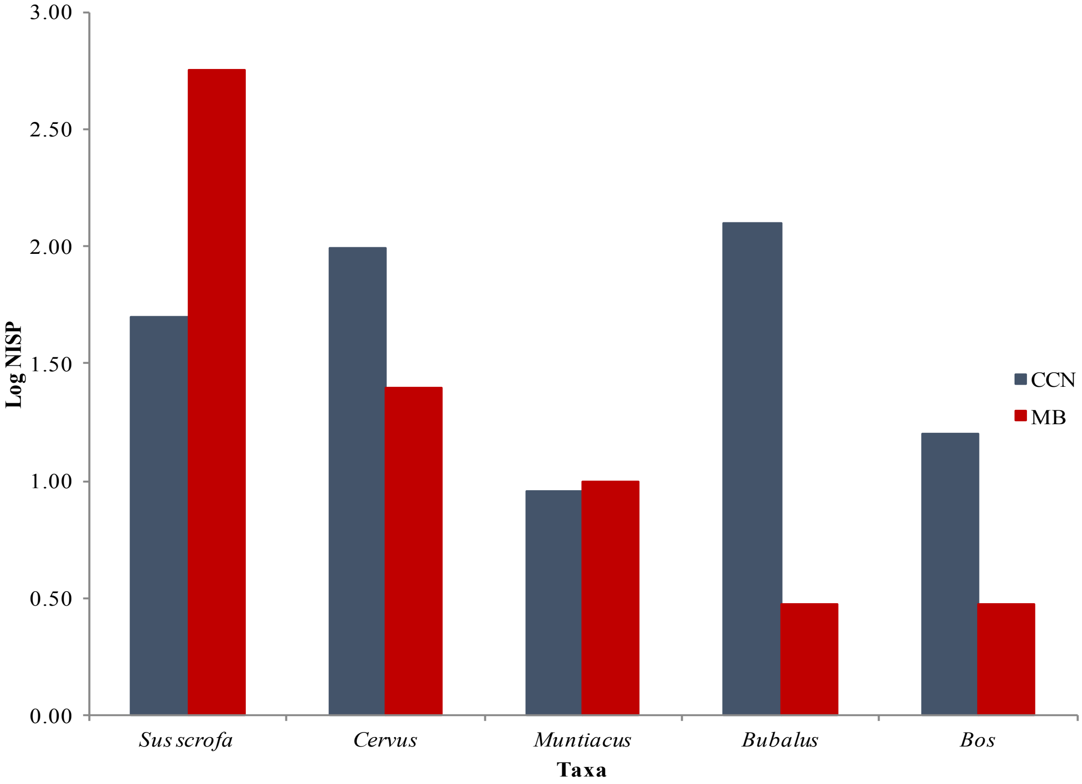

Figure 9-3 A comparison of the log NISP of the five most abundant mammalian taxa for CCN and MB.

9.2.4. Chi-square analysis

To determine whether the differences between the assemblages of CCN and MB (as indicated by the indices above), were statistically significant a χ^2 analysis was performed. The benefit of χ^2 is that not only can the abundances of taxa be checked as statistically significant, the adjusted residuals provide a determination of whether the observed and expected values per taxa are significant. This allows an assessment of which particular taxa are causing the observed significant difference. The initial χ^2 test performed on the mammals from CCN and MB suggests the samples differ significantly: $\chi^2 = 603.66$; $p = <0.0000001$. Spearman's correlation indicates the samples are not correlated, which suggests they may have been derived from different populations: Spearman's = 0.500055; $p = 0.0345765$.

To determine which particular taxa were contributing to this statistically significant difference the adjusted residuals were calculated; a value of <2 or >2 is significant at $p = <0.05$ (Table 9-6). The adjusted residuals suggest that most of the taxa within the assemblage are creating a degree of significant difference. However, a comparison of the values between CCN and MB show that two taxa are contributing the most to this difference, *Sus scrofa* and *Bubalus*. At MB there is comparatively more pigs and fewer water buffalo, while the opposite is the case for CCN.

To determine whether it was indeed these two particular taxa that were playing the major role in the statistical difference between the assemblages another χ^2 analysis was performed, with both *Sus scrofa* and *Bubalus* removed. When these taxa are removed the assemblages are no longer statistically significant $\chi^2 = 47.37$; $p = 0.135697$ and Spearman's test suggests they are correlated Spearman's = 0.0389681; $p = 0.135697$.

9.2.5. Summary taxonomic structure and composition

The Jaccard and Sorenson indices suggested the two assemblages were not particularly similar. This difference was further emphasised when using the adjusted Sorenson index taking into account taxonomic abundance. The Shannon-Wiener index suggested that CCN is relatively heterogeneous in taxonomic composition, while MB is relatively homogeneous. The measure of evenness of MB shows that *Sus scrofa* dominates the taxonomic assemblage and this influences the Shannon-Wiener measure of heterogeneity. The $\chi2$ analysis indicates that the two assemblages are statistically significantly different. The two taxa that are contributing most of the difference are the relative abundances of

Table 9-6 Results of χ^2 analysis for CCN and MB (below) showing observed versus expected NISP and the adjusted residuals (AdR). Taxa that are statistically significant are noted with an asterisk (*). The two taxa contributing to the major difference are highlighted in bold.

CCN taxa	Observed	Expected	AdR
Macaca	6	2.5	2.23*
Trachypithecus	1	0.4	2.84*
Rattus	7	3.9	1.26
Hystrix	1	0.7	0.65
Atherurus macrourus	1	0.4	2.82*
Manis	5	1.8	2.85*
Panthera tigris	3	1.1	2.85*
Neofelis/Pardofelis	7	2.5	2.86*
Canis familiaris	0	2.8	-1.56
Viverra	4	2.5	0.97
Cuon alpinus	1	0.4	2.84*
Aonyx cinerus	5	2.5	1.6
Sus scrofa	**50**	**216.6**	**-3.26***
Cervus	99	43.7	2.24*
Muntiacus	9	6.7	0.54
Bubalus	**126**	**45.4**	**3.16***
Bos	16	6.7	2.19*
Rhinoceros	0	0.7	-1.55
MB taxa	**Observed**	**Expected**	**AdR**
Macaca	1	4.5	4.10*
Trachypithecus	0	0.6	5.23*
Rattus	4	7.1	2.32*
Hystrix	1	1.3	1.19
Atherurus macrourus	0	0.6	5.23*
Manis	0	3.2	5.25*
Panthera tigris	0	1.9	5.24*
Neofelis/Pardofelis	0	4.5	5.26*
Canis familiaris	8	5.2	-2.86*
Viverra	3	4.5	1.78
Cuon alpinus	0	0.6	5.23*
Aonyx cinereus	2	4.5	2.94*
Sus scrofa	**565**	**398.4**	**-5.99***
Cervus	25	80.3	4.12*
Muntiacus	10	12.3	1
Bubalus	**3**	**83.6**	**5.81***
Bos	3	12.3	4.03*
Rhinoceros	2	1.3	-2.84*

Sus scrofa at MB and *Bubalus* at CCN.

The counter argument to these patterns could be that these statistically significant differences are based on imposing a Linnaean taxonomic system of identification onto the faunal data. As one of the reviewers of this thesis pointed out, we simply cannot know whether these same taxonomic divisions existed in the past. I agree that this is an inherent issue with this analysis, but also with many zooarchaeological studies in general. As discussed in Chapter four, across many human cultures people categorise animals and plants at the species level, akin to Western taxonomic traditions (Descola 1996; Fijn 2011, 202). However, these categories are highly variable, and this suggests people place specific meanings on taxa above taxonomy (Descola 1996, 85). Nonetheless, Descola (1996, 93) argues there are some general patterns in the way people perceive non-humans, including: morphological resemblance, analogies, contrasting features or uses, and relations of spatial or temporal contiguity. Many of these aspects are difficult for the archaeologist to quantify, without being able to observe or ask people directly. In many respects, it is difficult to avoid this conundrum, but one possible way of working around it is to consider environmental or other biological differences between fauna in the assemblage, which will be explored in the following sections.

9.3. Taxonomic habitat index

To compare ecological diversity and the palaeoenvironment, the taxonomic habitat index developed by Evans et al. (1981) and Andrews (1990) was performed (see section 5.8.6. for methodology). For comparison purposes, only medium-large mammals were used. The weightings for each taxa are displayed below in Tables 9-7 and 9-8. The average is then used to summarise the differential environmental niches represented (Figure 9-4). The distribution suggests the habitat exploitation preferences of CCN and MB were relatively similar, however, CCN is mostly represented by fauna from dense forests and woodland environments (Figure 9-4). Conversely, MB seems to have more taxa from lowland wet environments (estuarine, riverine, marshes), followed by grasslands. For both sites, mountainous and rocky environments are the least represented. Whether or not these observed differences in environmental niches of taxa are a result of a change in human exploitation or environmental change is an interesting question, which leads into the next section of the chapter.

Table 9-7 Taxonomic habitat index, weightings for each taxa from CCN.

CCN Mammals	**Habitat preference**					
Taxa	**Feeding strategy**	**Dense Forests**	**Woodlands**	**Mountains/ rocky**	**Scrublands/ Grasslands**	**Water (Marshes, riverine, estuarine)**
Macaca	Omnivore	0.2	0.2	0.2	0.2	0.2
Trachypithecus	Herbivore	0.7	0.3			
Hystrix	Herbivore	0.1	0.1	0.5	0.3	
Atherurus macrourus	Herbivore/insectivore	0.5	0.2	0.1	0.1	0.1
Manis	Insectivore	0.33	0.33		0.33	
Panthera tigris	Carnivore	0.4	0.2	0.2		0.2
Neofelis/Pardofelis	Carnivore	0.6	0.1	0.1	0.1	0.1
Viverra	Carnivore	0.3	0.3		0.3	0.1
Cuon alpinus	Carnivore/omnivore	0.3	0.3	0.1	0.2	0.1
Aonyx cinereus	Carnivore					1
Sus scrofa	Omnivore	0.1	0.4		0.4	0.1
Cervus	Browser/grazer	0.4	0.3	0.1	0.1	0.1
Muntiacus	Omnivore	0.4	0.25		0.1	0.25
Bubalus	Grazer	0.1	0.1		0.2	0.6
Bos	Grazer/browser	0.1	0.1	0.1	0.6	0.1
Total		**4.53**	**3.18**	**1.4**	**2.93**	**2.95**
Average		**0.3**	**0.21**	**0.09**	**0.2**	**0.2**

Table 9-8 Taxonomic habitat index, weightings for each taxa from MB.

MB Mammals	**Habitat preference**					
Taxa	**Feeding strategy**	**Dense Forests**	**Woodlands**	**Mountains/ rocky**	**Scrublands/Grasslands**	**Water (Marshes, riverine, estuarine)**
Macaca	Omnivore	0.2	0.2	0.2	0.2	0.2
Hystrix	Herbivore	0.1	0.1	0.5	0.3	
Canis lupus familiaris	Carnivore	0.2	0.2	0.2	0.2	0.2
Viverra	Carnivore	0.3	0.3		0.3	0.1
Aonyx cinereus	Carnivore					1
Sus scrofa	Omnivore	0.1	0.4		0.4	0.1
Cervus	Herbivore	0.4	0.3	0.1	0.1	0.1
Muntiacus muntjak	Omnivore	0.4	0.25		0.1	0.25
Bubalus	Herbivore	0.1	0.1		0.2	0.6
Bos	Herbivore	0.1	0.1	0.1	0.6	0.1
Rhinoceros	Herbivore	0.3	0.1		0.3	0.3
Totals		2.2	2.05	1.1	2.7	2.95
Average		**0.2**	**0.19**	**0.1**	**0.25**	**0.27**

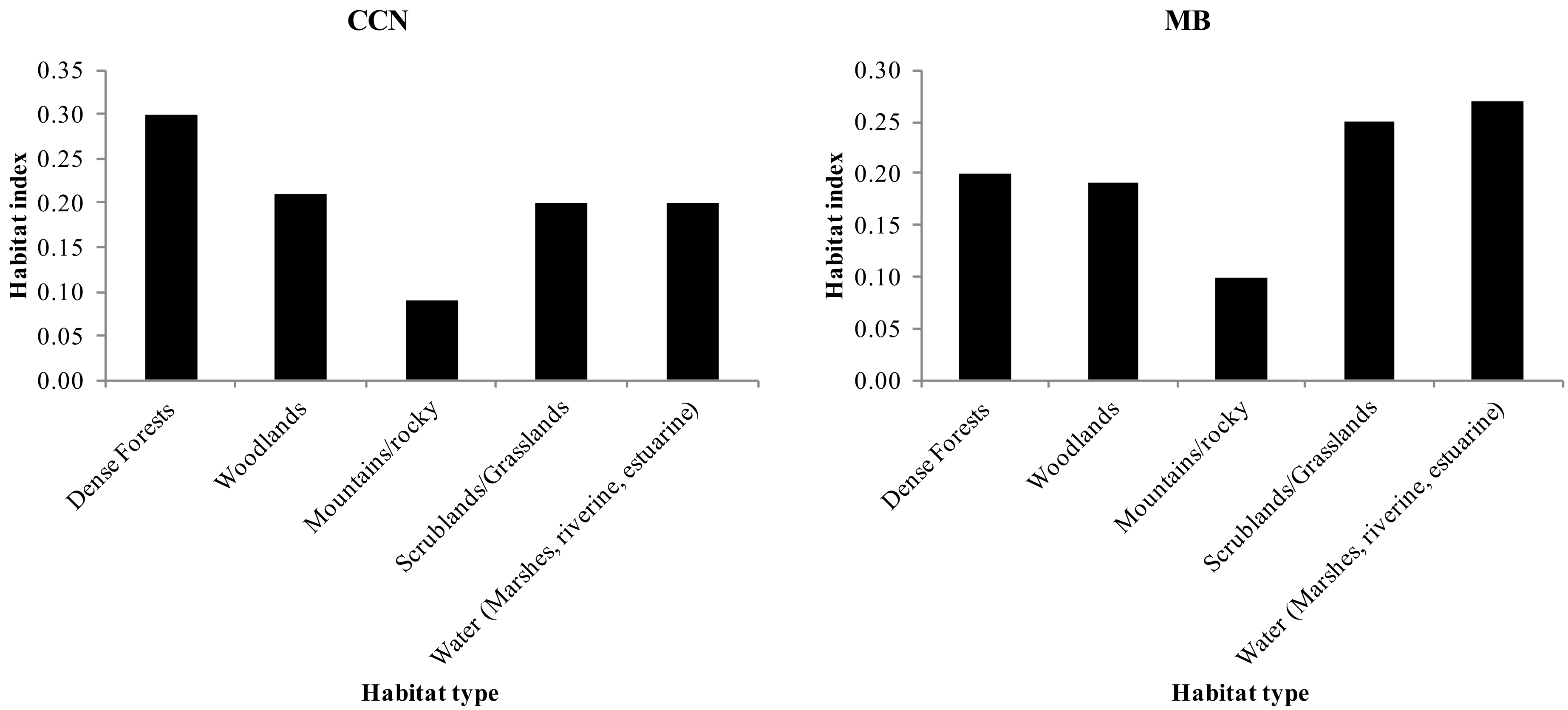

Figure 9-4 Comparison of habitat index values for CCN and MB.

9.4. Multivariate analysis: regional site comparison

As outlined in Chapter five, section 5.9 the main questions driving the multivariate analysis were:

1. **Are there regional patterns in faunal assemblages in diversity or abundance of fauna?**
2. **Is there a perceivable change in faunal composition from assumed hunter-gatherer sites to agricultural sites with domestic fauna?**
3. **How do CCN and MB compare, when studied within their broader regional and temporal context?**

A variety of different sites and taxa were tested. For a detailed rationale of why particular sites and mammalian families were chosen see Chapter five section 5.9. The following is a summary of the two most applicable and significant analyses.

9.4.1. Principal component analysis: 32 sites

For a detailed summary of PCA methodology see Chapter five, section 5.9.1. Families of mammalian taxa were grouped together with no distinction between wild or domesticated taxa within the family. For instance, within Canidae there is a number of potential species that could occur in archaeological sites in SEA: the wolf (*Canis lupus*), the jackal (*Canis aureus*), and domesticated dog (*Canis familiaris*). The decision was made to combine taxa into families (e.g. Canidae, Suidae) to allow for easier comparison between sites, but also because defining taxa at some sites as ‘wild’ or ‘domesticated’ (such as pigs and dogs) would be a subjective interpretation.

Nine mammalian families from 32 sites across SEA, ISEA, and China were selected for PCA (see section 5.9. and Table 5-6 for complete rationale behind selection of mammalian families and sites). A range of different environments are represented (see Table 5-6). Earlier sites tend to be located in caves or rockshelters, while Mid Holocene sites are usually near rivers in open environments. This is representative of where sites have been excavated, and as discussed in Chapter three, this may be biased by sea level changes and not entirely reflective of choice in location (sections 2.2.3; 3.3.1; 3.4.). Further, most of these sites are classified as ‘riverine’ (n = 19), while coastal (n = 3), riverine/estuarine (n = 4), and cave (n = 6) sites are fewer in number. The over-representation of riverine sites, and the strong association between Hoabinhian and Terminal Pleistocene sites with caves/rockshelters, and Mid Holocene sites with riverine environments, may have resulted in some bias in the data and results. Likewise, the environmental classification is based on a combination of paleoenvironmental reconstructions and current conditions, but this is probably not completely reflective or as nuanced as the past habitat.

The eigenvalues suggested there were three significant components within the data accounting for 80.7% of the variation. The rotated component matrix displays which components are weighing on each factor (Table 9-9). This table shows component one is positively correlated with Viverridae, Cercopithecidae, and Felidae and negatively correlated with Canidae. Component two is positively correlated with Cervidae, Bovinae, and Mustelidae. Component three is positively correlated with Suidae, Canidae, and to a lesser extent Mustelidae and Felidae.

Table 9-9 Rotated component matrix for 32 sites.

	Component		
Family	**1**	**2**	**3**
Viverridae (civets)	0.89		
Cercopithecidae (monkeys)	0.83		
Felidae (felids)	0.78		0.44
Cervidae (deer)		0.92	
Bovinae (cattle, buffalo)		0.88	
Mustelidae (otters, weasels)	0.37	0.69	0.51
Suidae (pigs)			0.84
Canidae (canids)	-0.56		0.66

To understand these weightings in greater detail it is beneficial to visually plot the data to compare where each site falls. To help determine whether there were any patterns within the data, groups were assigned firstly based on time period (i.e. Pleistocene, Holocene), and site type (i.e. cave, riverine, coastal). Multiple combinations were tested, however, the clearest pattern emerged when subsistence base (hunter-gatherer, agricultural, unknown) was taken into account.[1] For instance, Figures 9-5 and 9-6 both compare components one and three, however, Figure 9-5 highlights sites according to time period, and Figure 9-6 according to subsistence base. Although there is some separation between Pleistocene and Holocene sites in Figure 9-5, this becomes much clearer when taking into account subsistence base in Figure 9-6. In general, subsistence base was the most fruitful and useful grouping. Thus, for the sake of clarity in the PCA plots, subsistence base groupings will be

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[1] For the purposes of this test, subsistence base was determined according to what researchers have suggested (see Table 5-6 in section 5.9.1.) or left as unknown.

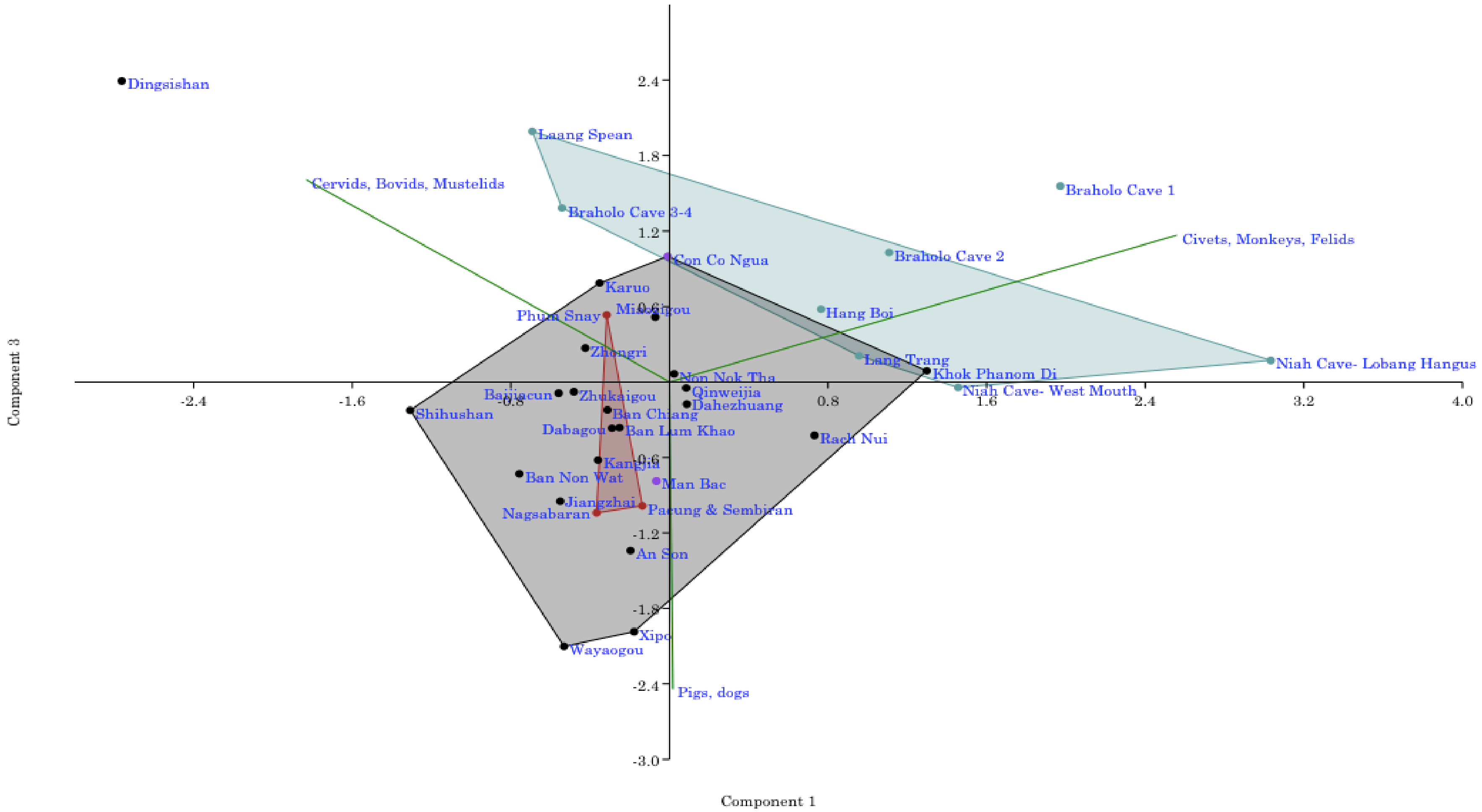

Figure 9-5 PCA with 32 sites, component one versus three. Dividing the sites into time period, Green = Pleistocene, Black = Early-Mid Holocene, Red = Late Holocene. See Table 5-6 in Chapter five for a complete list of sites. The green lines show how the variables are weighting on the components.

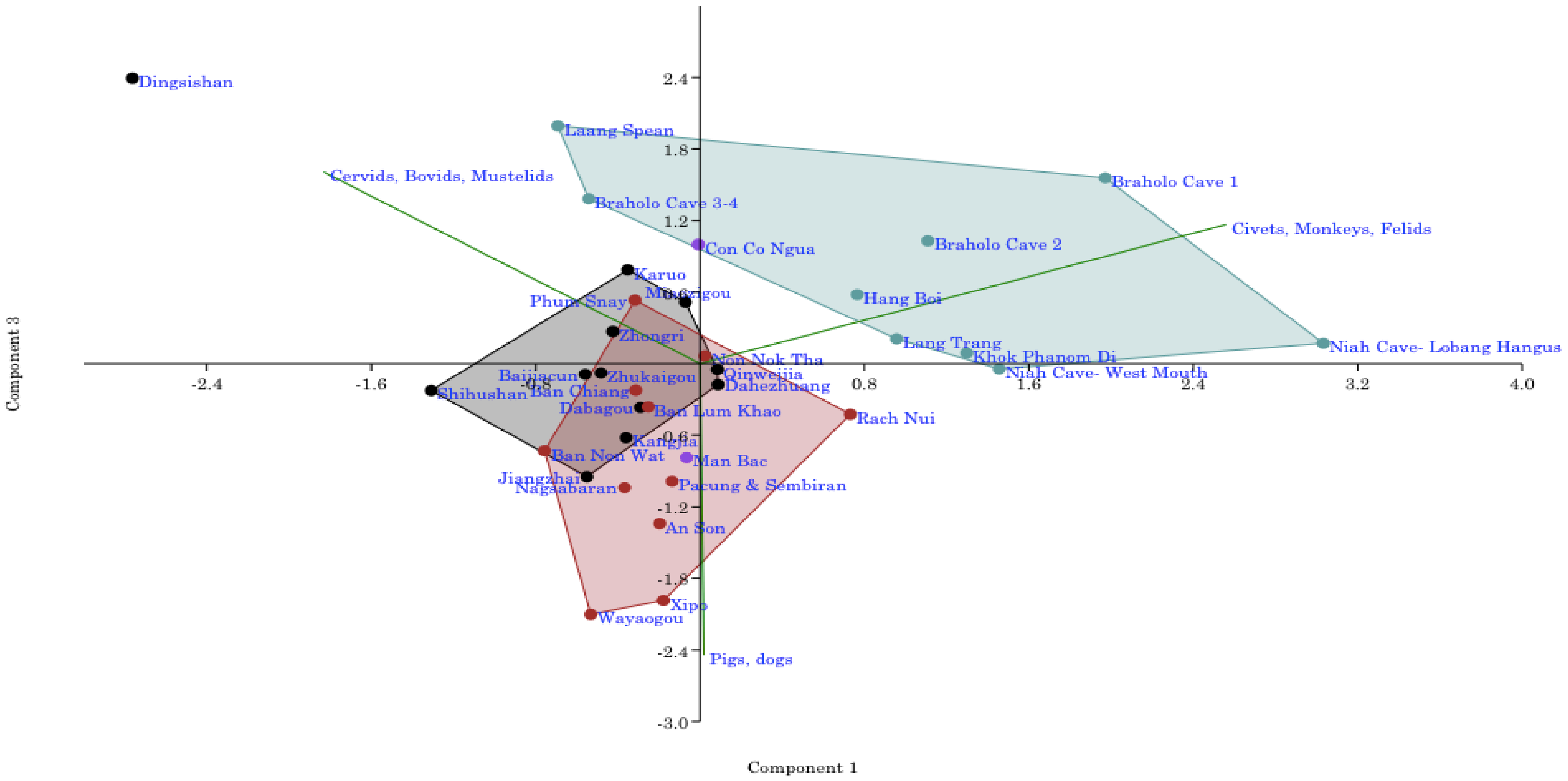

Figure 9-6 PCA with 32 sites, component one versus three. The green group represents sites that are thought to be hunter-gatherer, the red group represents agricultural sites, and the black group are Chinese Mid Holocene sites that potentially represent early agriculture or domestication. The green lines show how the variable are weighting on the components.

displayed, with a discussion on how temporality and other factors play a role below.

Returning to Figure 9-6, there is a fairly clear distinction between sites with a large abundance of Viverridae, Cercopithecidae and Felidae compared to sites with higher proportions of Suidae and Canidae. This generally separates out into Pleistocene or hunter-gatherer sites versus Holocene and agricultural sites. CCN falls within the hunter-gatherer group while MB comfortably sits within the agricultural sites group. Dingsishan is a clear outlier, due to the extremely high proportion of Cervidae in the assemblage. Lobang Hangus (Niah Cave) is also a slight outlier due to the high proportion of Cercopithecidae. Interestingly, the only Holocene site that falls within this Pleistocene group of cave sites is Khok Phanom Di, a site that Higham and Thosarat (2004b) has argued is based on hunter-gatherer subsistence.

When comparing components two and three a similar, albeit, less clear pattern emerges (Figure 9-7). CCN and MB still comfortably sit within their respective groups, and Dingsishan is still an extreme outlier. In this particular comparison Wayaogou (an early agricultural site on the Wei River of China), is an outlier due to the high proportion of pigs as well as deer. Conversely, Lobang Hangus sits more comfortably within the hunter-gatherer group, close to Lang Trang.

Comparison of components one and two produces an unclear result with no discernible pattern (Figure 9-8). This potentially suggests that the presence and relative abundance of pigs and dogs (component three) is often the most distinguishing factor between Pleistocene and Holocene sites.

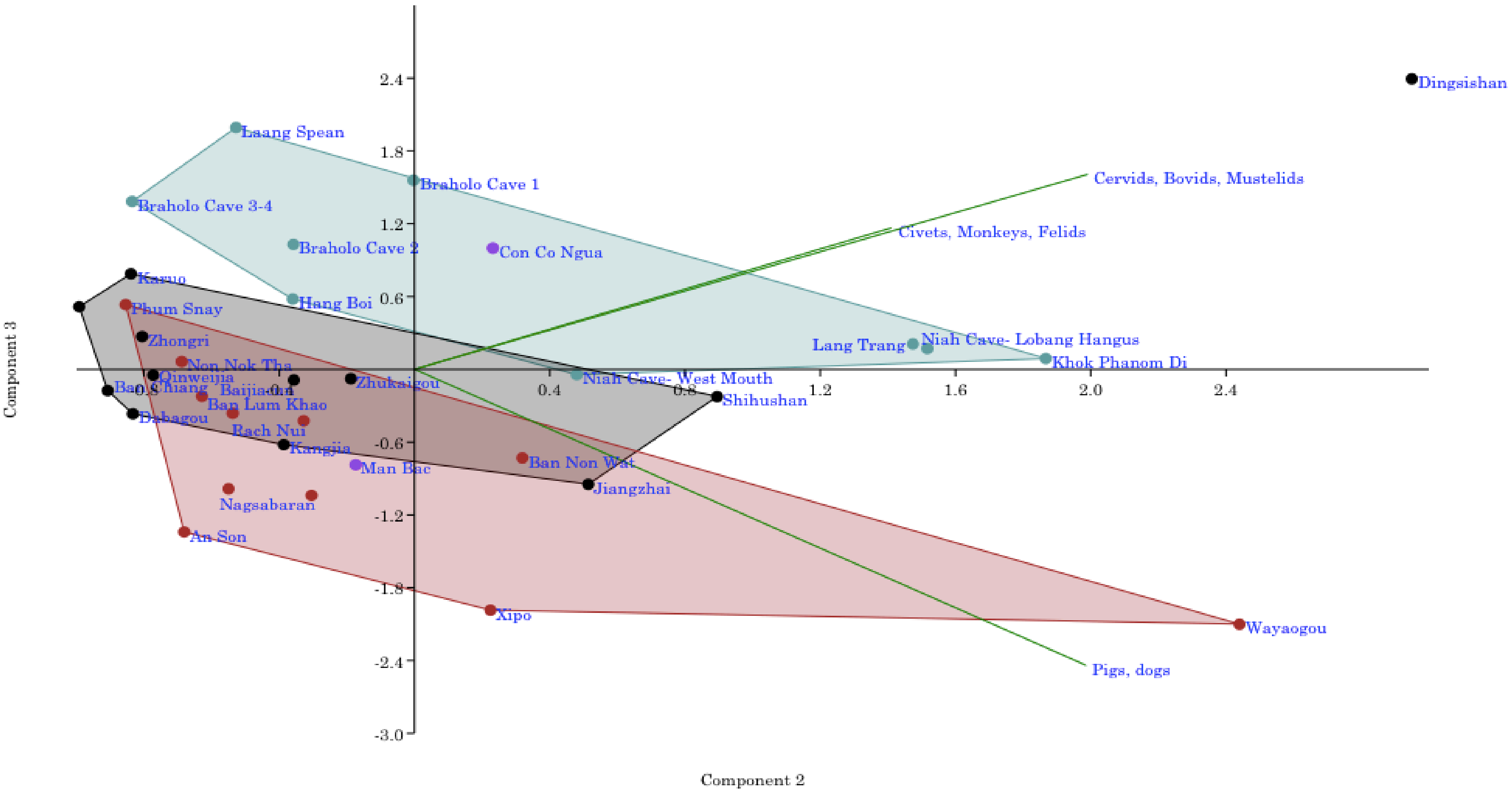

Figure 9-7 PCA with 32 sites, comparison of components two and three. Green = hunter-gatherer, red = agricultural, black = unknown, potentially early agriculture/domestication.

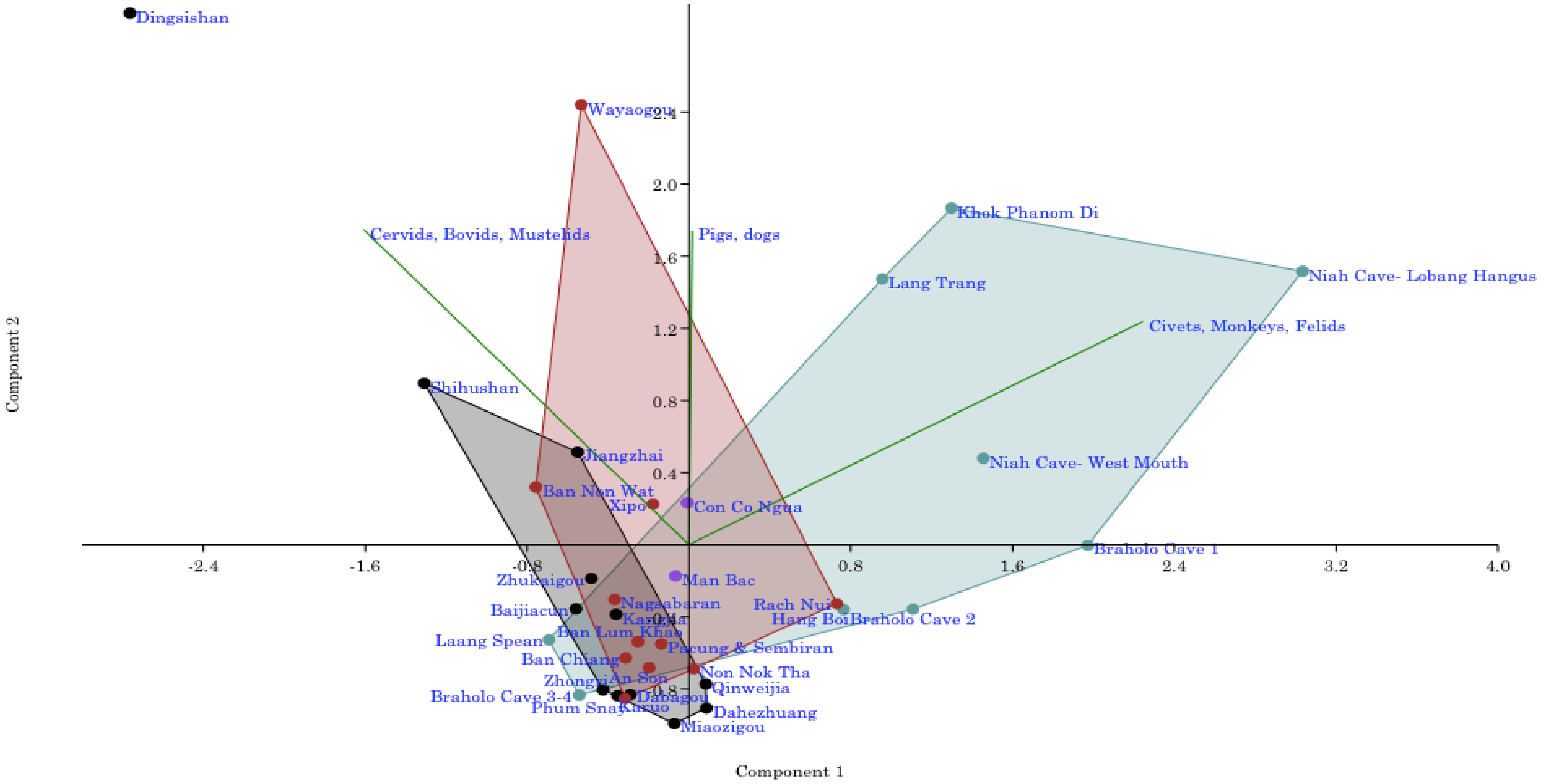

Figure 9-8 PCA with 32 sites, comparison of components one and two. Green = hunter-gatherer, red = agricultural, black = unknown, potentially early agriculture/domestication.

9.4.2. Principal component analysis: 30 sites

In PCA it can be difficult to determine how to handle outliers. Although removing an outlier can result in increasing the statistical integrity of your data, archaeologically speaking, the fact a site is an outlier may be of interest in itself. To determine whether Dingsishan and Lobang Hangus were having a sizeable affect as outliers they were removed, and the PCA analysis was rerun. As before, the eigenvalues suggested there were three significant components within the data that accounted for 81.7% of the variation. However, when comparing what factors were weighing in on each component the results were a little less clear (Table 9-10). Component one positively correlated with Mustelidae, Cervidae, and Felidae, and Suidae and to a lesser extent Canidae. Component two positively correlated with, Viverridae, Cercopithecidae, Felidae and negatively with Canidae. However, component three positively correlated only with Bovinae, and negatively with Suidae.

Table 9-10 Rotated component matrix for 30 sites.

	Component		
Family	**1**	**2**	**3**
Mustelidae (otters, weasels)	0.89		
Cervidae (deer)	0.88		
Felidae (felids)	0.75	0.56	
Suidae (pigs)	0.65		-0.53
Viverridae (civets)		0.90	
Cercopithecidae (monkeys)		0.86	
Canidae (canids)	0.46	-0.65	
Bovinae (cattle, buffalo)			0.93

Different groupings were again tested (site type, period etc.) and compared but subsistence based groupings were determined to have the clearest results, as before with 32 sites. When Dingsishan and Lobang Hangus are removed Wayaogou becomes more of an outlier, due to the high proportion of pigs recorded at the site (Figure 9-9). There is also some slight overlap between groups with Rach Nui falling inside the hunter-gatherer sites (see 9.4.3. below for discussion). It is interesting to note that Canidae are relatively strongly negatively correlated with Viverridae and Cercopithecidae; this is what the previous analysis with 32 sites also suggested (Table 9-9).

A comparison of components two and three produces a clearer separation between groups (Figure 9-10). The negative association between Bovinae and Suidae is interesting and somewhat puzzling (see 9.4.3.). It is possible that once domesticated pigs become the dominant protein resource in mid-late Holocene sites, hunting of wild bovids becomes less necessary.

Finally, a comparison of components one and three produced an unclear pattern (Figure 9-11). This is perhaps not surprising because component three is only positively correlated with Bovinae while component one has five positive correlations.

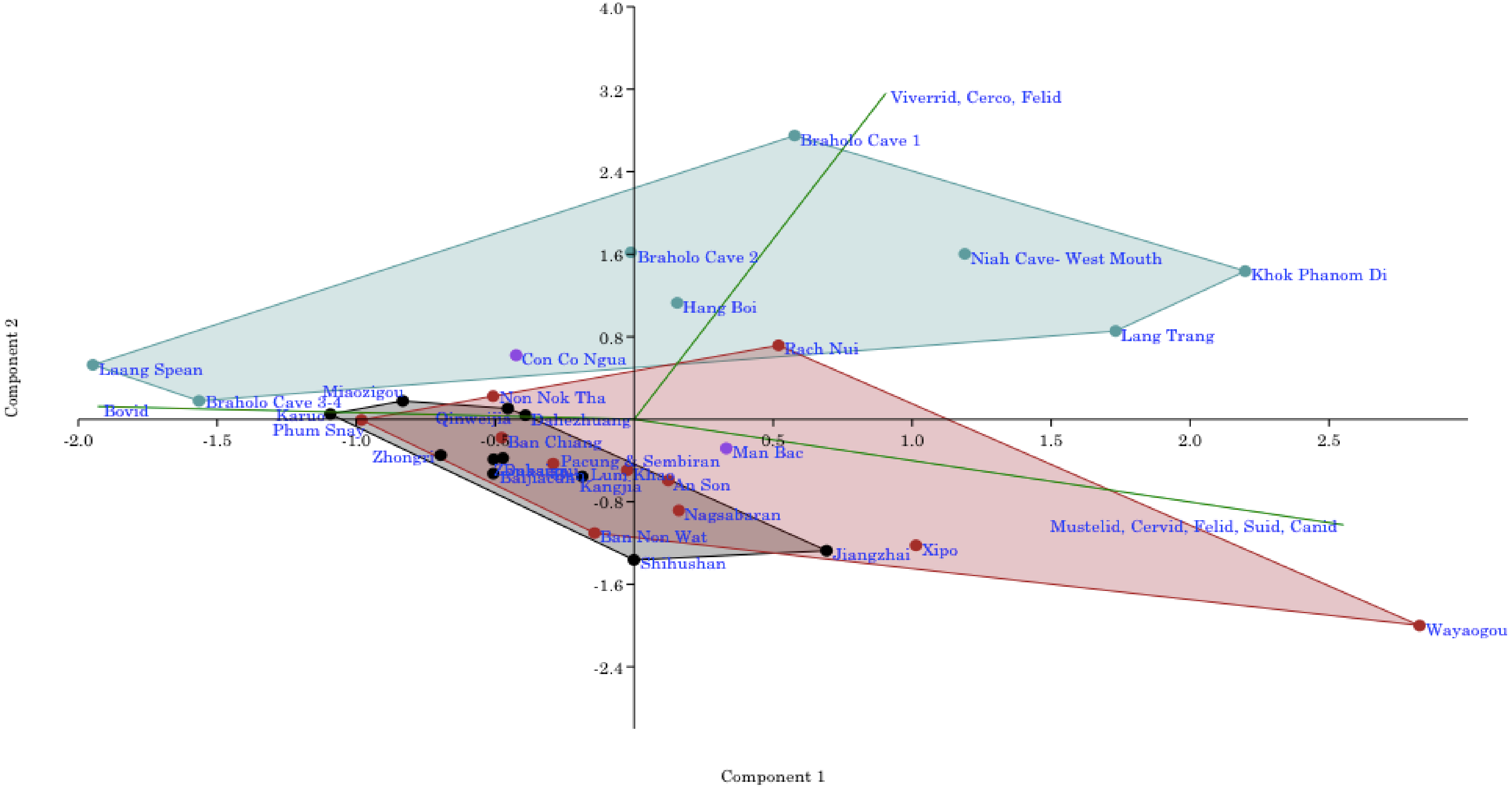

Figure 9-9 PCA with 30 sites comparing components one and two. Green = hunter-gatherer, red = agricultural, black = unknown, potentially early agriculture/domestication.

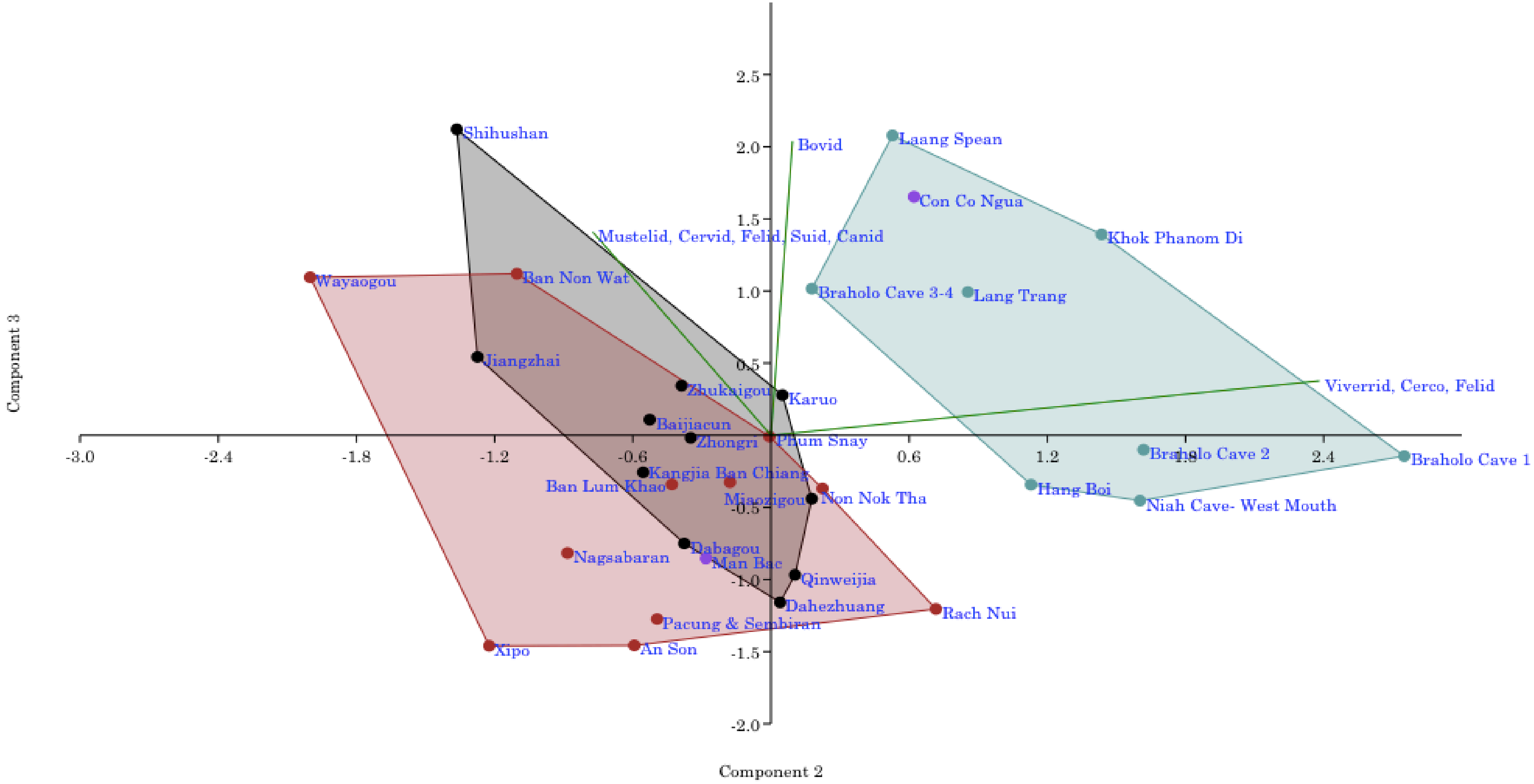

Figure 9-10 PCA with 30 sites comparing components two versus three. Green = hunter-gatherer, red = agricultural, black = unknown, potentially early agriculture/domestication.

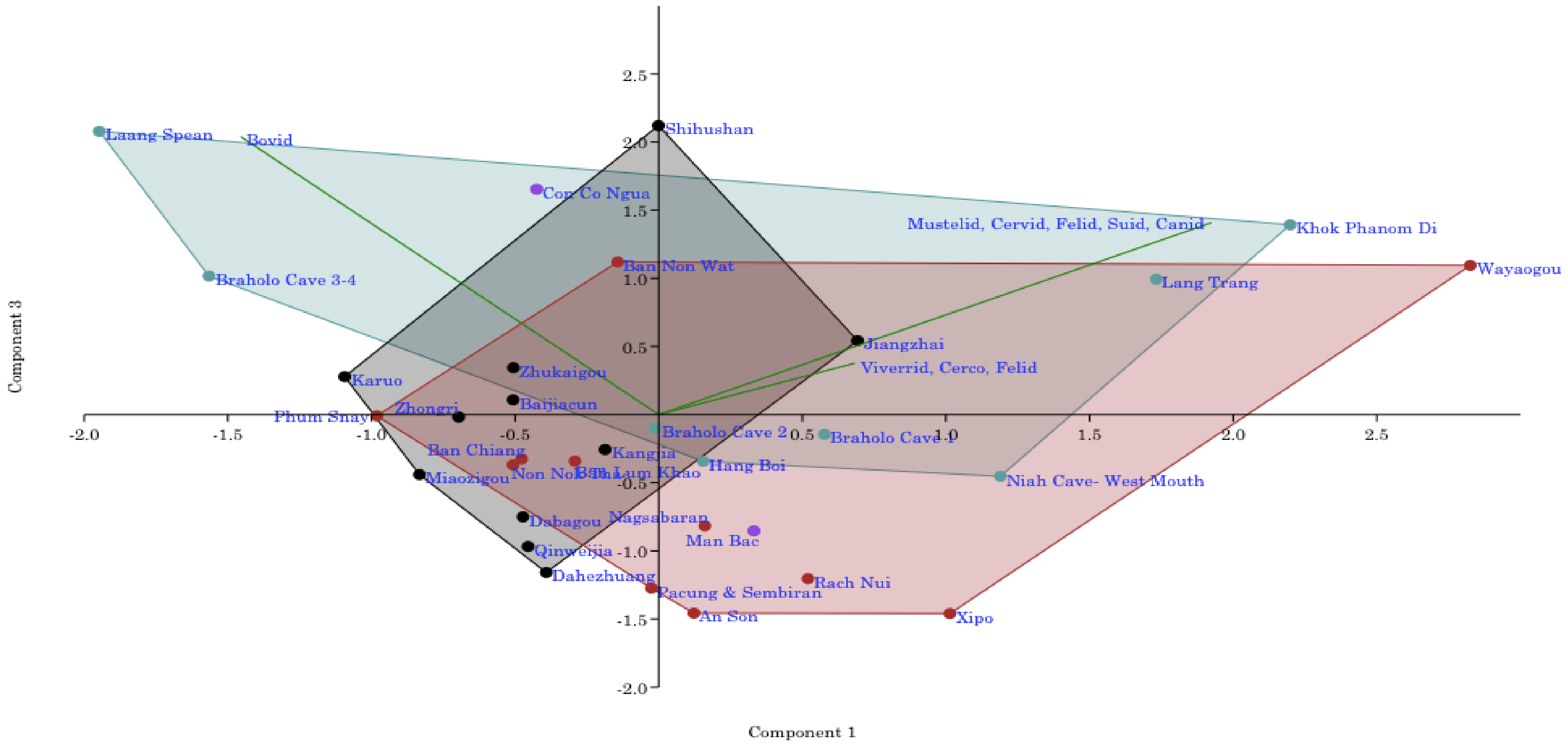

Figure 9-11 PCA with 30 sites comparing components one and three, this figure is the least clear. Green = hunter-gatherer, red = agricultural, black = unknown, potentially early agriculture/domestication.

9.4.3. Regional patterns

Before drawing broader patterns and conclusions it is important to reiterate the limitations of the dataset. Firstly, this analysis largely relies on the taxonomic identifications and quantifications of numerous faunal assemblages that were excavated by a variety of researchers from the late 1970s onwards. Therefore, some discrepancies in the quality of the zooarchaeological analyses is possible. Further, for comparative purposes only mammals were included in this analysis. In the future it may be particularly valuable to test whether reptile and fish abundance in SEA assemblages follow similar or differing patterns.

Despite these limitations, the results for PCA of 32 and 30 sites were overall relatively similar in pattern and suggest there are some interesting changes occurring from the Late Pleistocene to Mid Holocene. The abundance of Cercopithecidae and Viverridae are always important factors for Late Pleistocene sites, or sites based on hunter-gatherer economies. Conversely, the abundance of Suidae and Canidae tend to be more important factors in Holocene or agricultural based sites. The components and correlation matrix for the PCA with 37 sites generally makes more ‘sense’ than when removing Dingsishan and Lobang Hangus. Within this analysis, Suidae and Canidae positively correlate, as do the Cervidae and Bovinae, and the forest taxa (Cercopithecidae, Felidae, Viverridae). The family that is slightly at odds are Mustelidae, which positively correlate on all components.

These correlations suggest that there is less hunting of Cercopithecidae, Felidae, and Viverridae within farming communities with domestic animals. Although domesticated and wild animals were intentionally not separated in this analysis it is interesting there was a positive correlation between Canidae and Suidae. This positive correlation makes ‘sense’ in that it suggests within the context of agricultural sites domesticated dogs and pigs are likely to be found together. Likewise, the positive correlation between Cervidae and Bovinae may relate to their similarities, as the habitats of both taxa overlap and they are large animals that provide considerable protein. This could indicate that people hunting or exploiting Cervidae taxa are also likely to exploit Bovinae taxa.

Aside from CCN and MB some sites which produced noteworthy results include Dingsishan, Rach Nui, and Khok Phanom Di. Dingsishan was always the most extreme outlier regardless of the grouping (i.e. period, site type, subsistence base) or component selected. This is related to the extremely high proportion of deer within the assemblage.

However, the relatively low proportion of monkeys, civets, and felids compared to other Pleistocene or Early Holocene sites is another factor contributing to Dingsishan's irregularity. It is worthy to note that dogs appear only in the upper layers at the site so it is possible a faunal transition occurs late in the site's history (see Chapter eleven section 11.5.1.).

The Mid Holocene site of Rach Nui (south Vietnam) falls into an ambiguous area in some of the graphs. Particularly in Figure 9-9, Rach Nui falls within the hunter-gatherer group, which is largely related to the high proportion of monkeys identified (255 = NISP) in the assemblage. However, it is also interesting to note that despite the presence of domesticated dog and abundance of pig (222 = NISP), Oxenham et al. (2015) suggest that the subsistence seems to have been strongly geared towards fishing and hunting. For the pigs there was no indication of a selective kill-off pattern and Oxenham et al. (2015, 21, 24) conclude it is unclear whether the pigs represent domesticated/managed stock. Further, rice and millet appears to have been imported to the site rather than locally grown (Oxenham et al. 2015; Barron 2016; Castillo et al. 2017). Thus, it is interesting the PCA gave an ambiguous result for Rach Nui as the excavators have previously argued for a mixed subsistence strategy.

Similarly, Khok Phanom Di has long been argued by Higham and Thosarat (2004b) to represent a community largely existing off a hunter-gatherer lifestyle. This suggestion is supported by this PCA analysis, as although KPD has an abundance of pigs (587 = NISP), this is relatively low compared to the deer (810 = NISP). Further, the high abundance of monkeys (418 = NISP) is more in line with other Pleistocene and/or hunter-gatherer sites than sites that are mostly reliant on domesticated animals. It is worth noting that domesticated dogs only appear in the upper layers and are relatively low in numbers (13 = NISP). For further discussion on regional patterns and outliers see section 11.5.1.

9.4.4. Cồn Cổ Ngựa and Mán Bạc patterns

Within this regional analysis, no matter which outliers were included or excluded CCN and MB remained clearly within the groupings of hunter-gatherer and agricultural/domesticated sites, respectively. The high proportion of pigs and presence of dogs at MB were important factors influencing this attribution. For CCN the relatively higher proportion of felids, civets, and monkeys place this site within the grouping of hunter-gatherer sites. Intriguingly, the high proportion of Bovinae at CCN does not separate the site from other hunter-gatherer sites. This is because the presence of Bovinae in hunter-gatherer assemblages is not uncommon. For instance, Laang Spean, a Hoabinhian site in Cambodia, has a high proportion of *Bos* sp. (NISP 996; 77.3% of mammals).

9.5. Conclusion to Chapter nine

There were two major sections to this chapter: a taxonomic comparison specifically of CCN and MB, and a multivariate regional analysis. The purpose of undertaking these methods of analysis was to compare the faunal assemblages of CCN and MB, understand and account for any perceivable similarities or differences, and explore wider regional patterns within SEA faunal assemblages.

Firstly, an analysis of NTAXA versus NISP between the different sites in the analyses portrayed that sample size had a small but relatively limited affect on NISP values (section 9.2.1). This suggests that some degree of caution should be applied when making inferences, however, since the correlation is weak it is acceptable to proceed with statistical analyses.

The results of the taxonomic indices (section 9.2.) indicated that CCN and MB were not similar faunal communities. The Shannon-Wiener index suggested that CCN is relatively heterogeneous in taxonomic composition, while MB is relatively homogeneous. The measure of evenness suggested this was because MB is dominated by pigs. The $\chi 2$ analysis of the two assemblages suggests they are statistically and significantly different from one another. In particular, the relative abundance of pigs and water buffalo are influencing the $\chi 2$ result. This suggests that the main contributing factor in the differences between the assemblages is the high proportion of pigs at MB and water buffalo at CCN.

The results of the taxonomic habitat index (section 9.3.) suggest that CCN is mostly represented by fauna from dense forest and woodland environments. Conversely, MB seems to have more taxa from lowland wet environments (estuarine, riverine, marshes) followed by grasslands.

The results for PCA analysis produced some interesting overall patterns (section 9.4). The abundance of Cercopithecidae and Viverridae are important factors for Late Pleistocene sites, or sites based on hunter-gatherer economies. Conversely, the abundance of Suidae and Canidae tend to be important factors in Holocene or agricultural based sites. There positive correlation between Canidae and Suidae is understandable within the context of agricultural sites, where domesticated dogs are pigs are likely to be found together.

No matter which outliers were included or excluded, CCN and MB remained clearly within the groupings of hunter-gatherer and agricultural/domesticated sites respectively. The high proportion of pigs and presence of dogs at MB and relatively high proportion of felids, civets, and monkeys at CCN were important factors influencing these attributions. Whereas, the high proportion of Bovinae at CCN is not uncommon in hunter-gatherer assemblages.

In summary, CCN and MB are significantly different in their taxonomic composition. This is primarily caused by the high proportion of pigs in MB and water buffalo at CCN., though CCN is also more taxonomically heterogeneous. When compared at a regional level, CCN and MB fall into separate groups which can be characterised as 'hunter-gatherer' (CCN) and 'agriculturalist' (MB). This indicates that the perceived differences in taxonomic composition is the result of a difference in human subsistence strategies. Further, the PCA results suggests these patterns are visible within the wider SEA region, and this method could potentially be used to predict or validate the subsistence base for other sites. For an in-depth discussion of theoretical implications of the PCA results, refer to Chapter eleven.

CHAPTER TEN
Radiocarbon dating

10.1. Introduction

This chapter provides the results of radiocarbon analysis of faunal material from CCN and MB. For a detailed discussion of the methodology behind enamel and collagen dating see Chapter five section 5.10. Firstly, the rationale of why radiocarbon analyses was a necessary component of the thesis is discussed below.

10.1.1. Aim of ^{14}C analysis

Radiocarbon analysis was one of the main aims of this thesis and was an essential aspect of the project, as outlined in section 5.10. Prior to this project, the chronology of CCN was reliant on relative dates based on ceramic and lithic typology (Bui Vinh 1991; Nguyen Viet 2005). Previous attempts to ^{14}C date human skeletal material had shown no collagen was preserved in the bone (Oxenham 2014, pers. comm.). Due to the lack of well-associated charcoal and complications with dating shell in limestone environments, it was necessary to attempt ^{14}C dating of human and faunal enamel. The dates are therefore considered to be minimum dates, see section 5.10 for a detailed discussion of potential issues with dating enamel. Despite the ‘younger dates’ that enamel samples usually produce, enamel dates are sufficient evidence that CCN is considerably older than MB.

Secondly, obtaining a secure collagen age on selected faunal material from MB was critical to securely pin a minimum date for the introduction of domesticated animals into northern Vietnam. As discussed in Chapters seven and eight, morphometric analyses of the dogs in the assemblage suggest they are almost certainly domesticated. Further, morphometric and ageing analysis of the pigs from MB suggests they were probably in early stages of management or domestication (Chapters seven and eight). Thus, direct collagen dates on securely identified and provenanced pig and dog elements was essential to record their initial introduction into Vietnam. In this instance, enamel dates would not have provided sufficient resolution to establish the chronology of the introduction of domesticates.

The calibration of dates was done using Oxcal version 4.2 (Bronk Ramsey 2009) and calibration curve IntCal13 (Reimer et al. 2013).

10.1.2. Radiocarbon results for Cồn Cổ Ngựa

The results of the radiocarbon analyses are summarised below in Figure 10-1 and Table 10-1.

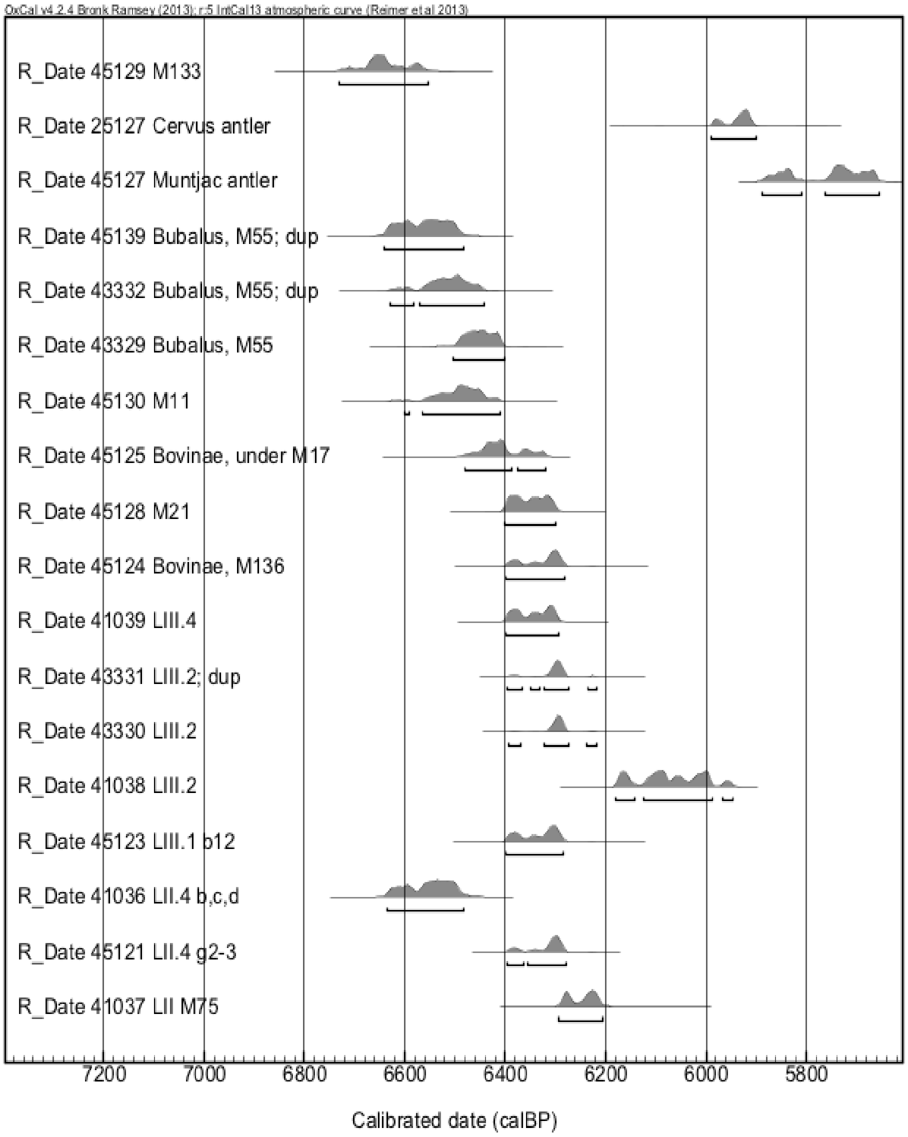

Figure 10-1 Results of radiocarbon analyses of CCN. Samples are arranged with stratigraphically lower samples at the top and the stratigraphically highest samples at the bottom of the graph.

Table 10-1 Summary of CCN samples radiocarbon dated and detailed results.

ID	SANU	CONTEXT	SAMPLE	MATERIAL	δ ^{13}C	^{14}C age (BP)	±	cal. BP (95.4%)	Notes
13CCN-407	41037	LII M75	*Bubalus*, L molar	Enamel	-4.6	5,440	25	6,300–6,214	
	41107					5,485	24		duplicate of CCN-407
13CCN-1918	45121	LII.4 g2-3	Bovinae, LI2, R	Enamel	-6.7	5,514	28	6,397–6,278	
13CCN-062	41036	LII.4 b,c,d	*Cervus*, UM3, L	Enamel	-5.5	5,750	25	6,636–6,484	
13CCN-1216	45123	LIII.1 b12	Bovinae, L molar	Enamel	-6.7	5,528	32	6,398–6,284	AT-358
13CCN-408	41038	LIII.2	*Bubalus*, L molar	Enamel	-11.5	5,280	25	6,180–5,947	
13CCN-516	43330	LIII.2	*Bubalus*, UP1, R	Enamel	-1.5	5,497	25	6,318–6,276	
	43331				-2.5	5,502	26	6,395–6,219	Repeat of CCN-516, more rigorous acid
13CCN-409	41039	LIII.4	Bovinae, LM3, L	Enamel	-3.8	5,545	25	6,398–6,294	
13CCN-1079	45124	M136	Bovinae, L molar	Enamel	-2.6	5,521	31	6,398–6,281	
M21	45128	M21	Human, LM3	Enamel	-18	5,560	27	6,400–6,300	
13CCN-1222	45125	under M17	Bovinae, UP3, R	Enamel	-4.1	5,631	28	6,480–6,319	
M11	45130	M11	Human, LM3	Enamel	-17.6	5,708	28	6,601–6,410	
13CCN-082	43329	M55	*Bubalus*, LM1, R	Enamel	-2.9	5,673	26	6,533–6,413	
	43332				-2.7	5,724	26		Repeat of CCN-082, more rigorous acid leach
M142	45139	M142	Human, LM3	Enamel	-17.1	5,758	28	6,641–6,483	
13CCN-951-2	45127	close to M133, F43, E6-7	*Muntiacus*, antler	Calcined antler	-17.4	5,008	29	5,889–5,655	
13CCN-949-950	45126	close to M133, F43, E6-7	*Cervus*, antler	Calcined antler	-19.6	5,172	27	5,990–5,901	
	45129	M133	Human, LM3	Enamel	-17.8	5,828	29	6,730–6,554	

10.1.3. Discussion of Cồn Cổ Ngựa dates

Twelve initial dates for the Đa Bút sites (Đa Bút, CCN, Ban Thuy, Lang Cong, Go Trung) were originally published in Nguyen (2005, 91), and are calibrated in Table 10-2. The one shell date for CCN is in line with the new dates presented here and the dates in Table 10-2 suggests the general Mid Holocene chronology for the Đa Bút period is correct, with Đa Bút itself being the oldest site. However, the dates were mostly on *Corbicula* shell, and in limestone environments shell can be affected by the freshwater reservoir effect, where older carbon dissolved from the groundwater can contaminate the sample and appear 100s or 1000s of years older than their context (Goodfriend and Stipp 1983; Pigati et al. 2013). Further, the opposite problem can occur with shell as the introduction of secondary carbon can make the dates appear younger or older depending on the age of the contaminants (Pigati et al. 2013, 116). Both issues can be tested, but it is uncertain whether the dates were tested for these potential problems. Further, the exact provenance of many of the samples is uncertain given the excavation methodology of these early excavations.

Table 10-2 A summary of dates originally published in Nguyen Viet (2005, 91) and calibrated by RKJ using Oxcal, IntCal13. *could not be calibrated as no error margin or ^{14}C age was provided.

Site	Lab No.	Context	Material	^{14}C age (BP)	±	cal. BP (95.4% probability range)
Da But	Bln–1047	DB 71(70)	*Corbicula*	6,095	60	7,161–6,797
Da But	Bln–3507 II	DB 86 (40)	*Cyclophorus*	5,810	50	6,734–6,493
Da But	Bln-3508 II	DB 86 (80)	*Corbicula*	6,400	60	7,431–7,180
Da But	Bln-3509 II	DB 86 (100)	*Corbicula*	6,540	60	7,566–7,325
Da But	Bln-3510 II	DB 86 (120)	*Corbicula*	6,460	60	7,473–7,266
CCN	HNK-88	CCN01(70-80)	*Corbicula*	5,520	95	6,527–6,016
Ban Thuy	HNK-90	BT01(100)	*Corbicula*	5,560	95	6,627–6,182
Ban Thuy	HNK-89	BT01(40)	*Corbicula*	5,000	5	5,930–5,586
Lang Cong	HCM V02/93	LCg91(70-80)	*Angulyagra*	4,850	70	5,739–5,330
Lang Cong	HCM V01/93	LCg91(100)	*Angulyagra*	4,900	85	5,892–5,469
Lang Cong	Unknown	LCg98	Charcoal AMS	Unknown		3,960–3,710 cal. BC*
Lang Cong	Unknown	LCg98	Charcoal AMS	Unknown		4,460–4,320 cal. BC*
Go Trung	Bln-2090	GT77H1(60)	Charcoal	4,790	70	5,647–5,324

Nonetheless, the new dates from CCN (Table 10-1) confirm the general Mid Holocene chronology, although it should be reemphasised that enamel and calcined bone dates represent minimum ages as the pretreatments applied can rarely fully remove contamination (Zazzo 2014; Wood et al. 2016). With two samples, a combination of standard and rigorous acid leaching was conducted to determine whether this would help to remove contaminants (Table 10-1). However, there is no significant difference in age between these samples. Since this experiment, Wood et al. (2016) have discovered that contamination is primarily located between grain boundaries, thus removing material – regardless of location in the enamel – is unlikely to improve contamination removal.

There appears to be some relationship between stratigraphy and dates as the samples that were excavated in the lower layers are generally older than those in the upper layers (Figure 10-1). For instance, burial M133 yielded the oldest date and it represents the stratigraphically lowest sample.

There are notably some outliers, especially the two calcined deer antlers. The *Muntiacus* and *Cervus* antlers were recorded as being associated with burial M133. Hence, the c. 1,000 year difference between the burial and antlers is puzzling. Further, the *Muntiacus* and *Cervus* antlers yielded different dates and considering they were part of the same calcined deposit of antlers, this is troublesome. This discrepancy in dates may represent a methodological problem, as calcined bone has mainly been dated in European contexts and the method is not standardised for the tropics (Rachel Wood 2016, pers. comm.). Although the method for dating calcined bone in Mid Holocene Europe is generally thought to give reliable dates (Lanting et al. 2001; Zazzo 2014), it has also occasionally given inaccurate younger ages (Strydonck et al. 2009). Thus, calcined bone can be affected by diagenetic processes that are likely to be accelerated in hot and wet environments (Rachel Wood 2016, pers. comm.). Further, there have been a limited number of experiments on samples with ‘known’ ages to properly test the method. Consequently, the dates of the calcined deer antlers should be treated with caution until more is understood about the taphonomic factors affecting calcined antlers in the tropics.

In summary, most of the new CCN dates range between 6,600–6,200 cal. BP. Since enamel dates represent minimum ages, these dates suggest the chronology proposed by Bui Vinh (1991) and Nguyen Viet’s (2005) for the early Đa Bút phase should be pushed earlier than c. 6,000 cal. BP, and perhaps closer to 7,000 cal. BP (Chapter three, Table 3-4). This is also indicated by the calibrated ages in Table 10-2, and emphasises the importance of calibrating dates rather than only reporting ^{14}C ages. To properly resolve the chronology of the Đa Bút period, more ^{14}C dates from well-provenanced collagen samples will be necessary.

10.1.4. Radiocarbon results for Mán Bạc

The results of the radiocarbon analyses are summarised below in Figure 10-2 and Table 10-3.

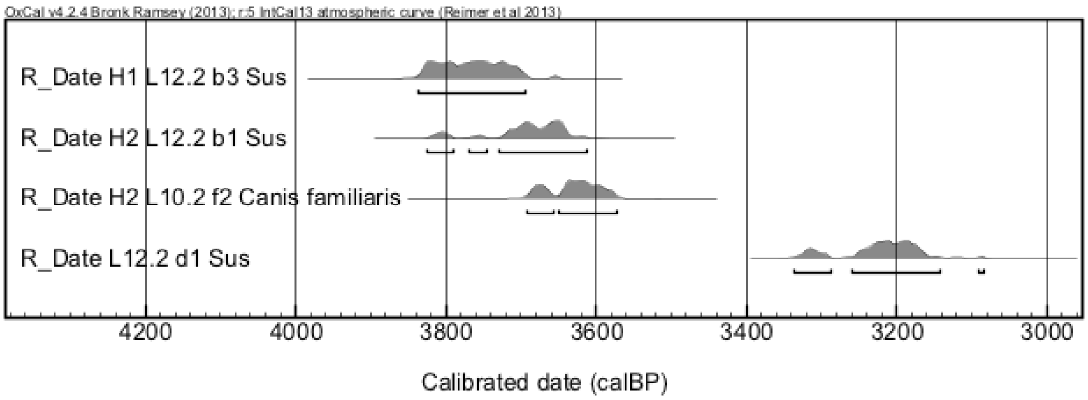

Figure 10-2 Results of radiocarbon analyses of MB.

10.1.5. Discussion of Mán Bạc dates

Three of the dates fall between 3,500–3,800 cal. BP, while one pig UM3 is slightly younger at 3,338–3,083 cal. BP. These dates conform to dates previously reported on charcoal: 3,341 ± 38 cal. BP, (1,737–1,524 cal. BC, AA-69832), 3,393 ± 36 cal. BP (1,775–1,608 cal. BC, AA-69831), 3,560 ± 30 cal. BP (2,016–1,775 cal. BC, IAAA-102761; Dung et al. 2011, 169; Matsumura and Oxenham 2011, 4). This places the introduction of domesticated dog into northern Vietnam from at least 3,693–3,573 cal. BP. Similarly, Chapters seven and eight have argued that the pigs are likely to be in the early stages of domestication. This places the minimum date for the domestication or management of pigs in Vietnam at 3,836–3,694 cal. BP.

The issue of how the ‘occupation layers’ relate to the burial assemblage has yet to be properly resolved. Dates on human skeletal material were attempted but failed due to poor collagen preservation (Oxenham 2016, pers. comm.). It was argued based on stratigraphy that the burials predate the occupation layers (Dung et al. 2011, 169; Tilley

Table 10-3 Summary of MB samples radiocarbon dated and detailed results.

ID	Sawada ID	CONTEXT	SAMPLE	SANU	MATERIAL	$\delta^{13}C$	^{14}C age (BP)	±	cal. BP (95.4%)
MBANU-1715	MB05-108	L12.2 d1	*Sus scrofa*, Upper M3, R	40036	Collagen- dentine	-26	3,385	25	3,338–3,083
MBANU-044	MB07-002	H2 L10.2 f2	*Canis familiaris* mandible	40032	Collagen- bone	-20	3,490	25	3,693–3,573
MBANU-1714	MB07-046	H2 L12.2 b1	*Sus scrofa,* M1 and maxilla, L	40035	Collagen- bone	-19	3,435	25	3,825–3,612
MBANU-1713	MB05-097	H1 L12.2 b3	*Sus scrofa*, molar frag	40033	Collagen- bone and dentine	-26	3,020	25	3,836–3,694

and Oxenham 2016). The grave fill contained virtually no charcoal, or faunal material and it was essentially a sterile burial layer. However, material culture similarities – such as ceramic style – suggest a continuity between phases. It has been tentatively suggested that people may have been buried in family groupings (Oxenham et al. 2008), in an analogous way to sites in the Near East where people bury their deceased relatives underneath the floors of their houses. Similarly, An Son and Loc Giang in southern Vietnam are settlements that extended throughout several generations. At An Son, the burials were initially located at the periphery of the settlement but as housing expanded, the burials were covered by the midden (Bellwood et al. 2011; Piper et al. 2017). It is quite possible an analogous situation occurred at MB. If this hypothesis holds, the difference in date between the burial and occupation layers may not be that significant (i.e. potentially less than a few hundred years). The similarity in material culture between the occupation and burial layers at least implies a cultural continuity if not temporal. Intriguingly, the current dates for the southern Vietnamese sites An Son, Rach Nui, and Loc Giang are slightly older than MB. Resolving this discrepancy in dates between the northern and southern sites is an issue which needs to be addressed in future research (see Chapter twelve).

10.2. Conclusion to Chapter ten

The ^{14}C dates of CCN confirm a minimum Mid Holocene date for the site, and suggest the proposed chronology for the early phase of the Đa Bút is probably earlier than originally considered. More radiocarbon dates are essential for determining the chronology of the Đa Bút period. These new CCN dates represent the first securely dated series of ^{14}C dates for the Đa Bút period, it would be interesting to compare these dates to other Đa Bút sites in the future.

The ^{14}C dates clearly demonstrate that MB is significantly younger than CCN, by at least 2,000 years. Further, the dates on dog and pig remains from MB pin the minimal age for the management of pigs in northern Vietnam at 3,836–3,694 cal. BP and at least 3,693–3,573 cal. BP for the introduction of domesticated dog. These dates conform to the dates yielded from charcoal in the occupation layer. This indicates the spread of Phùng Nguyên sites along the edges of the Red River occurred just after c. 4,000 cal. BP. These dates provide a yardstick upon which to compare the introduction of domesticated animals against other sites in Vietnam and SEA.

CHAPTER ELEVEN
DISCUSSION

11.1. Introduction

This chapter is organised into two main sections. The first presents a summary of the results and a discussion covering each of the main objectives and related questions outlined in Chapter one (section 1.2.1). These main objectives are arranged into three parts: taphonomic, taxonomic, and radiocarbon dating. The second section discusses the research questions presented in section 1.2.2. Unlike Chapters six and seven where the results of taphonomic and taxonomic analyses were presented separately for CCN and MB, this chapter integrates and discusses the findings from the two sites together to provide a comprehensive comparative analysis.

~ 1. TAPHONOMIC ANALYSIS OF VERTEBRATE REMAINS ~

11.1.1. Site formation processes and paleoenvironmental conditions

In general, the faunal remains from both CCN and MB were in robust condition, with minimal evidence of weathering, and relatively little post-depositional disturbance.[1] Manganese (Mn) staining was especially common in the CCN assemblage, which indicates the skeletal elements were exposed to a wet and decomposing environment (López-González et al., 2006; Marín Arroyo et al., 2008). Some of the faunal remains from MB had a hard crust on the outer surface, which could be related to percolation of calcium carbonate from the surrounding bedrock (O'Connor et al., 2017).

The level of bone fragmentation between sites was predominately comparable, with the majority of fragments measuring <50 mm in greatest dimension. However, at MB pig maxillae were more fragmented than mandibles and there was also an under-representation of mandibles in NISP and MNE (section 7.4.8.). Thus, it was argued that differences in bone density alone do not explain the higher fragmentation in maxillae, as the greater proportion of maxillae was probably a contributing factor. This disparity in

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[1] Detailed taphonomic and taxonomic results for CCN and MB can be found respectively in Chapters six and seven.

fragmentation is potentially related to human butchery practices, such as exploitation of the brain, as opposed to purely post-depositional breakage (see section 7.4.8. and section 11.1.3. below).

There was also comparatively more evidence of carnivore and rodent activity at MB than CCN. Most of the bite marks and digestive marks were on pig or mammalian long bones. This higher abundance of carnivore bite and digestive marks is probably related to the presence of dogs at MB, and indicates that canids had access to bone scraps (see section 11.3.1.1. below for further discussion).

Paleoenvironmental evidence outlined by Masanari (2005, 99) clearly shows that the coastline during the Early–Mid Holocene (9,000-7,000 BP) was located near modern day Hanoi. After this peak transgression period, the sea level slowly fell to its present level (see Chapter two, section 2.2.3 and Figure 2-3). Both of the faunal assemblages help to confirm nearby access to a variety of water resources during the time of occupation. At CCN, the range of shark, ray, and fish species in the assemblage indicates estuarine, offshore ocean, and coral reef habitat exploitation (section 6.4.2.). Many of the taxa (such as catfish) can live in a variety of habitats from saltwater, to brackish, and freshwater, while Scaridae are more selective and only inhabit coral reef environments. Similarly, at MB Toizumi et al. (2011) identified a range of fish, shark, and ray taxa that are environmentally flexible, with a predominance of black seabreams (*Acanthopagrus* spp., NISP 188), barramundi (*Lates calcarifer*, NISP 75), and rays (Rajiformes, NISP 77). The presence of both hard-shelled and soft-shelled turtles also indicates the presence of still or slow-moving bodies of shallow water at both CCN and MB. Likewise, monitor lizards (*Varanus* spp.) and oriental small-clawed otters (*Aonyx cinerea*) particularly inhabit mangroves, swamps, and wetlands.

Regarding the terrestrial landscape, a range of different forested environments surrounding CCN at the time of occupation is implied through the presence of remains from macaques, leaf monkeys, pangolins, tigers and other large felids, civet cats, pigs, deer, and bovids. While pigs and most bovids are relatively flexible in their habitat choice, the preferred environments of water buffalo are alluvial grasslands, riparian forests, and woodlands, within close proximity to freshwater (Hedges et al., 2008). The large number of water buffalo in the assemblage suggests a particular exploitation of these environments. This is mirrored in the contemporary site Dingsishan in southern China, which portrays a dominance of buffalo and deer, suggesting the region between north Vietnam and south China was a landscape that supported herds of large grazing herbivores.

The main difference in mammalian taxonomic composition between the sites was the presence of domesticated dog and the dominance of pig at MB, the implications of which are discussed in section 11.4. Overall, the taxonomic similarity between CCN and MB implies similar palaeoenevironmental conditions despite the difference of around two thousand years (see radiocarbon section 3 below). However, the presence of domesticated dogs and pigs at MB and the body part representation, implies these animals were probably kept close to human habitation (see below section 11.1.3.). Conversely, at CCN there is no evidence for habitation (i.e. no post holes).

11.1.2. Spatial concentration and distribution of remains

The vast majority of the faunal remains at CCN came from Layers 2 and 3. When comparing the TNF and the dominant taxa, there are three main periods of accumulation, which may be related to site usage (Figure 11-1). Two of these peaks are in Layer 2 spits 1 and 4, and the lowest spike (Layer 3 spit 1) represents the deposit of calcined deer antlers (Feature 43). The ^{14}C dates obtained from human and faunal tooth enamel suggest Layer 3 is around 6,730–6,554 to 6,398–6,284 cal. BP, and Layer 2 around 6,294–6,205 and 6,397–6,278 cal. BP, with potentially some mixing between layers (Figure 11-1 and Chapter 10, section 10.1.3.). Since these dates were obtained from enamel and calcined bone it is important to remember they represent minimum ages (see section 5.10.3).

Deer and bovids are mainly concentrated around Layer 2 spit 4, and Layer 3 spits 1 and 2. While fish and turtles are more abundant in the upper layers. Rare taxa such as, pangolins, monkeys and rodents only occur in Layer 2. Carnivores are mostly in Layer 2, although there are a couple of larger felids (a tiger and clouded leopard/marbled cat) in Layer 3 spit 1. This is the same layer and spit as the whale radius and calcined deer antler deposit. Layer 3 is thus dominated by the calcined deer antlers and a few unusual 'special' taxa such as the whale and large felids.

The spatial distribution of the faunal remains from MB also indicates at least three different periods of accumulation, potentially representing different phases of site use.[2] Most of the fragments are concentrated in Layer 1, particularly spits 6–7 (Figure 11-2). The pattern of distribution of pigs and the TNF throughout the sequence largely correlates. Pigs are especially abundant in Layer 1 and Layer 2 spit 4. There appears to be a hiatus in

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[2] The 1999 and 2001 excavations season were unable to be used in spatial analyses due to lack of contextual information, see Chapter 7 section 7.2.1. Hence, this section mostly concerns the 2004–05 and 2007 excavations.

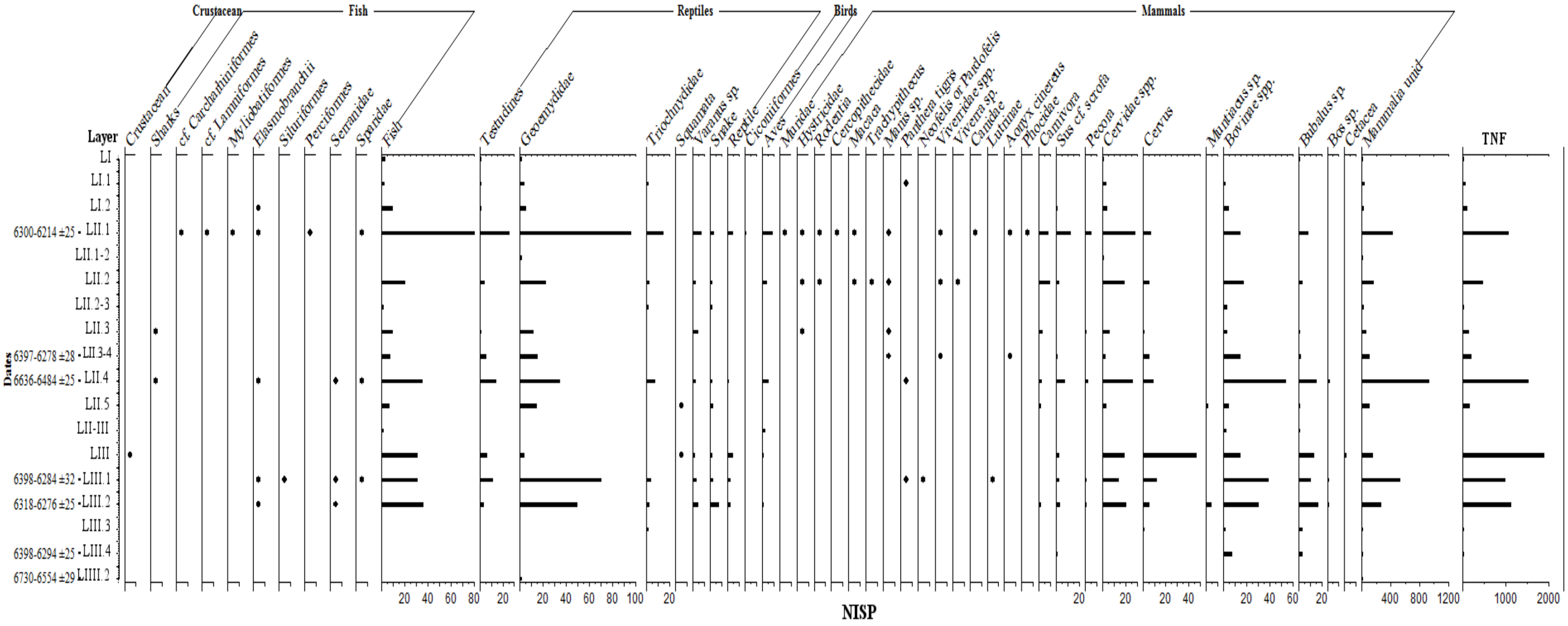

Figure 11-1 Distribution of faunal remains from CCN, arranged from stratigraphically highest to lowest. Selection of ^{14}C dates approximately where the samples were located within the stratigraphy.

deposition of all taxa between Layer 3 spits 6–11.

Other taxa that follow a notable pattern are rodents, as although they are low in NISP, their presence from Layer 2 spit 14 coincides with the other main peaks in accumulation. The increase in rodents may be related to an increase in food scraps being deposited in the midden. Also related to the human occupation are dogs, their elements are spread throughout Layers 1 and 2, but the earliest appears in Layer 3 spit 13. The peak in carnivores in Layer 1 spit 7 is the result of dog elements that could not be further identified beyond carnivore cf. dog size.

Rhinoceros are low in NISP but are present throughout Layers 1, 2, and 3, including one molar that was a surface find (MBANU-284, see Figure 7-23). Given the critically endangered status of rhinoceros in SEA, and virtual extinction in MSEA by the beginning of the 20th century, this surface find probably predates the early 1900s (Talukdar et al., 2008; van Strien et al., 2008a; 2008b). The stratigraphically lowest rhinoceros remains are between Layer 3 spits 13–15, which is on the same level as some of the stratigraphically higher human burials. These lowest rhinoceros elements must predate 3,836–3,694 cal. BP, the oldest date from Layer 2. All four ^{14}C dated pig and dog samples came from Layer 2, and were between 3,338–3,083 and 3,836–3,694 cal. BP, which provides a chronological boundary for the presumed older Layer 3 and the younger Layer 1. How great the difference in age between layers is still uncertain.

To conclude this section on patterns of spatial distribution, it is worth mentioning that both the lower layers of CCN and MB have special animal deposits. At CCN this includes the calcined deer antlers (squares E6–7, Feature 43) and the buried whale radius (square G5). They were both deposited in Layer 3 and may have been deliberately deposited during early or initial use of the site (see discussion below 11.6.6.). Similarly, at MB the burial of an elephant maxilla (Layer 3, spits 16–17; Figure 7-22) is an interesting deliberate deposition. The maxilla was buried above most of the human burials, and there does not appear to have been a direct association between the human burials and the elephant maxilla. These special depositions will be discussed in detail in section 11.3.3.

11.1.3. Butchery practices and selective culling of fauna

At both sites, there is extensive evidence for butchery on both cranial and postcranial elements, which indicates that all stages of carcass processing occurred near or at the sites, including artefact production. This clearly shows that animals were being exploited

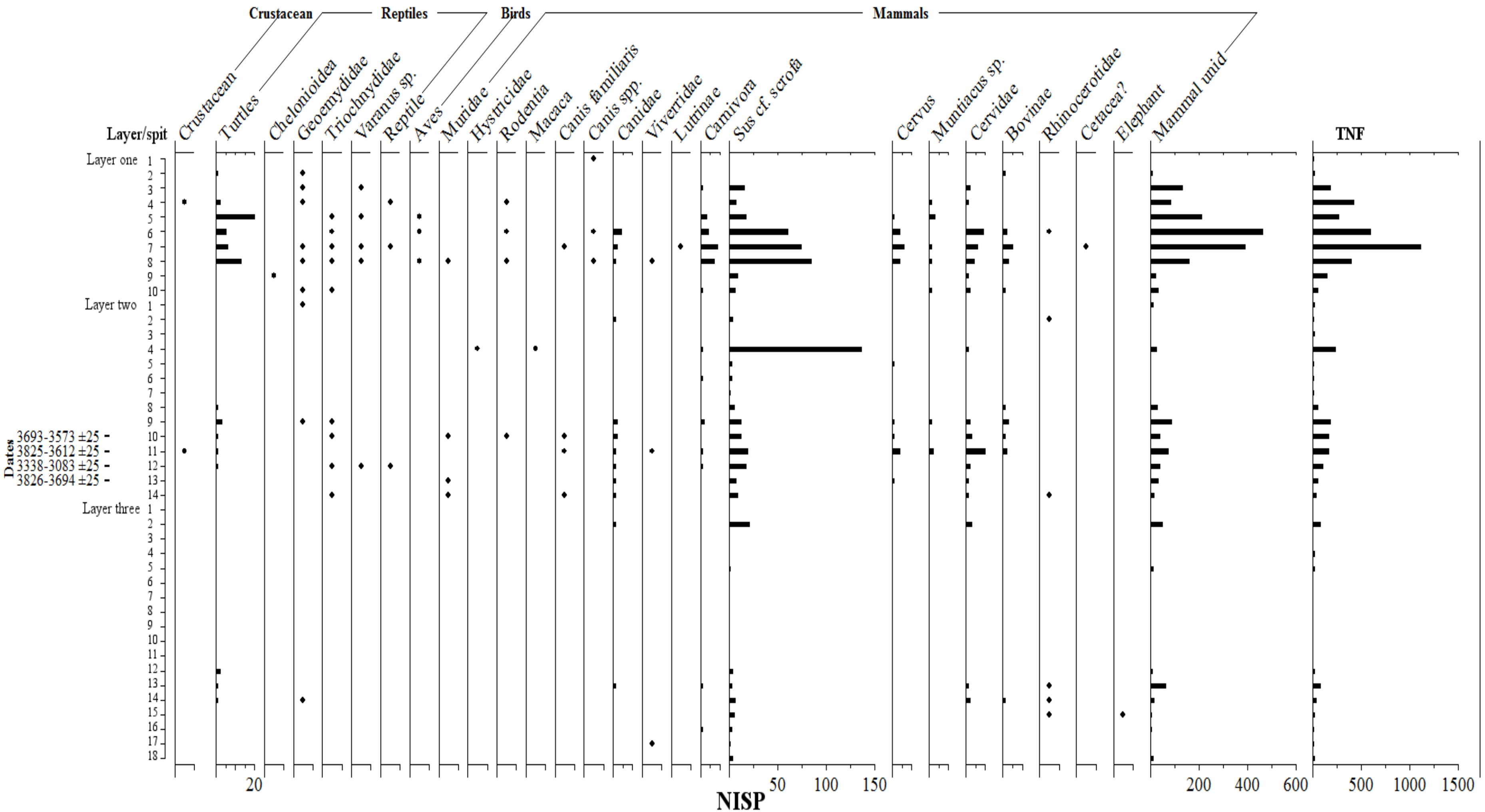

Figure 11-2 Distribution of faunal remains from MB, arranged from stratigraphically highest to lowest. The ^{14}C dates are approximately where the samples were located within the stratigraphy.

for a combination of their body parts, including, but not limited to: meat, marrow, skins, and bones. However, an interesting pattern was the relative paucity of axial skeletal elements (ribs, vertebrae) of deer and bovids at both sites. It is difficult to interpret the under-representation of axial elements at CCN because it may simply reflect differences in bone density as opposed to butchery practices (section 6.4.13). Except, this was clearly not the case for MB, as the pig axial skeleton is well-represented and there was an over-representation of fragile elements like maxillae (section 7.4.8.). Thus, differences in bone density do not seem to have affected the representation of the pig elements in the assemblage, which suggests the paucity in axial elements of deer and bovids reflects different butchery practices between these taxa.

This skeletal representation pattern relates to what is known as the ‘schlepp effect’, which argues that larger animals killed far from the point of consumption will result in less skeletal elements being transported back to habitation (Lyman et al. 1992; Marean et al. 1992). This pattern is expected to exponentially increase the further away the kill site is from the site base. The more complete representation of pig skeletons suggests pigs were butchered close to MB, as the schlepp effect has not affected skeletal representation. Conversely, there is a paucity of axial elements in both deer and bovids, and instead they are mostly represented by meat-bearing elements such as the anterior and posterior limbs. This discrepancy in high and low meat-bearing elements suggests that deer and bovids were probably hunted at a considerable distance from the site resulting in differential transportation of skeletal elements. Low meat-bearing elements were left behind at the kill or butchery site, while anterior and posterior limbs were carried back to MB.

The implied difference in acquisition of pigs compared to deer and bovids at MB is especially interesting when considering age at death profiles. It is clear from cranial data that younger pigs were selectively targeted as there is a drop in survivorship c. 8–12 months with the vast majority of individuals being culled either before or shortly after 24 months (Figure 11-3). A comparison of three different pig exploitation strategies, detailed by Lemoine et al. (2014, 190) provides a useful comparison to MB (see Figure 11-4). Hallan Çemi is a small early sedentary community of foragers (11,700–11,270 cal. BP), Banahilk is an established village site dominated by domestic caprines, cattle, and pig (c. 7,000–6,200 BP), and Tell Lelian (2,650–2,200 BC) is an urban site with controlled rationing of meat production (Lemoine et al. 2014). The culling strategy of MB and Banahilk (Figures 11-3 and 11-4 B) display a striking similarity in targeting pigs that are less than 12 months old. The postcranial fusion data adds to the picture, showing only a few individuals lived beyond five years (see Chapter seven, section 7.4.8.1. for more detail). These individuals may have only been slaughtered once it was decided they were no longer useful to the breeding population. These age at death profiles are a good indication that the pigs at MB were strategically managed to maximise meat procurement whilst maintaining a breeding population. Unlike other domesticated animals, pigs are unique 'meat machines' as they are only exploited for meat as opposed to other secondary products (Fillios 2006). This pattern of targeting relatively young pigs matches that of an intentionally managed or domesticated population of pigs and has been well-documented globally (see section 4.2.2.1; Yuan and Flad 2002; Ma 2004; Albarella and Payne 2005; Ma 2005; Fillios 2006; Anezaki 2007; Rowley-Conwy et al. 2012; Lemoine et al. 2014; Price and Arbuckle 2015; Zeder et al. 2015).

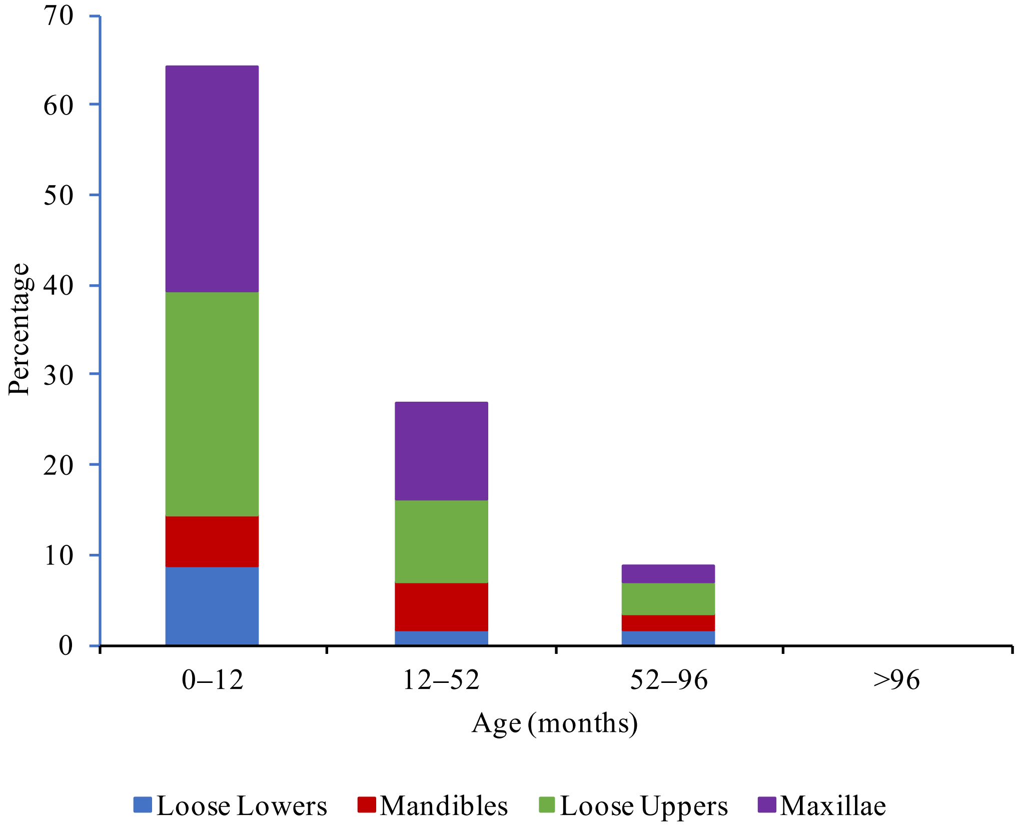

Figure 11-3 Mortality profiles for pigs at MB based on dental wear, n=56. The different categories of dentition used for ageing have been distinguished. Note the striking similarity to Banahilk in Figure 11-9 (B).

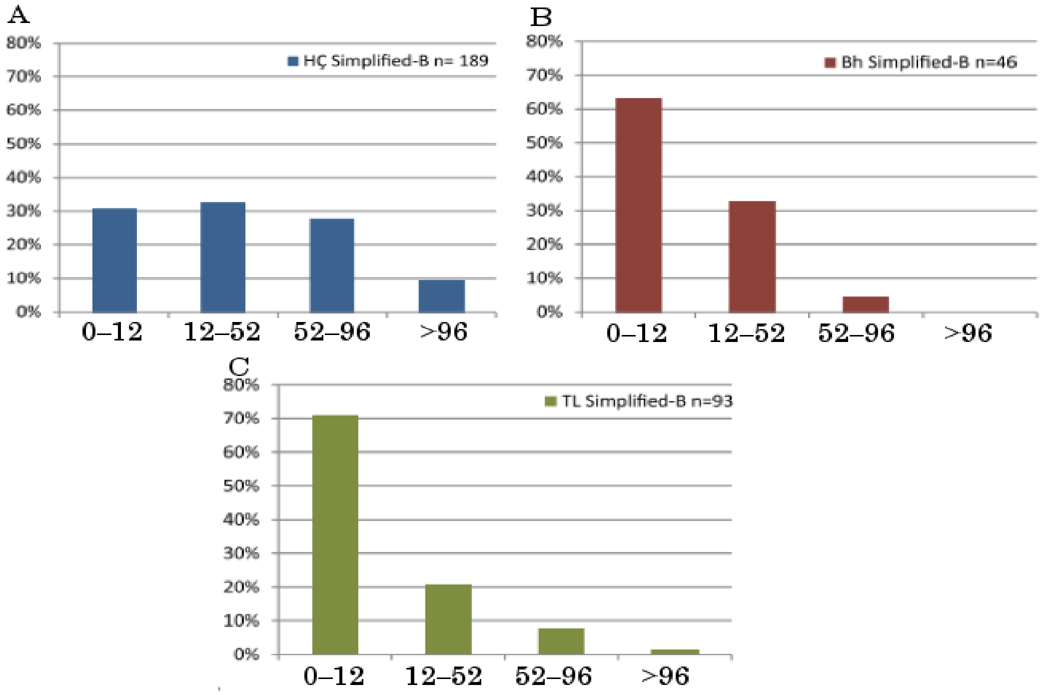

Figure 11-4 Pig mortality profiles from Lemoine et al. (2014, 190), age in months. A; Hallan Çemi, a small Late Epipaleolithic site southern Turkey 11,700–11,270 cal. BP, interpreted as initial husbandry in an early sedentary community of foragers. B; Banahilk, an established village site from the Halafian period c. 7,000-6,200 BP in Iraq, dominated by domestic caprines, followed by cattle, and pig. C; Tell Lelian, an urban Akkadian period site c. 2,650–2,200 BC in Mesopotamia, which had a highly-controlled subsistence economy with provisioning and rationing of meat from surrounding farms.

Conversely, at CCN such a management strategy of the pigs, bovids or cervids is not visible. The low abundance of pig elements makes it difficult to determine an exploitation strategy, however, there is at least one sub-adult and one adult individual in the assemblage based on postcranial fusion and dental wear (section 6.4.8.). For Bovinae, dental wear shows that mostly adults or elderly individuals (8 MNI) were targeted, with at least two sub-adult individuals also present (Chapter six, section 6.4.10.). For Cervidae, a mixed strategy is suggested through the presence of elderly, adult, and juvenile individuals (section 6.4.9.). Similar patterns of caprine age profiles have been interpreted as typical hunting practices, where older male individuals tend to be targeted with the occasional presence of a few younger animals (Zeder and Hesse 2000; Arbuckle and Atici 2013; Arbuckle 2014). Thus, the exploitation of bovids and deer at CCN is more in line with exploitation of wild taxa where maintaining the abundance of wild herds is the primary objective. This is also supported by the biometric data which suggests water buffalo were very large and comparable in size to wild bovids in SEA (see 11.2.1.4.).

~ 2. TAXONOMIC ANALYSIS OF VERTEBRATE REMAINS ~

11.2.1. Taxonomic composition and exploitation

It is clear from the butchery analysis presented in Chapters six and seven that the fauna from CCN and MB were exploited for their meat, marrow, potentially skins, and bones for artefact production. However, analysis of body part representation indicated different butchery patterns at MB between domestic pigs and wild taxa (deer, bovids), and the culling strategy of pigs was clearly managed to maximise meat production (section 11.1.3). Further, the taxonomic composition between CCN and MB was significantly different, both in terms of taxa present and relative proportion (Chapter nine). CCN's faunal assemblage comprised a wider taxonomic range, while MB was dominated by an abundance of pigs. The χ^2 analysis suggested the differences between the faunal assemblages were significant, and post-hoc testing confirmed that the relative proportions of water buffalo at CCN and pigs at MB were the main factors causing these statistically significant results (section 9.2.4.).

The taxonomic habitat index suggests different exploitation strategies of fauna between sites (section 9.3.). Most of the fauna at CCN corresponded to dense forest and woodland environments, whereas, the faunal assemblage from MB had more taxa associated with aquatic environments (estuarine, riverine, marshes), followed by grassland species. This is in accordance with the importance of fish in the MB diet, as evidenced from Toizumi et al.'s (2011) study of the fish remains which portrayed an abundance of large Serranidae (groupers), Siluriformes (catfish), and Perciformes (*Lates calcarifer*, barramundi). This is an interesting pattern as one of the argued differences between the Hoabinhian and Đa Bút period was a more coastal and estuarine focus (Bui Vinh 1991; Nguyen Viet 2005). These preliminary results from MB could indicate that the subsequent Phùng Nguyên period saw a further exploitation and emphasis on these environmental niches. In order to succinctly test whether this is the case, more comparative studies need to be conducted between other Phùng Nguyên and contemporary sites.

A summary of the four most abundant mammalian taxa is provided below.

11.2.1.1. Canidae: dogs and dhole

The canids at CCN were determined to be most likely the dhole (*Cuon alpinus*) based on biometrics and morphology. Conversely, the canids at MB showed a clear separation in size between wolves and dogs (Chapter eight) and, based on morphological differences of upper and lower dentition, a distal humerus, and distal tibia (Chapter seven, section 7.4.7. and Chapter eight, section 8.5), the dhole and jackal were ruled out. Consequently, the canids at MB were classified as dog, and are the clearest instance for a domesticated animal at the site. In taxonomic abundance, dogs are the third most abundant mammal at MB, yet, the numbers are not especially high (27 NISP, 23 MNE, 4 MNI, section 7.4.1. Table 7-15).

This is similar to contemporary sites in Vietnam (Rach Nui), and Thailand (Khok Phanom Di, Ban Lum Khao, Non Nok Tha, Ban Non Wat, Ban Chiang), where domesticated dog are present but relatively low in abundance (Higham 1975b; Higham et al. 1980; Grant and Higham 1991; Higham 2004a; Kijngam 2010; Piper et al. 2012; Oxenham et al. 2015). For An Son in southern Vietnam, domestic dogs actually outweighed pigs in terms of NISP (109 versus 83), and there was evidence of butchery and trauma (Piper et al. 2012). The dog bones were also recovered from the midden area of the site and displayed no variation in treatment from other subsistence animals, suggesting to Piper et al. (2012) that dogs did not receive special care.

Similarly, the burnt mandible with cutmarks on the interior/lingual surface found at MB suggests that dogs may have been butchered for meat on occasion. Further, the pathologies found on one Canidae tibia, and two carnivore cf. Canidae calcanei suggest some potentially interesting parallels between these dogs and the bioarchaeology of care model developed by Tilley and Oxenham (2011; 2016), and their analysis of burial M9 (see section 11.4.1. below).

11.2.1.2. Sus scrofa: pigs

At CCN there were only 50 elements identified as *Sus* cf. *scrofa* (0.9% of total NISP 5585), this is considerably less than the deer (298 NISP) and bovids (378 NISP). No evidence for domestication of pigs or bovids could be perceived based on biometrics or mortality profiles.

By contrast, pigs were the most abundant identified taxa in MB with a NISP of 565. Although this only accounts for 18.8% of total NISP (3039) this is related to the high proportion of elements that could not be identified beyond Order, due to fragmentation (1745, 57.4%). It is likely that a large amount of the skeletal elements that could only be identified as mammal, or medium-sized mammal, are pig (1947 NISP, 64% of total NISP). The total proportion of deer in the assemblage is only 3% (91 NISP), and both canids (27 NISP) and bovids (21 NISP) account for less than 1% respectively.

As detailed above (section 11.2.2.), age at death profiles of pigs at MB portrays a selective culling strategy that mirrors a managed population. Cluster analysis of pig dental metrics suggested the presence of at least three groups of pigs within the dataset (Chapter eight, section 8.4.), which was also supported by the significant variability in molar size. These three data groups can be generally classified as small, medium, and large; sometimes additional groups of 'narrow' or 'wide' were added (section 8.4 Table 8-28). Most of the MB samples were classified into the medium/wide group, followed by large, with a few samples falling into the small and narrow groups.

Generally, older sites contained a higher number of large samples (Lobang Hangus, Gan Kira, Dingsishan), while Mid–Late Holocene sites show a spread in size (Xipo, An Son, Rach Nui, Nagsabaran; section 8.4 Table 8-28, Appendix 5.3). Particularly interesting is the comparison of MB and Xipo, a Mid Holocene site in the middle Yellow River that clearly has an intense pig-management system (Ma 2004; 2005). Both sites show a spread in molar size, however Xipo is asymmetrically leaning towards small and narrow sized molars, while MB has comparatively more wide and large molars. These asymmetrically-leaning patterns make sense as Xipo represents an established pig-management system, while the large molar size of pigs at MB suggests they were in an early phase of management, with possible interbreeding with wild populations. This relates to what Larson and Fuller (2014, 121–2) term 'introgressive capture' where domesticated animals are translocated from one geographic location to another and subsequently interbreed with local wild populations. Introgressive capture is particularly prevalent among pigs in SEA and is one of the reasons why domestication of pigs in this region is complex (Piper 2017, 254). Though these are preliminary results, the significant discrepancy in size between the Xipo and MB pigs may imply that the domestic pigs in southern China and northern Vietnam are not directly related to the Yellow River pigs in northern China. The domestication of pigs in the Yellow and Yangtze River regions in China may have been separate events with minimal interbreeding between populations.

11.2.1.3. Cervidae: deer

Three aspects that both CCN and MB have in common are that, A) deer are the second most abundant taxa at both sites (378 NISP at CCN, 91 NISP at MB), B) both large and small species are present, and C) the larger species is more abundant. The large species of deer have been classified as *Cervus* ('true' deer) and the smaller specimens as *Muntiacus* (muntjac).

At CCN, dental wear indicates the presence of at least one elderly, two adults, and one young individual in the assemblage, which is supported by postcranial fusion data. Although the entire carcass is represented, there is an over-representation of cranial antler fragments compared to the rest of the body (section 6.4.9.). The presence of the pedicle proximal to the burr on some of the antlers shows they were deliberately removed from the skull. Although butchery confirms that deer carcasses were being exploited for meat, the use of male deer antlers for artefact production and/or their subsequent burning and deposition indicates multiple purposes and a significance that goes beyond subsistence (see section 11.6.2. below).

At MB, deer appear to have been exploited across the age range (section 7.4.9.). The whole skeleton was utilised, though axial elements are under-represented (see section 11.2.3.), as was similarly the case for bovids at MB.

11.2.1.4. Bovinae: water buffalo and cattle

Bovinae were the most abundant taxa at CCN (378 NISP, 248 MNE, 7 MNI, section 6.4.1 Table 6-10). The majority of Bovinae that could be further classified were identified as water buffalo (*Bubalus* sp., 96 NISP) due to their size, robusticity, and morphology. Cattle (*Bos* spp., 6 NISP) were also identified based on morphological differences between the genera, especially in metacarpals and metatarsals.

The biometrics of Bovinae from CCN showed that the majority of individuals were large compared to modern domesticated water buffalo and cattle. They are also relatively large compared to comparative samples from Non Nok Tha (Thailand, Neolithic-Bronze Age) and Prei Khmeng and Phum Lovea (Cambodia, Iron Age; Chapter eight). They are most similar in size to Dingsishan (southern China, Early Holocene), although the smaller samples overlap with the Cambodian samples (Figures 8-14 to 8-16, section 8.6.2.). Overall, based on the above comparative data the majority of the CCN samples probably represent wild water buffalo (*Bubalus* sp.), with the presence of at least one wild cattle (*Bos* spp.). Given the large size and considerably greater robusticity of the gaur (*Bos gaurus*), the wild cattle at CCN are probably either the banteng (*B. javanicus*) or kouprey (*B. sauveli*).

The dominance of large bovids in Terminal Pleistocene and Early Holocene sites, such as CCN, Lang Spean (Cambodia), Dingsishan and Tangzigou (south China), indicates the region between northern MSEA and southern China was a landscape suitable for herds of large grazing animals. Although the water buffalo from CCN were most likely wild populations (based on their large size and older age at death profiles), numerous lines of evidence suggest their relationship with humans was physically close and potentially mirrored a type of intensive management/interaction strategy not commonly associated with hunter-gatherer economies (see Oxenham et al. in press).

Bovinae are also present at MB, though in much smaller numbers (21 NISP). Within this count, three elements were recorded as cf. *Bubalus* and three as cf. *Bos*, with an MNI of 1 each respectively. Due to the limited skeletal elements it is difficult to determine their domestication status. Their relatively low NISP and MNI could indicate that their role in meat subsistence was not as important as pigs, however, the bovids may have held a special significance or another use.

An interesting regional faunal difference is the lower abundance of bovids in MB and contemporary sites in Vietnam compared to Thailand. Higham et al. (1981) stipulated the water buffalo from Ban Chiang may have been used for ploughing of rice fields based on the increased robusticity of the terminal phalanx, and their 'sudden' appearance in the faunal record around 1,600 BC. The earliest evidence for rice in MSEA comes from Khok Phanom Di, roughly contemporary with MB at around 2,000–1,500 BC; however Higham and Thosarat (2004b) argued the rice was initially imported from elsewhere then later adopted. Given the purported presence of long grain rice at MB (Peter Bellwood 2013, pers. comm.), and the argument that MB represents a community with an agricultural subsistence base (Bellwood and Oxenham 2008; Matsumura et al. 2008; Oxenham et al. 2008), it is puzzling that bovids do not hold a more prominent place in the faunal deposit. Similarly, at An Son, Rach Nui, and Loc Giang in south Vietnam, rice has been identified but bovid skeletal remains are also relatively low. At both Loc Giang and Rach Nui husk impressions of domesticated rice were identified within pottery temper, but there were few remains of rice phytoliths (Castillo et al. 2017; Piper et al. 2017). Castillo et al. (2017) and Piper et al. (2017) argued that rice was not cultivated at either site, but was probably locally imported. Conversely, the nearby site of An Son had rice phytoliths in abundance indicating that rice was both processed and consumed on site (Bellwood et al. 2011, 168; Castillo et al. 2017; Piper et al. 2017). At present, there is no skeletal or archaeological evidence that bovids played a role in rice agriculture in Vietnamese sites, so this discrepancy between Thai and Viet sites needs further investigation in the future.

11.2.2. Subsistence base at Cồn Cổ Ngựa and Mán Bạc

One of the primary aims of this thesis was attempting to differentiate between domestic and wild fauna. Central to this aim was the question of whether zooarchaeology can determine the subsistence base of CCN and MB. In other words, can CCN and MB be conclusively shown to represent hunter-gatherer and agricultural economies respectively?

Principal components analysis of comparative data throughout SEA was performed to determine whether the differences between both sites in taxonomic composition (section 9.4.) and habitat index[3] were the result of human behavioural practices in subsistence base (section 9.3.). Results revealed that the relative proportion of monkeys, viverrids, and felids are the most important factors in distinguishing sites based on hunter-gatherer economies throughout the Pleistocene and Early Holocene. However, for Mid–Late Holocene or agricultural based sites the abundance of pigs and dogs are important factors. These correlations suggest that there is less hunting of monkeys, viverrids, and felids, within farming communities with domesticated animals. Crucially, even though domestic and wild fauna were intentionally not separated in this analysis,[4] there was a positive correlation between pigs and dogs at agricultural sites, were domesticated dogs and pigs are likely to be present.

Importantly, in every PCA undertaken (no matter how many variables were changed or which outliers were included and excluded), CCN and MB always fell distinctly apart into different groups (section 9.4.4), largely composed of hunter-gatherer versus agricultural sites. The high proportion of pigs and presence of dogs at MB associate it with agricultural economies, while the relatively higher proportion of monkeys, viverrids, and felids at CCN is associated with hunter-gatherer subsistence bases.

Intriguingly, the high abundance of water buffalo at CCN did not separate the site from other hunter-gatherer based sites. For instance, Laang Spean (Cambodia, Terminal

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[3] It was demonstrated in section 9.3. that the people from CCN were mostly exploiting dense forest and woodland environments, while the inhabitants at MB were mainly focused on water and grassland fauna.

[4] By ‘not separated’ this means taxonomic species were combined into their families. For instance, rather than *Canis familiaris* being separated from wolves or the dhole, they were listed as Canidae in the PCA. The reason for this was related to methodological and theoretical purposes, see Chapter five, section 5.8 for discussion and rationale.

Pleistocene–Early Holocene) Dingsishan (southern China, Early Holocene), and Ban Non Wat (Thailand, Mid–Late Holocene) also had relatively high proportions of bovids in the assemblages. Thus, the abundance of bovids in an assemblage does not appear to be a useful criterion to judge whether a site is hunting or agricultural based. This is similarly the case with deer, as the relative proportion of deer in the assemblage did not particularly separate sites. This is probably explained by the fact that many agricultural based sites continue to exploit deer well after the introduction of domesticated pigs and dogs.

Another taxa that was slightly at odds with expectations was mustelids (otters), which positively correlated with all components and did not help in differentiating between subsistence bases. Whether this is reflective of direct exploitation of otters for subsistence, or largely a product of humans and otters cohabiting similar environments is an interesting question. Today, otters are classified as vulnerable throughout Asia as a result of widespread poaching for their pelts that possess high quality and waterproof fur (Wright et al. 2015).

11.2.3. Summary: Domestication of fauna

In summary, there is no evidence for domesticated fauna at CCN. Neither the morphometrics or age profile of the bovids or pigs at CCN match those of managed populations, and the presence of a couple of canid elements are most likely the dhole. The faunal composition of CCN is most similar to a society primarily relying on hunting animals for subsistence.

By contrast, there is clear evidence of domesticated dog at MB. Further, the age profiles of the pigs markedly suggest a managed population with controlled culling of younger individuals. However, these pigs do not display the full traits of domestication as there is variation in molar size, and many of the specimens are comparative in size to wild boars. This could simply be a reflection of how long it takes before size reduction becomes skeletally apparent in managed or domesticated populations. It could also be related to the exploitation of both wild and managed boars, or introgressive capture (Larson and Fuller 2014), i.e. wild boars interbreeding with managed pigs. Either way, it is clear pigs dominate the assemblage compared to other taxa, and they were being selectively targeted at young ages. Together these factors suggest the most likely explanation is the pigs were in an early stage of management.

It is unclear whether the bovids at MB were domesticated based on morphometrics.

However, there was an interesting distinction in butchery practices between pigs, and deer and bovids, as skeletal elements of pigs were well-represented, while there was a paucity of axial elements for deer and bovids (section 11.2.3.) It was argued this pattern could be explained by the ‘schlepp effect’, as the more complete representation of pig skeletons suggests they were butchered close to the site and probably kept close to habitation. Conversely, the paucity of axial elements and relative abundance of meat-bearing elements in deer and bovids suggests they were hunted at a far enough distance from MB to result in differential transportation of skeletal elements. Thus, the body-part representation patterns at MB indicate butchery practiced differed between wild and domestic taxa.

~ 3. RADIOCARBON DATING ~

Radiocarbon dating (^{14}C) of CCN and MB was one of the primary aims of this project. The Mid Holocene Đa Bút chronology of CCN was based on ceramic and lithic typologies, thus scientific dating was essential to test these relative dates. For MB, direct dating of select pig and dog elements was performed to provide a minimum age for the introduction of domesticated animals into northern Vietnam.

The 14C dates confirmed the age of CCN is Mid Holocene, with the majority of dates between 6,600–6,200 cal. BP. It is important to restate that these dates are based on enamel samples and thus represent minimum ages. This time frame largely agrees with the previously hypothesised dates for CCN, although it suggests the initial Đa Bút phase is earlier than Bui Vinh (1991) or Nguyen Viet (2005) proposed from c. 6,000 cal. BP to c. 70,00 cal. BP. The range of dates at CCN indicates the site may have been used as a burial ground and communal place to gather for around 500 years.

For MB, the radiocarbon dates also align with previous dates, which places the site into the Phùng Nguyên period (Dung et al. 2011; Matsumura and Oxenham 2011). Three of the dates fall between 3,500–3,800 cal. BP, while one pig UM3 is slightly younger at 3,338–3,083 cal. BP (section 10.1.5.). This shows there is indeed a significant time difference between CCN and MB, of around 2,000 years. This places the introduction of domesticated dog in north Vietnam at a minimum of 3,693–3,573 cal. BP and the early management/domestication of pigs at 3,836–3,694 cal. BP. These samples importantly represent the only direct dates on domestic pigs and dogs in Vietnam. These dates generally fit into farming dispersal models or two-layer hypothesis (see Chapter two 2.3.11. and

Chapter three 3.6. for in-depth discussion).

Unfortunately, it is difficult to determine the occupational span of MB based on radiocarbon analysis, as the human skeletal material unable able to be dated. One of the unanswered complications with MB is exactly how the lower burial layer relates to the occupation layers above. If Oxenham et al.'s (2008) suggestion that people buried their dead relatives below their house is correct, this could indicate a direct connection between the layers and relatively short time frame of occupation. However, if this was the case there should be more occupational midden within the burial layer. If people were living directly on top of burials, surely there would be slightly more mixing between the burial and midden layers.

A further possibility regarding site development is that MB expanded in a similar fashion to An Son, where there was outward dumping of midden material around the edge of the occupation mound (Bellwood et al. 2011, 149). As the settlement grew the midden eventually expanded to cover the burials. Bellwood et al. (2011, 149) argued this expansion did not accumulate continuously around one centre in a uniform fashion, but sporadically and asymmetrically. This would explain why the midden is on top of the burials and why there are several hiatuses in the faunal accumulation. The implication of this is the burials may be slightly older than the midden layer. However, as argued by the excavators (Oxenham et al. 2008), the continuity in material culture between the burial and midden layers indicates some kind of cultural continuity between layers, if not temporal.

~ 4. MEETING THEORY AND PRACTICE ~

One of the ultimate goals of zooarchaeology is to contribute to our understanding of how people interacted with their environment, with other animals, and how they perceived the world around them. The comparison of CCN and MB offers a unique potential for addressing complex issues as the sites sit on either side of hunter-gatherer and domesticated subsistence economies and both are large burials sites. This allows specific queries relating to how archaeology and faunal remains can reveal the belief systems and ontology of the people and human-animal relationships. Pertaining to these goals are overarching questions of how transitions or changes in faunal assemblages occur on local and regional scales, and what this says about the society. As outlined in Chapter one (section 1.2.1.) this project was summarised into three specific inquiries that relate to overarching theoretical and methodological frameworks, these are detailed below.

11.4. Is there a perceivable shift in faunal composition between Cồn Cổ Ngựa and Mán Bạc, and if so, does this relate to domestication?

This thesis found a clear and unambiguous perceivable shift in faunal composition between CCN and MB, and this transition can be confidentially attributed to the initiation of pig management and introduction of domesticated dogs. However, what should be emphasised is this transition cannot be characterised as a clean break from hunting wild deer to rearing pigs. The variable size range of the pigs at MB is indicative of initial selective culling of targeted fauna and their 'domesticated status' is caught within a state of flux of that which we typically characterize as 'wild' or 'domestic'. Oxenham and Matsumura (2011, 131) have suggested that MB captures a community of people undergoing a significant transition, both in terms of genetic makeup and social and economic life-ways. In this sense, the pigs can be considered analogous to the humans – they have been caught in a transition to a management strategy.

Asides from pigs, two further elements will be explored below using comparative sites in SEA and ethnographic examples to frame the relationship between humans and animals at CCN and MB. The first section (11.4.1.) will explore the relationship between canids and humans, the second (11.4.2.) will examine how the introduction of domesticates impacted the relationship with wild taxa.

11.4.1. Canids at Cồn Cổ Ngựa and Mán Bạc

An ambiguous relationship between humans and animals is implied through the canids, an interesting parallel between both sites. At CCN, an ulna, femur, and P4 were identified as canid, most likely dhole (*Cuon alpinus*). Dholes are habitat generalists that live in packs and they are one of a few canid species that have dental adaptations for an exclusively carnivorous diet (Kamler et al. 2015). Although they are known to consume a variety of prey sizes, their preferred prey are ungulates 40–60 kgs in size (Kamler et al. 2015). Ethnographic accounts from SEA show people often take advantage of their hunting prowess by following them and stealing their kill (Fox 1984; Chacon 2000). The appearance of these canids in the assemblage shows that taxa very similar to dogs in appearance and behaviour were in the human environment for a considerable time prior to the introduction of domesticated dogs. Indeed, dholes have been identified in other archaeological assemblages in Asia and Europe from the Late Pleistocene onwards, and occasionally occur alongside domesticated dogs (Hoáng Xuân Chinh 1991; Baryshnikov 1996; Vu The Long et al. 1996; Flad et al. 2007; Voeun 2008; Ripoll et al. 2010; Wang 2011; Mallye et al. 2012; Conrad 2015). When dogs were introduced into Vietnam and Thailand their numbers seem to remain relatively low (section 11.2.6.).

At MB, the burnt dog mandible with abrasive cutmarks on the lingual aspect suggests dogs may have been occasionally eaten. Additionally, the relationship between humans and dogs becomes more complex when considering the pathological canid elements found at MB (sections 7.4.7.3. and 11.2.6.). The presence of pathologies on a proximal canid tibia and two carnivore cf. canid calcanei hint at a potentially interesting parallel with the bioarchaeology of care model developed by Tilley and Oxenham (2011; 2016) for individuals at MB. All three elements were found in different contexts, which suggests either there has been some significant stratigraphic mixing (which is not suggested by the taphonomic analysis) or there were at least two dogs at MB with severe pathologies to their posterior limb. Despite these pathologies these individuals managed to survive until adulthood as indicated through epiphyseal fusion.

Tilley and Oxenham's (2011; 2016) analysis of burial M9, a young male quadriplegic, suggests managing his care would have required constant balancing of specialised needs with considerable flexibility and organisation. Although included within the main burial ground, he was peculiarly flexed on the right facing north-south (Tilley and Oxenham 2016, 105). Tilley and Oxenham (2016, 105) argue the fact he was well cared for suggests the different mortuary treatment "was not punitive or exclusionary, but intended to indicate that concern for this individual's well-being during his lifetime extended into the afterlife." Further, this indicates "the community's ability and willingness to accommodate individual's differences within the group during life" (Tilley and Oxenham 2016, 106).

There are clearly distinct differences between a human with severe disabilities being intensively cared for and a domestic dog with pathologies. However, drawing some comparisons the survival of the dog/s could indicate special provisioning with scraps of food which improved the quality of life. There were more carnivore bite marks on skeletal elements at MB compared to CCN, which is an indication that canids had access to leftover bone scraps (see section 11.1.1. above).

Conversely, there is no other evidence for the special treatment of canids at MB, and the butchery of dog remains suggest that they were not particularly specially treated. This is similar to the situation at An Son, roughly 500 years[5] before MB where it was suggested that dogs were probably butchered and consumed and did not receive special post-mortem treatment (Piper et al. 2012). Similarly, at Nagsabaran in the Philippines there was evidence for differential treatment of dogs with one individual given an internment similar to human burials, while other dog elements had butchery marks suggesting they were utilised for food, though the low NISP suggests they did not constitute a large portion of the diet (Amano et al. 2013, 330). Akin to MB, there was also evidence of canid gnawing and digestion marks on bone at Nagsabaran, indicating that dogs were free to roam and scavenge. Amano et al. (2013, 330) suggested the treatment of dogs at Nagsabaran indicates differential worth of individuals, in a similar fashion to ethnographic accounts in Northern Philippines from the early 20th century, where greater value was placed on hunting dogs. Further, dogs were occasionally sacrificed in rituals on ceremonial occasions, such as funerals or marriages (Amano et al. 2013, 330). This is similarly the case in Hmong communities in MSEA, where dog sacrifice is occasionally performed (Tapp 1989, 63).

There is no reliable evidence for domestic dog in Vietnam or the rest of MSEA prior to their Mid–Late Holocene introduction. The canid ulna recorded at Đa Bút by Patte (1932, 48) was noted as being similar in appearance to a dingo. However, no comparison was made to other potential canid species (such as dhole or jackal), which makes the domesticated status uncertain. As mentioned in section 11.4.2.1, when dogs were introduced into SEA they were relatively low in numbers. At An Son 109 fragments of dog were identified (Piper et al. 2012), which is considerably higher than at MB or sites of comparable age, such as Khok Phanom Di (13 NISP; Grant and Higham 1991), Ban Lum Khao (26 NISP; Higham 2004a), Non Nok Tha (10 NISP; Higham 1975b), and Ban Chiang (37 NISP; Higham and Kijngam 1979). This is however comparable to Ban Non Wat where 102 dog elements were identified (Kijngam 2010). The similarity in age between the Thai and Viet sites suggests that the introduction of domesticated dogs into Vietnam and MSEA probably occurred around 4,000 cal. BP.

In Chapter four, Fijn's (2011) study on the differences between the perception of wolves and dogs amongst herders in Mongolia was discussed, showing they were not

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[5] The dates for An Son dogs were reported as approximately 4,811–4,182 cal. BP (or 2,862–2,233 cal. BC, Bellwood et al. 2011), Oxcal was used to calibrate using IntCal 13 at 95.4% probability. The lowest An Son dog specimen was in Test Pit 190–200 cm, however, the radiocarbon date comes from residue on ceramic below these canid remains (230–240 cm). In contrast, the MB dog samples were directly dated. Thus, the date for the An Son dogs may actually be closer to the MB.

considered similar animals because of their separate roles. Dogs in herder encampments largely perform guard dog duties, and a particularly good dog is carefully buried (Fijn 2011, 213). However, given there is no evidence of special treatment of canids at CCN or MB, perhaps the most useful analogy for this interspecies relationship are modern village dogs in Vietnam that often function as guard dogs and pest eaters, rather than 'pets'. Greig et al. (2016, 467) provide a useful summary of ethnographic accounts of modern village dogs in SEA contexts, where dogs live in settlements in association with people, but are free from direct human control. Case studies from the Philippines, Indonesia, and PNG portrays how village dogs are highly independent and played varying roles in people's lives as guard dogs, pest controllers, assistant hunters, and occasional meat supplementers. They are free to roam around villages, scavenge, are provisioned for, but also occasionally eaten.

In Avieli's (2012, 65) interviews with dog owners around Hoi An she found they were not seen as quasi-family members (akin to Western ideology), though they were definitely given special treatment. Dogs were not allowed indoors, and although they were fed leftovers none of the dogs' owners brought food specifically for their dogs. Nonetheless, owners were fond of their dogs, and would nurse them when they were injured or sick. If their dogs were lost and unable to be found people bitterly expressed they were probably stolen and eaten. In a country where Buddhism has a big influence on ideologies the notion of eating dog is problematic, and many people express that eating dog is a type of cannibalism (Avieli 2012; Rosen 2014). This suggests that dogs are often viewed as a type of human (or humans a type of animal), a concept not unfamiliar in the West. Overall, the perception of the SEA village dog could relate to how canids were treated at MB. While dogs at MB were probably not regarded as 'pets' in the modern Western sense, there is some evidence to suggest they may have been provisioned for or at least had access to scraps.

11.4.2. Impact of domestication on relationship with wild taxa

In many societies, hunting plays an important social and symbolic role, offering a window into how people perceive themselves in relation to the animal they are hunting (Ingold 2000c; Hamilakis 2003; McNiven 2010; 2013). McNiven (2010) notes hunting provides a praxis to investigate how humans and animals meet both economically and ontologically. Further pertaining to the question of domestication, is how does the introduction of domesticates or managed animals affect the hunting of other taxa at MB? Despite the presence of dogs and pigs, the fauna at MB shows a continued reliance on hunting deer and fishing. Deer contribute to around 3% of the total NISP (91 NISP), which is considerably lower in abundance than pigs. However, when taking into consideration other hunted fauna and the abundance of large fish (Toizumi et al. 2011), wild taxa are clearly still playing an important role in the diet. In my analysis, taxa that are clearly wild contribute to at least 34% (302/881 NISP), compared to specimens identified as pig or dog at 66% (579/881 NISP). Further, isotopic evidence on human skeletal material supports the suggestion that people had a diet that was enriched in marine sources of food (Anna Willis 2015, pers. comm.). Clearly, although pigs were the dominant source of terrestrial meat, hunting and fishing certainly continued to play a role, and probably on a regular basis. This argument supports the conclusions of the original preliminary study of the mammalian fauna from MB by Sawada et al. (2011).

The continued reliance on hunting and wild fauna at MB despite the introduction of domesticates is a pattern across SEA. In the south of Vietnam, sites An Son and Rach Nui are useful analogies to MB. They are both strategically placed along rivers, which provided stable access to water resources such as shellfish, fish, and turtles year-round. The An Son faunal remains were dominated by fish (NISP 6077, 68%), followed by turtles (NISP 1084, 13%), while domestic animals and associated commensals were decidedly less abundant: domestic dog (109 NISP), domestic pig (83 NISP), and commensal rat (5 NISP, *Rattus* sp(p) (Bellwood et al. 2011, 165–6). Rach Nui was also largely dominated by fish (1889 NISP, 50%), though mammals were second (1131 NISP, 30%) and reptiles were comparatively less abundant than An Son (737 NISP, 19%). This difference in mammalian abundance is mainly because there were considerably more pigs, monkeys, and rats at Rach Nui compared to An Son. Nonetheless, both sites show the continued importance of aquatic resources despite the presence of domestic pigs and dogs. This suggests that fish probably provided the basis of daily protein in the diets of both foraging and farming societies in SEA.

Compared to Thai faunal assemblages, although there is variability in the presence of certain species and their relative proportions (as shown by PCA in Chapter nine section 9.4.), there are some overall similar patterns. Ban Non Wat (Kijngam 2010), Khok Phanom Di (Grant and Higham 1991), Ban Lum Khao (Higham 2004a), Non Nok Tha (Higham 1975b), and Ban Chiang (Higham and Kijngam 1979) all have domesticated dog, and pigs and bovids are present and in large proportions in BNW and KPD (though not necessarily domesticated). Commensal rats (*Rattus rattus*) are also present in each assemblage, (except for BLK) and are in considerable abundance at KPD (819 NISP; West 1991). However, all sites also have considerable abundances of deer, and a varied combination of other wild mammals, such as viverrids, turtles (especially Geoemydidae), and felids. The NISP of Geoemydidae at KPD (3820) and BNW (1288) is particularly high, as was the plethora of freshwater fish and shellfish at BNW (Thosarat 2010). For NNT, detailed faunal analyses are currently being revisited by Cyler Conrad, but Higham's (1975b) original study indicated the presence of deer, viverrids, and a tiger. Similarly, Higham and Kijngam's (1979) study of BC only listed the NISP for one square, but they suggested aquatic resources were an important aspect of the subsistence economy.

Widely across Asia, the continuance of hunting despite the presence of domesticated fauna is also apparent in other later sites such as Nagsarbaran (Amano et al. 2013) in the Philippines and Phum Snay (Voeun 2008) in Cambodia. Even in contexts where pig management has become standardised, such as Mid Holocene sites in China, the hunting of deer remains common (Ma 2004; 2005; Flad et al. 2007; Yuan et al. 2008; Wang 2011; Wang et al. 2012). This can be seen especially at Wayaogou (c. 4,320–3,710 BC) in the Wei River region with a high NISP of pigs (2338) that resulted in the site being an outlier in some of the PCA graphs (Chapter nine section 9.4. and 9.4.3.), but deer still dominate the NISP compared to domestic pigs (3440 NISP; Wang 2011; Wang et al. 2012).

The continued hunting of deer may be related to the suitability of their antlers and metapodials in bone artefact production. At Nagsabaran, Amano et al. (2013) argued there was a preference for deer metapodials based on the numerous cutmarks and chopmarks on the diaphysis of deer metapodials and their over-representation in the assemblage (Amano et al. 2013, 327). Philip Piper (pers. comm. 2017; see forthcoming paper) argues a similar case for the Bronze Age site of Lo Gach in southern Vietnam, where almost all of the bone artefacts were produced on deer metapodials and antlers. At CCN deer antlers and metapodials were certainly specifically collected for further exploitation either in bone artefact production (see Table 6-9), or as fuel for burning (see section 11.6.4. below). This continues to be the case at MB, where antlers of muntjacs were used in bone artefact production (see Table 7-12).

This pattern of continued hunting despite the introduction of domesticates has parallels in other parts of the world, perhaps most famously at Çatalhöyük in Turkey. Hodder (2007) framed the continued reliance and imagery of hunting at Çatalhöyük as an attempt to control the wild, a familiar argument within a Post-Processualist critique.

Although this may be appropriate for a large urban site such as Çatalhöyük, this is not necessarily a universal model that can be applied to Neolithic SEA or to MB. Further, Hodder's notion of 'controlling the wild' rests on largely Western nature/culture binary oppositions that are not automatically applicable to other cultures. In Hamilakis' (2003, 241) critique of Hodder he warns against using these dichotomies as a framework for hunting in early agricultural societies. Hamilakis (2003) argues hunting acquires values beyond subsistence in his study of Mycenaean Early Bronze Age Greece, a period which relied mostly on farming for subsistence. Hamilakis (2003, 240–1) suggests rather than simply 'controlling the wild', hunting was linked to exercising and legitimising power as well as negotiating a complex combination of new conceptions regarding gender, age, and socio-political roles.

The continuation of hunting at MB probably cannot be explained using the exact framework of Hamilakis (2003), as the specific socio-political context of Mycenaean Greece is quite separate from Neolithic Vietnam. However, the basic concept that hunting acquires new values, meanings and significance when domestic animals become integrated into daily life is a strong proposal that could be applied. The analysis of body part representation of pigs compared to wild taxa at MB portrayed an interesting difference in the way they were exploited (section 11.2.3. and 11.2.6). Pigs were well-represented skeletally, while there was a distinct paucity of axial elements for deer and bovids, suggesting that the managed pigs were kept close to habitation, while deer and bovids were hunted at a considerable distance, enough to result in differential transportation of skeletal elements. Thus, these taxa were being treated and exploited differently at MB, with a physically closer relationship between dogs, pigs, and humans.

Even if the motivation behind the continuation of was risk management, it is reasonable to suggest this closer physical relationship with pigs and dogs could have encouraged a reconceptualisation of the relationship, and perhaps domesticated and wild animals became imbued with different meanings or significance. For instance, Amano et al. (2013, 329) identified both domestic and wild pigs at Nagsabaran, but there was a higher predominance of wild pigs and deer, suggesting that wild taxa continued to provide the main dietary component. Amano et al. (2013, 329) argued that the domestic pigs and dogs had gained a special significance; ethnographic accounts from the northern Philippines show that domestic dogs and pigs were consumed during ritual practices on specific occasions – a practice that continues in some regions today. In a similar fashion, it is likely that pigs, dogs, and hunted taxa at MB acquired new meanings beyond subsistence value.

11.5. How can the transition from 'foraging to farming' be characterised in Vietnam and Southeast Asia?

The continued importance of hunting at MB should come as no surprise. We know this is the case for many sites in SEA well into the 'Neolithic' period. As Oxenham (2015) has argued for Vietnam and others have argued for China (Flad et al. 2007; Cohen 2011), reliance on domesticated animals and plants does not start in earnest until the later Iron Age, when the majority of the dietary proportion was met by produce. As argued above, the transition appears to be patchy and cannot be viewed within a dualistic hunter-gathering versus agricultural lens. However, there are some intriguing general regional patterns that are perceivable.

11.5.1. General regional trends

The PCA results in Chapter nine (section 9.4.) show some interesting patterns:

1) PCA suggested that the main mammalian taxa found in SEA assemblages can be used to indicate and potentially 'predict' the subsistence base of a site (Table 11-1). Hunter-gatherer groups in SEA relied more heavily on forest and semi-arboreal taxa, such as monkeys, viverrids, and felids. Conversely, the relative proportion of pigs and dogs was a useful indicator of agricultural sites, while bovids and deer were not useful in separating between subsistence groups.

Sites that clearly portray hunter-gatherer subsistence include: Niah cave (Lobang Hangus and West Mouth), Lang Spean, Braholo Cave, Hang Boi, Lang Trang, Dingsishan, and CCN (Table 11-1). For Niah cave in Borneo, Piper and Rabett (2012) argued there was a transition to hunting arboreal taxa, potentially reflecting a combination of rainforest closure and the development of projectile technology. This is reflected in the PCA results that particularly portray Lobang Hangus being heavily dominated by monkeys and viverrids (section 9.4.1., Figure 9-6). Interestingly, Braholo Cave in Indonesia also portrays this transition from hunting bovids and cervids to arboreal taxa (especially monkeys) from the Late Pleistocene to Terminal Pleistocene/Early Holocene (Amano et al. 2015). This can be perceived in Figure 9-6 (section 9.4.1.) as the stratigraphic layers of Braholo Cave were separated, and Layers 1 and 2 particularly show a transition to

Table 11-1 Summary of sites that are clearly hunter-gatherer or agricultural/domestic subsistence economies, and interesting outliers as indicated by the PCA results in Chapter nine.

Economy	Location	Site
Hunter-gatherer	Borneo, Malaysia	Niah cave sites
	Cambodia	Lang Spean
	Indonesia	Braholo Cave
	Vietnam	Hang Boi
		Lang Trang
		CCN
	China	Dingsishan
Agricultural / domestic	China	Most Mid–Holocene sites
	Wei River, China	Wayaogou
	Henan, China	Xipo
	Vietnam	An Son
		Rach Nui
		MB
	Indonesia	Pacung and Sembiran
	Philippines	Nagsabaran
	Thailand	Ban Non Wat
		Ban Lum Khao
		Ban Chiang
		Non Nok Tha
	Cambodia	Phum Snay
Interesting outliers	Thailand	Khok Phanom Di (monkeys, civets)
	South China	Dingsishan (deer)
	Wei River, China	Wayaogou (pigs)

arboreal taxa.[6] By contrast, the MSEA sites tend to concentrate more on large mammalian game (especially bovids and deer), and this is particularly the case for Dingsishan, Lang Spean, and CCN. The dominance of large grazing herbivores from sites in north MSEA and south China during the Terminal Pleistocene and Early Holocene suggests a landscape of grasslands and woodlands rich in freshwater resources (also see section 11.1.1.).

Sites that are clearly reflective of agricultural/domestic economies or influence include: Wayaogou, Xipo, most of the Mid Holocene Chinese sites (that were classified as ‘unknown’), An Son, Rach Nui, Pacung and Sembiran, Nagsabaran, Ban Non Wat, Ban Lum Khao, Ban Chiang, Non Nok Tha, Phum Snay, and MB (Table 11-1). The relative abundance of pigs and dogs are the main components influencing this grouping.

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[6] The dates according to Amano et al. (2015, 6–7) are as follows: Layer 1 is Early Holocene, Layer 2 is 13,765 ± 143 to 14,014 ±202 cal. BP, Layer 3 is 18,734 ±153 cal. BP, Layer 4 is 25,798 ±536 cal. BP.

This is in line with supporting archaeological evidence (such as post holes, structures, and archaeobotany) which indicated these sites are sedentary communities (Higham and Kijngam 1979; Higham and Thosarat 2004a; Ma 2005; O'Reilly et al. 2006; Oxenham and Matsumura 2011; Wang 2011; Piper et al. 2012; Amano et al. 2013; Higham et al. 2014; Higham 2015; Oxenham et al. 2015; Fenner et al. 2017). Some of these sites also have relatively high proportions of bovids and deer (such as Ban Non Wat), and this suggests that comparing the relative proportions of bovids and deer versus pigs and dogs is not a useful method in separating out hunter-gatherer versus agricultural economies (Figure 9-7). This is probably because deer and wild bovids continue to be hunted well beyond the introduction of domesticates into MSEA.

2) PCA also highlighted outliers, revealing differences between localised environments and/or group/individual choice on subsistence at particular sites (Table 11-1, Figures 9-6 and 9-7). These sites are also potentially reflective of a transitional faunal assemblage. For instance, Dingsishan (Early Holocene, South China), Lobang Hangus (Terminal Pleistocene, Niah Cave), and Wayogou (Mid–Late Holocene Yellow River China) were all outliers because their assemblages were characterised by high percentages of deer (Dingsishan), monkeys (Lobang Hangus, as was also argued by Piper and Rabett 2009), and domesticated pigs (Wayogou).

Khok Phanom Di (KPD) was an outlier of a different kind; it was the only later Holocene site that distinctly fell into the 'hunter-gatherer/Late Pleistocene/Early Holocene' group. The PCA results showed a subsistence signature very typical of hunter-gatherer sites (high proportion of monkeys and viverrids) – despite the presence of dogs in the upper layers. This strengthens Higham and Thorsarat's (2004b) idea that KPD may have been a hunter-gatherer community that interacted with agricultural groups in the surrounding neighbourhood. For future research, it is possible that if the assemblage of KPD was separated into early and later faunal components, the PCA may have separated the early phase into the hunter-gatherer group and the later phase into the Mid Holocene group. In the analysis, the stratigraphic layers of KPD were combined together as it proved to be too subjective to distinguish between 'hunter-gatherer' and 'domestic' layers. This is similarly the case for the Early Holocene site Dingsishan in Southern China, which was an outlier due to the extremely high proportion of deer. Interestingly, dog was also identified in the upper layers,[7] and it is possible this reflects a later transition or adoption of domestic dog. Presently the dating of Dingsishan is ambiguous and it would be an interesting development to test whether the dates for the dog at Dingsishan are Mid Holocene compared to the Early Holocene layers.

11.5.2. Permeable boundaries and niche construction theory

The concept of niche-construction theory (NCT), is a useful framework for considering how we might characterise the transition of 'foraging to farming' in SEA, because it allows for permeability and deviance from overarching narratives and encourages questions of group and/or individual choice to be considered (see Chapter 4, section 4.4.). As detailed in Chapter four, NCT theorises that organism, environment, and genes all actively contribute towards shaping evolution (Lewontin 1982; 1983; Odling-Smee et al. 2003; Laland and Brown 2006; Laland and O'Brien 2010; O'Brien and Laland 2012). This allows broad processes like agriculture and domestication to be investigated within the context of human/animal agency and interaction with the environment. With NCT framework in mind, this thesis supports the notion that hunter-gatherer and agricultural sites are not in opposition. Rather, they can be understood as different modes of engagement with the environment, as opposed to opposite ends on a scale, as this inherently implies the idea of 'progress' and a promised trajectory. Even with the introduction of domesticates, at many locations around SEA there appears to be a coexistence of 'agricultural' and 'hunter-gatherer' communities, such as the 'mosaic' communities at MB or Khok Phanom Di. In SEA there are still marginal communities that live a largely 'hunter-gatherer' subsistence way of life (Sellato 1994; Hunt and Rabett 2014). This portrays the permeability between the lifeways of 'agriculture' and 'hunter-gatherer', both presently and in the past.

As detailed above, the PCA analysis was particularly useful at portraying regional trends but also highlighting outliers, and these outliers are arguably just as interesting archaeologically as the 'overall narrative'. In SEA, domestication cannot be characterised as a change from coexistence to domination of animals. Rather, the domestication of animals is more characteristic of a subtle shift in the relationships and interactions that took place over hundreds if not thousands of years. Indeed, Arbuckle (2014) has recently made a similar argument for southwest Asia (Near Eastern Fertile Crescent) where he suggests domestication of sheep, goats, cattle and pigs had a long gestation period and was

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[7] Lu (2010) does not specify the methodology behind identifying these specimens, so one can only assume this is accurate.

characterised by regional and local variation. Similarly, Fuller et al. (2011) argue against the single core hypothesis plant cultivation, and contend the data suggests an extended period of ‘pre-domestication cultivation’ of at least a millennium and slow evolution of domestic adaptations. Further, as shown in Chapter three China displays great diversity in the timing and nature of the development of agriculture and domestication. This is particularly visible in the difference between the relatively early adoption of domesticated pigs in Yellow River region compared to the prolonged reliance on hunting and fishing in the Yangtze region (Yuan et al. 2008; Zhang and Hung 2010; 2012). Although the precise timing of domesticated introductions in China remains poorly resolved, like the rest of Asia the data suggests a patchy adoption of domesticates and considerable regional and local variability (see section 3.5.3.). This seems to be particularly the case for the south, where hunter-gatherer economies continue alongside rice agriculture (Yuan et al. 2008; Zhang and Hung 2010; 2012). This variability in response across Asia suggests that local environments and human response and decision making was always an important aspect of the domestication story. Rather than humans always adjusting to adverse conditions, the variety in human-animal relationships during the Mid Holocene implies humans played an active role in shaping the surrounding environment. At both CCN and MB, hunting deer and fishing from marine and estuarine resources were important. However, the presence of domesticated dogs, the selective culling of early-domesticated pigs, and the probable cultivation of rice at MB signals a significant shift in focusing exploitation on particular species. This in turn gestures towards a transformation in human-animal-plant relationships, and this is a crucial point of difference between CCN and MB, and the Đa Bút and Phùng Nguyên periods.

Arguably, animals are never considered to be ‘just meat’; in both hunter-gatherer and agricultural contexts they carry meanings and values and are often seen as agentic, sentient entities (see Chapter four). This idea was described most famously by Levi-Strauss (1962, 89) who argued that “natural species are chosen [as totems] not because they are ‘good to eat’ but because they are ‘good to think’.” Levi-Strauss (1962, 89) argues that animals do not serve purely as symbols or for culinary purposes, but they form part of the structural ideology within society. The daily management and interaction with crops, pigs, and dogs at MB must have influenced and affected the social structure and ideology of the community. More specifically, the way animals and human-animal relationships were perceived between the CCN and MB communities must have changed, but how?

11.6. What can be inferred about human-animal relationships and the ontology of people in Cồn Cổ Ngựa and Mán Bạc? How can domestication be reframed into a less anthropocentric perspective?

This section seeks to explore how people interacted and engaged with their surroundings, especially with animals, drawing from themes presented above. As discussed in Chapter four, scholarship surrounding domestication within archaeology has been frequently characterised by pessimistic human-domination viewpoints, largely influenced by current concerns on the negative impacts humans are having on the environment (i.e. the Anthropocene and climate change). However, current trends in interspecies studies are part of a larger academic discourse distancing itself from anthropocentric perspectives, greatly influenced by theorists such as Latour (2005) and Haraway (2008b; 2016). This 'animal turn' emphasises species-specific characteristics, relationality, and co-creation. This thesis proposes that Haraway's (2008b) use of asymmetrical relationships and a relational approach to agency offer useful tools to conceptualise human-animal relationships and a less anthropocentric approach to domestication (see Chapter four).

As hypothesised in Chapter one (section 1.2.1.) and four (section 4.5.), since both CCN and MB are large burial sites, they have the potential to display something about the belief systems and ontology of the people. This thesis argues the faunal assemblages are not simply middens reflecting what people ate, rather they pose intriguing insights into human-animal interactions.

These concepts will be approached below with case studies attempting to shed light on agency of the animal. The first section queries how special deposits of animals at CCN and MB may illuminate rituals and the relationship between humans and animals (sections 11.6.1.–11.6.6.). The whale radius is discussed in detail, exploring ethnographies of whales in Vietnam in contemporary and historical contexts. These special animal deposits are investigated within the concept of liminality and how their stratigraphic positioning may reflect site use (11.6.5.). This is followed by a discussion on how the concept of landscape may have changed during the Mid–Late Holocene in SEA, a period of transitions in agriculture, domestication, and sedentism (11.6.7.). It is argued that both sites can be understood within this wider context of changing conceptions about the landscape and human-animal relations.

11.6.1. Ritual and special animal deposits

Attempting to determine ritual and belief systems in archaeology is often met with scepticism and has a reputation of involving a large amount of conjecture. Discussions on defining 'ritual' tend to be contrasted with 'functional'; a dualism that does not necessarily exist. Further, as Sykes (2014, 114) argues this difficulty is compounded by the fact that many societies regard ritual as integrated into daily life. Thus, ritual does not necessarily imply something that is only performed or engaged with occasionally or sporadically. Likewise, scholarship on ritual involving animals has too frequently concentrated on the dead animal rather than the lifetime of interaction (Sykes 2014, 114). However, investigation into the belief systems and ontologies of people is arguably an important and essential aspect of social science. For this project, the question of ritual and belief systems holds special significance because both CCN and MB are burial sites. This makes the suggestion that the faunal assemblages may shed light on ritual or ontological beliefs of the people more compelling.

Defining a 'special deposit' of faunal remains in archaeological sites is difficult, as distinguishing between 'rubbish' and 'ritual' is not only challenging but it is also often not possible to identify a clear-cut distinction between ritual and economic behaviour (Hamerow 2006, 2). In Hamerow's (2006, 3) study of special animal deposits in Anglo-Saxon settlements there were four broadly defined categories: complete inhumations, skulls or parts of skulls, articulated limbs or trunks, and disarticulated bone deposited en masse. These special deposits were often found placed in the postholes of buildings and were often in direct association with entrances and boundaries. Hamerow (2006, 9) argues that the special deposits were not only ritually treated but they "acted to reinforce the liminal, transitional nature of the locations where they were buried" (see section 11.6.6. below for more discussion on liminality).

Within the context of SEA there are increasing associations between special animal deposits and human remains from the Terminal Pleistocene onwards. At West Mouth (Niah Cave) a rhinoceros radius was used as a 'pillow' in a flexed human burial (Piper 2016, 26–7). Piper (2016) argues there is increasing evidence for rituals in association with animal remains during the Terminal Pleistocene. At Niah Cave the under-representation of pig and monkey mandibles, for no foreseeable taphonomic reason, suggested to Piper (2016) they may have been retained for trophies and/or ritual purposes, as is a common practice in ethnographic accounts. At Mid Holocene sites in SEA this pattern continues, as is particularly evident at Ban Non Wat where Higham and Wiriyaromp (2010a; 2010b) reported deposits of complete and partial pig skeletons within at least five human burials.

Both CCN and MB have several intriguing animal features akin to Hamerow's (2006) definitions of special deposits, and they have clearly been intentionally and carefully deposited. Clear examples of 'special' animal deposits include the burial of an elephant maxilla at MB in Layer 3 (spits 15-17, squares A-B1), and at CCN the large quantity of calcined deer antlers in Layer 3 (squares E6-7 near M133), and the whale radius in Layer 3 (square G5). However ambiguous these deposits at CCN and MB were, it is clear that the animals in these instances were understood as 'more than purely meat'.

11.6.2. Elephant maxilla at Mán Bạc

A complete and articulated male elephant maxilla was buried at MB in a layer slightly above most of the human burials (Chapter seven, Figure 7-23). Although there is no clear association with the human burials, the careful burial and placement of the maxilla in anatomical position suggests the deposit was intentional.

Fossil and archaeological remains of Asian elephants are very rare and tend to be isolated finds. In Peninsula Malaysia, Tshen (2013, 145) reported that most recorded elephant remains were encountered when significant alluvial modifications had occurred (such as mining), but provenanced finds in paleontological or archaeological sites are rare. Fragments of tusks were reported at Lang Rongrien in Thailand, but were not collected from the site for analysis (Mudar and Anderson 2007, 314). In Vietnam, one tooth fragment was found in the Upper Pleistocene site Ma U'Oi cave, and Bacon et al. (2004, 311) list four other sites of similar age where isolate finds have been recorded (Tham Kuyen, Tham Om, Hang Hum, Lang Trang). Given the isolated nature of these deposits and lack of any associated evidence of human activity, Tshen (2013, 146) argues the presence of elephant remains in cave deposits are probably the result of taphonomic agents, such as, the movement of underground water, large scavengers (i.e. porcupines), and carnivores (i.e. felids).

At later Holocene sites, there are few reports of elephant remains but once again they appear to be isolated finds. At An Son, a site roughly contemporaneous with MB, an artefact made from elephant ivory was excavated (Bellwood et al. 2011). Similarly, at the Iron Age site of Prei Khmeng in Cambodia an elephant molar was excavated in the midden area of the site, in association with sherds of pottery, charcoal, and other debris (Dougald O'Reilly 2017, pers. comm.; Figure 11-5). However, O'Reilly (2017, pers.

comm.) believes this fragment was clearly not an 'intentional burial', and is classified more correctly as an isolated find within a midden context. The deliberate burial of an elephant maxilla at an archaeological site is therefore very rare, and the MB elephant is the earliest recorded example for Vietnam and potentially SEA.

Figure 11-5 Elephant molar excavated from Prei Khmeng, photograph courtesy of Dougald O'Reilly.

11.6.3. Large felids at Cồn Cổ Ngựa

At CCN there was at least two animal deposits that can be classified as 'special': the calcined deer antlers (section 11.6.4.) and the whale radius (section 11.6.5.). Before these are detailed it is worth noting the presence of large felids, as they also offer an insight into engagement with animals that certainly would have been classified as unusual and probably dangerous.

There was an MNI of 3 felids at CCN, this included: a tiger left and right mandible without teeth (Layer 3 spit 1), the left mandible and upper dentition (including canines) of a medium-sized felid (either clouded leopard, marbled cat, or Asiatic golden cat, burial M22/23), and another left mandible of a medium-sized felid (Layer 3 spit 1 Feature 7, see Chapter six for photos). As mentioned in section 6.4.8., body parts of tigers and large felids are commonly used as ornaments in SEA, particularly the skins and teeth (Piper et al. 2007; 2008). No cutmarks or damage was perceivable on the medium felid elements, but the tiger mandible displayed two cutmarks on the lateral surface, suggestive of skinning (Figure 6-11). The teeth were also all removed (or at least not present in the assemblage), potentially indicating they were repurposed.

Tiger remains have been recorded in low NISP values in other sites in SEA and China (Table 11-2). Felidae spp. are more common in assemblages, especially at: KPD (37), and Niah (Lobang Hangus, 45). Felids are particularly associated with sites based on hunter-gatherer economies (Table 11-2), which was also suggested by the PCA results above. However, isolated finds occasionally appear in agricultural-based sites. In all cases, tiger remains are rare and have clearly been treated as a 'special' object. At NNT, Higham (1975b) briefly mentions two tiger canines that clearly display holes perforated through the root (Figure 11-6), indicating they were strung and perhaps worn. In Borneo, early travellers noted the use of tiger canines as totemic objects by several groups (Piper et al. 2007). It is possible the missing tiger teeth were used in a similar fashion at CCN. No evidence for perforated holes or usewear could be discerned on the medium-felid canines (Figure 6-21). However, contextually they were found within burial M22/23, with a strange assortment of fauna including a turtle (Geoemydidae) carapace and plastron (CCN-2255–2258), and an anthropogenically modified pig (*Sus* cf. *scrofa*) canine with a perforated round notch on the tip and a triangular notch towards the root, and transverse abrasive marks on the lingual surface (see Figure 6-28). Thus, canines of wild boars were clearly modified and repurposed at CCN, the tiger teeth may have been given similar treatment. Both the tiger's teeth and the skin were undoubtable valued items repurposed but unfortunately, for archaeologists, seemingly not discarded at the site.

Table 11-2 List of recorded NISP values for tigers and felid skeletal remains across SEA.

Site	Tiger	Felid	Reference
Ban Lum Khao	present		(Higham 2004a, 160)
Khok Phanom Di	1	37	(Grant and Higham 1991)
Non Nok Tha	2		(Higham 1975b, 121)
Ban Non Wat	9		(Kijngam 2010, 189)
Lang Trang	6	15	(Vu The Long et al. 1996)
Niah (West Mouth)	1	13	(Piper et al. 2008b, 92)
Niah (Lobang Hangus		45	(Piper et al. 2008b, 93)
Braholo Cave	5		(Amano et al. 2015, 6–7)
Gua Hunung	2		(Conrad 2015)
Kangjia	1		(Flad et al. 2007, Table 1)
Wayaogou	1	15	(Wang 2011, 93)

Figure 11-6 Tiger canines from NNT with hole perforated in the root (4F 6 Middle Period 5), image from Higham (1975, plate 38, 187).

11.6.4. Calcined antler deposit at Cồn Cổ Ngựa

In Layer 3 above burial M133 (squares E6–7) a large quantity (1584 TNF, 1.5kgs) of calcined bone fragments were excavated. The majority of the fragments that could be identified were deer antlers, of at least two species (*Muntiacus* spp. and *Cervus* spp.). Some of the calcined antlers had the pedicle attached to the burr, which shows the antler was deliberately separated from the skull rather than naturally shed (see Chapter six, section 6.4.9.).

The large quantity of calcined antlers indicates they would have burned for a considerable length of time at a high temperature. This raises the question of whether the antlers at CCN were deliberately collected as fuel for fire. Bridault et al. (2009, 140) posed this question in their study of antler exploitation at a Mesolithic site in France, which also contained large deposits of calcined red deer antlers. They postulated that antlers may have been preferentially collected soon after they were shed, at the end of winter or in spring, when the antler is optimally fresh (Bridault et al. 2009, 151). After the antlers were collected they were knapped and worked, and unused parts of the antlers were discarded and burnt, before being deposited in pits (Bridault et al. 2009, 151–2). Their experiment showed deer antlers burn twice as long as vegetal wood, which gives it inherent quality as fuel, though the authors argue osseous fuel appears to be the second intention and that animals were primarily targeted for meat consumption (Bridault et al. 2009, 152). This is argued on the basis of a range of different skeletal material being present in the hearths.

The calcined osseous material at CCN was clearly dominated by deer antlers, some of which had been intentionally separated from the skull. This is in addition to the exploitation of deer for their meat, as evidenced by postcranial elements with butchery marks. Thus, deer were clearly being exploited for different parts of their body for different purposes. Additionally, the placement of the calcined antlers towards the base of the stratigraphically potentially indicates early site use (see section 11.6.4.). The deposition of such a quantity of calcined antlers in one place suggests a single event, or interrelated events, that could have been associated with burial rituals taking place at the site.

11.6.5. Whales radius from Cồn Cổ Ngựa and ethnologies of whales in Vietnam

Towards the southern edge of the excavation square at CCN the radius of a whale was found buried in an upright position (Figure 11-7). The radius was dug into sterile soil and bolstered by large rocks to keep the bone in a vertical position (see Figure 11-7 B). The effort spent to support the radius in an upright position suggests this was an above-ground, visible feature.

Surrounding the circumference of the bone are numerous cutmarks, indicating the radius may have been butchered and/or defleshed. This suggests the radius was found in some state of semi-decay and must have been transported from the coastline. There is no evidence that whaling was practiced at such an early time period, rather, it is more likely the carcass washed upon the nearby ocean shore and was carried back to the site. Nonetheless, carrying the 15 kg, 90 cm bone back to the site would have required considerable effort. Note, the radius probably would have been considerably larger and heavier originally, as the end that protruded above the ground has suffered from some decay and damage.

The intentional placing of the radius longitudinally into the ground in an upright position is an interesting, albeit ambiguous statement. There were no other marine mammals recorded in the assemblage, adding to its distinctiveness (see Table 6-12 for species list). Since there are so many burials at CCN it was difficult to assess whether there was a connection with one individual person, however, this does not appear to have been the case. Does this radius represent a burial marker for the cemetery? Is it some

Figure 11-7 Whale radius excavated from CCN, layer 3 G5. A: To the right of the photograph is a human burial. In the background is a 1m scale showing the proportion of the whale radius and human remains. B: radius extending into sterile layer and being bolstered vertically by surrounding rocks. Photographs courtesy of Marc Oxenham.

kind of boundary marker between places? Did the radius have a more functional role as a foundation for some kind of structure? Does the whale itself hold special significance to the person/people who placed it in the ground?

The radial length of at least 90 cm (excluding epiphyses) suggests the CCN cetacean was one of the larger whale species. For instance, Flower (1868, 359) measured the dimensions of six Sperm whale (*Physeter macrocephalus*) radii, and the length was between approximately 30–40 cm. Whereas, Omura et al. (1970, 16) report the length of a Blue whale (*Balaenoptera musculus*) radius without the epiphyses was 82.6 cm, or 102 cm with the inferior epiphysis, and these measurements are closer to the size of the CCN whale radius.

In many societies, marine mammals are revered and transfigurational beings, traversing the edges of normality for mammals in their size and need for submersion within water (McNiven 2010; Steinwand 2011; Adamson 2012). Hunting of marine mammals is often imbued with ritual performances, reflecting the ontological view of the sea as a sentient landscape (McNiven 2010, 219). McNiven (2010, 221–2) details dugong hunting rituals in the Torres Strait that involve charms of dugong body parts to gain access to the sensory and cognitive abilities of dugongs. Both the brain and trachea are cooked and eaten so the hunters can ‘see’ or ‘know’ where the dugongs are, establishing a connection and directing hunters and dugongs towards each other (McNiven 2010, 221–2). In this way, personhood and identity are blurred into a liminal state between human and dugong.

Within Vietnam there is a long and complex history of whale worshipping that continues to thrive within modern practice. Whales are called Cá Ông or ‘Lord Fish’ (literally translated to ‘Sir Fish’ or ‘Grandfather Fish’; Lantz 2009; Suzuki 2015). Suzuki (2015) has traced Cá Ông worship back to at least the Nguyễn dynasty (starting 1802 AD) with possible links to the preceding Cham culture. Lantz (2009) notes that fishermen believe the tradition stems from Cham culture and possibly early Khmer cultures. In a country that has often placed heavy control over religious practice, whale shrines are a place of tension between state control and community and individual life. Suzuki (2015, 14) points out this is true of both the current communist regime and the Nguyễn dynasty.

There are numerous stories of fishermen being shipwrecked and saved by a whale within Vietnam (Lantz 2009; Suzuki 2015; Vietnam Breaking News 2015). Fishermen recognise whales washed up on the shore as the animal who rescued them after being shipwrecked (Lantz 2009). Stranded whale carcasses are brought ashore for a funeral, and afterwards are either buried on the beach or in a special whale graveyard termed Lang Ông (Lantz 2009; Suzuki 2015). After 3 to 5 years when the body has decomposed it is enshrined, in many cases in a special building. Some scholars claim Cá Ông worship represents a fear of the ocean, but Suzuki (2015) argues it is much more complex than that. The name 'Lord Fish' implies a superior creature and the relationship is more akin to a guardian. This sense of protection extends beyond fishermen because the practice of whale worshipping is widespread throughout Vietnam.

The primary concentration of whale shrines is in central and southern Vietnam (Suzuki 2015, 4). One such example of a Lang Ông is at Đồng Hới along the Quảng Bình coastline in Central Vietnam (Figure 11-8). A Vietnamese article (Vietnam Breaking News 2015) cites the most recent whale funeral was May of 2014 when a 150 kg whale washed up on the coast. According to the article, the cemetery holds 17 whales, with each tomb given incense (similar to the practice for human inhumation, Figure 11-8 B), and annual anniversaries mark the death of each whale. According to the keeper of the cemetery, Nguyen Van Bieu, a special temple was also built to worship 'knight' whales. This temple contains two partially complete whale skeletons; one of a female whale who died in 1809, and a male who died in 1907.

During interviews Lantz (2009, 31–2) found that fishermen extend their respect to all cetaceans and will bury with ceremony any that are washed ashore. However, worship is restricted to two species of cetacean the fishermen term Chuông (Sperm whale) and Ngọc (probably the Irrawaddy dolphin, Orcaella brevirostris, Lantz 2009, 32).

One of the commonalities emphasised by fishermen is the relatedness between whales and humans; "The most important thing about Cá Ông, the fishermen say, is his eyes. The eyes reflect the soul, and whoever has looked into the eyes of Cá Ông know that it is the same thing as looking into human eyes" (Lantz 2009, 38). The fishermen can also tell the difference between male and female whales, and female whales are given a special temple (Lantz 2009, 38). This shows how Vietnamese fishermen not only revere Cá Ông, they also treat each whale as an individual with shared commonalities to humans. According to Lantz (2009, 57) whale worship is closely connected to ancestor worship. It is believed that Cá Ông helps bring souls lost at sea home so they can find peace.

Although I am not suggesting there is a direct relationship between current and historical practice of whale worship in Vietnam and the Mid Holocene site of CCN, it is worth noting commonalities. A complex and ambiguous relationship has existed between whales and people in Vietnam for potentially thousands of years. The burial of the radius within a cemetery again suggests a connection to ancestors or genealogy. Such a large bone, let alone animal, must have made an impression. During this period rhinoceroses and elephants would have been more commonly found within Vietnam. Yet, the sight

Figure 11-8 A: An example of a Lang Ông at Đồng Hới in the central coastline of Vietnam. B: close up of whale imagery and incense. Photographs courtesy of Elle Grono, taken on 10th May 2015.

of a whale carcass or even part of a whale must have been an impressive and unusual phenomenon. The presence of butchery marks may indicate consumption of whale flesh, or removal of decomposing flesh.

Although the whale radius, tiger mandible, and calcined deer antlers do not necessarily have a direct relationship with each other, they certainly attest to the presence of multiple rites within the burial ground as a whole. CCN was a special location imbued with meaning, and this has been emphasised through the particular treatment and deposition of select animal remains. This is important as it not only suggests the significance of place, or burial rites, but also a meaningful relationship between humans and these animals.

11.6.6. Liminality and ritual deposits

The very nature of CCN and MB being places to bury the dead suggests these sites would have carried meaning, as highlighted through special animal deposits. In Hamerow's (2006, 9) study of special deposits in Anglo-Saxon settlements, there was a particular association with entrances to buildings and boundaries – reinforcing the liminal, transitional nature of the location. Further, deposits were also frequently found placed in foundation pits, especially in the Iron Age in Roman Britain or the North Sea Zone (Hamerow 2006, 12, 26); in Anglo-Saxon Britain termination deposits were more common (Hamerow 2006, 28).

In order to determine whether the whale radius or calcined deer antlers at CCN were strategically positioned at an entrance or other significant location, a wider excavation pit would need to be dug. However, the whale bone was clearly dug into sterile soil, potentially indicating initial site usage. The calcined antlers were deposited stratigraphically just above one of the lowest burials (M133), which was also dug into sterile soil.[8] Temporally speaking it is possible both of these deposits relate to initial and/or early site use, and may represent a type of cleansing, or staking a claim to the land. As mentioned above, marine mammals especially whales are often theorised as being transfigurational or liminal beings (McNiven 2010; Steinwand 2011; Adamson 2012). As Steinwand (2011, 184) summarises, they are compelling because as mammals they are closely related and share many similar characteristics to us, yet their size and habitat is foreign. Though there were cutmarks all over the CCN whale radius this was not an animal killed by people,

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[8] It is also possible that the whale radius and calcined deer antlers were excavated through pre-existing layers, thereby not necessarily reflecting early site use. Unfortunately, both features were found towards the end of the excavation when time was limited and records of whether the deposits contained material from a later phase, or whether there was a cut through the deposit do not exist.

rather the radius is more akin to a 'manuport'. An object transported from the coastline and repurposed to have another meaning within a burial site.

Likewise, the elephant maxilla at MB is difficult to clearly associate with a human burial. Spatially, the maxilla was towards the stratigraphic base of the faunal deposit / midden (see Figure 11-2). It is worth noting that there are also four rhinoceros elements towards the base of Layer 3: one rib fragment from the 2007 excavation with differential weathering (MBANU-1620, spits 14-15), and from the 2004–05 excavations two rib fragments (MBANU-315, MBANU-1297 spits 15 and 13) and one humerus (MBANU-1298, spits 13). Though the majority of human burials are stratigraphically lower, there are also three human burials within the same layer as the elephant maxilla. It is interesting that the base of Layer 3 appears to be a type of transitional zone between the lower human burials and the faunal midden above, perhaps signalling the termination of the burials.

11.6.7. Environmental ontology: changing conceptions of the landscape

This project has specifically compared CCN and MB in light of major societal changes that took places during the Mid–Late Holocene in SEA, especially domestication and sedentism. It is argued in this thesis that both sites can be understood with respect to changing conceptions of the landscape, or environmental ontology. The reconceptualisation of the landscape during the Đa Bút period, and the introduction of domesticated animals during the Phùng Nguyên period can be seen as types of niche construction.

CCN is notable for providing the earliest evidence in Vietnam and MSEA for a large burial site/cemetery, and there are at least 252 individuals buried in flexed and squatting positions (Chapter two, section 2.3.7.). As many scholars have argued, the appearance of such a large cemetery surely indicates significant social and ideological changes have occurred from the preceding Hoabinhian period (Bui Vinh 1991; Nguyen Viet 2005; Oxenham 2006). Further, Oxenham et al. (2001) noted the surprisingly high number of extreme human skeletal trauma at CCN, and many of these injuries had healed. Given the lack of evidence for warfare during this period, or foreseeable methods of injury on the landscape, Oxenham et al. (2001) suggested the injuries could have related to hunting large and dangerous animals (see also Oxenham et al. in press). The faunal analysis in this thesis demonstrated a dominance of large water buffalo and the presence of several large felids, adding support to this theory.

The burial of 252 people at CCN indicates this was a meaningful place that people visited periodically over a prolonged time. Similarly, Zhang and Hung (2012) argue the contemporary Dingsishan sites in southern China were continually revisited and occupied over a long period of time. Dingsishan itself contained 149 human burials in flexed, squatting, and dismembered positions, and the site was divided into separate living areas with clear distinctions between the burials, middens, and 'living areas' (Zhang and Hung 2012, 18–9). While at the Baozitou shell midden, evidence for the manufacturing of pottery was reported (Zhang and Hung 2012, 19). These factors suggest an increased degree of sedentism in hunter-gatherer communities in northern Vietnam and southern China during the Early–Mid Holocene. This also indicates a change in the way the environment is perceived, as the deliberate burial of so many individuals implies a statement of land ownership and belonging to a landscape.

The increased evidence for ritual in association with animal deposits from the Terminal Pleistocene onwards indicates a significant change in human perception of the environment and human-animal relationships. Piper (2016, 36) argued this transition potentially relates to ideological behaviour and an increasing emphasis on social identity. Early sedentary/semi-sedentary sites appear to portray an increased sense of identity and ownership of the land throughout SEA and China. Within China, Cohen (2011) argues rather than a sudden transition to agriculture, domestication slowly emerged over the course of thousands of years after sedentism and socio-ideological changes had already begun. This process was a result of interaction and social exchange between regions. Thus, throughout southern China and northern Vietnam numerous socio-ideological changes contributed to the changing perception of the environment and how humans relate to it, and large burials sites such as Dingsishan and CCN became the physical manifestations of this.

Dated to a couple of thousand years later, MB attests to some major changes within human-animal relationships and materiality. In a comprehensive study Oxenham et al. (2011) portray a population of humans within a transitional period in SEA archaeology. This two-layer/farming dispersal hypothesis has stipulated that the introduction of domesticated rice, pigs, and dogs into northern Vietnam was probably at least partially stimulated by a migration of people from southern China (Bellwood and Oxenham 2008; Matsumura et al. 2008; 2011), based upon similarities in material culture, skeletal morphology, and timing of settlements.

Phùng Nguyên sites present a significant change in materiality from earlier periods. At MB, there is evidence of housing based on the presence of large postholes and compacted ‘floors’, indicating the presence of structures. Further, as Tilley and Oxenham (2016) have argued the extremely disabled individual (M9) would have needed elevation from the ground and shelter to survive into his teenage years. The abundance of managed pigs also suggests they would have been kept close to habitation and potentially tethered or in sties to keep them from destroying crops, escaping, or as safety from predators. The increasing imposition on the local environment suggests a permanence, a greater sense of ownership on the landscape. As argued above (11.4.2.), the continued interest in hunting despite the presence of domestic dogs and pigs would have encouraged a reconceptualisation of the meaning and significance of both wild and domestic animals. The act of hunting could have gained performative qualities, akin to Hamilakis’ (2003) arguments for Mycenaean Greece. Thus, the burial of the elephant maxilla at MB gains special significance within a society that relies heavily on domestic pigs and rice within their diet. It also offers an interesting parallel with the whale radius at CCN. This deliberate burial of a large mammal once again highlights an intriguing and ambiguous relationship with megafauna continued from the Đa Bút to the Phùng Nguyên.

The reasons and imbedded meaning behind the buried elephant maxilla and whale radius no doubt differ, as the people from CCN and MB must have interacted differently with animals and the surrounding environment. At MB, there is a clearer imposition on the environment and a reliance on pigs, compared to the more heterogeneous diet of the people from CCN. Yet, at both sites there is a perceivable change from the preceding period in the engagement with the landscape and animals that I argue relates to a reconceptualising of this relationship. Both ways of renegotiating human-animal relationships involved actively shaping the land and the animals.

11.7. Summary of section: Cồn Cổ Ngựa and Mán Bạc: asymmetricality and fluidity

At both CCN and MB the roles of animals are fluid and ambiguous. At CCN, the increase in sedentism during the Early–Mid Holocene, construction of large cemeteries, and hunting of large ‘dangerous’ fauna could be seen as new types of niche construction. Akin to the situation in China, this implies new conceptions of territoriality, land ownership, and the environment (Cohen 2011). The surprisingly high and extreme cases of human skeletal trauma at CCN (Oxenham et al. 2001) are also indications of new ways of negotiating and performing the hunting of large and dangerous animals.

At MB, the continued reliance on wild taxa and fascination with large species is indicative of the variable and patchwork adoption of domesticated animals in Vietnam during this period. It also suggests that the idea of hunting embodied new meanings. The 'domesticated' pigs and dogs at MB do not fit into the role of passive or dominated animals. Likewise, the fascination with large and/or dangerous animals at both MB and CCN does not neatly fit into concepts of 'controlling' the wild. The problem with both of these dualities is that they deny agency to animals. Within this framework, domesticated animals are denied personhood and they cannot be somebody. As Poole (2014) argues, perceptions of animals in the past were probably always fluid, because their ability to react and affect creates a dynamic and ambiguous relationship. This is why the notion of asymmetric relationships is so useful to zooarchaeology. It is particularly pertinent with respect to the special animal deposits at CCN and MB, they show a continued interest in megafauna, however ambiguous. Arguably, there are clear transitions between CCN and MB in terms of faunal composition which portrays a clear change in human-animal relationships. However, this change is not neatly summarised by a transition from hunting to domestication, or from trust to domination of animals.

11.8. Summary of Chapter eleven

This chapter has addressed each of the aims, objectives and questions initiated in Chapter one. Paleoenvironmental conditions during the time of CCN and MB were shown to be favourable to a diverse range of taxa. Through a range of different methodologies, it was determined that CCN represents a group of people engaged in hunter-gatherer activities, while MB represents an early agricultural community with domesticated dogs and pigs. Nonetheless, these boundaries are blurred and multifaceted, reflecting the complexity of the process throughout the rest of SEA.

Aside from traditional zooarchaeological methods of taphonomic and taxonomic analysis, this project has aimed to stimulate more theoretical discussion in SEA archaeology. Through the lens of NCT and an emphasis on agency of the nonhuman other this thesis hopes to provide an interspecies history that is less anthropocentric. As our concerns on the Anthropocene deepen, it is necessary to return to regional microhistories and allow for indigenous ethnologies to portray different ontological approaches to our environment.

CHAPTER TWELVE

CONCLUSION

12.1. Aims and objectives of thesis

COMPARING the faunal assemblages of CCN and MB and linking them to wider patterns has enabled a detailed analysis of the period of transition from hunter-gathering to domestication in SEA. In northern Vietnam, the farming dispersal/two layer hypotheses are paramount themes within research, owing to the geographic proximity to southern China. Zooarchaeology was yet to be used to specifically test these hypotheses – despite the huge potential of applicability.

For this thesis, taphonomic, taxonomic, and radiocarbon analyses of CCN and MB were undertaken. Further, biometric and faunal composition data were collected and compared in a meta-analysis of sites throughout Asia. The specific aims, objectives, and questions of this project were outlined in Chapter one (section 1.2.) and discussed in detail in Chapter eleven. The ultimate goal was to determine whether and how human behavioural practices changed and developed during the Mid Holocene of Vietnam. In this concluding chapter, the main archaeological and theoretical contributions to zooarchaeology in SEA are summarised, followed by a brief discussion on future perspectives and directions.

12.2. Archaeological contributions

The taphonomic, taxonomic and radiocarbon results were outlined and discussed in detail in the previous chapter. However, this project can be summarised into three main contributions that have wider implications to archaeological research.

1. TRANSITION TO DOMESTICATION

This thesis established that CCN had a hunter-gatherer subsistence economy and that MB had domesticated dogs and pigs. Thus, zooarchaeology was a powerful tool in distinguishing between different lifeways and economies. Nonetheless, it was emphasised that this transition from ‘hunting to farming’ was by no means clear-cut. MB still had a strong emphasis on hunting wild taxa and fishing. These permeable boundaries are also perceivable in other SEA sites of contemporary age to MB. The transition to domestication and agriculture in SEA can be characterised as patchy and drawn-out.

Additionally, major changes from the preceding Hoabinhian period to CCN suggest socio-ideological changes were occurring during the Đa Bút period. Likewise, there were substantial changes between the Đa Bút and Phùng Nguyên periods, showing an increasing reliance on certain taxa (specifically managed pigs) and the presence of domestic dogs. It was argued that this could be understood within the context of changing conceptions of the landscape and human-animal relationships, which saw an an increase in niche construction and a greater sense of land ownership.

2. Securing radiocarbon chronologies

Radiocarbon dating largely confirmed the proposed chronology of the Đa Bút and Phùng Nguyên periods. The ^{14}C dates for CCN are the first secure dates for the Đa Bút period, they suggest the site was used from around 6,600–6,200 cal. BP. Since these dates were retrieved from enamel they represent minimum dates, which suggests the Đa Bút period may have started slightly earlier than Nguyen Viet (2005) and Bui Vinh (1991) proposed. This provides a useful platform upon which to build concrete and precise chronologies.

With regards to MB, the ^{14}C dates were in line with previously published dates on charcoal (Dung et al. 2011, 169; Matsumura and Oxenham 2011, 4). This suggests that domesticated dogs were introduced into Vietnam from at least 3,693–3,573 cal. BP and pigs from 3,836–3,694 cal. BP. Unfortunately, since all of the dated material was from the same layer it is difficult to determine the length of occupation of MB, an unanswered query is how exactly the 'burial' and 'occupation' layers relate to one another.

Nonetheless, the ^{14}C dates were instrumental in setting a baseline of dates to compare other early domesticated animals in SEA. The dates for pigs and dogs are comparable to An Son in southern Vietnam and Khok Phanom Di, Ban Lum Khao, Ban Non Wat, Ban Chiang in Thailand (section 11.4.1.). This implies the initial introduction of domesticated aniamls in MSEA from southern China occurred around the same time at c. 4,000 cal. BP. As mentioned in Chapter ten, the current dates for the southern Vietnamese sites (An Son, Rach Nui, and Loc Giang) are slightly older than MB. This is odd as presumably since Neolithic populations and domesticated animals spread from China into MSEA, the northern Vietnamese sites should be older than the southern sites. Resolving the chronology of the northern and southern Neolithic sites in Vietnam needs to be addressed in future research.

3. Regional faunal patterns

PCA results indicated this type of methodology in conjunction with meta-analysis of faunal compositions has great potential in showing regional patterns. This thesis found a strong correlation between hunter-gatherer/Late-Pleistocene/Early Holocene sites and a greater abundance of arboreal taxa (such as monkeys, felids, and viverrids). Conversely, agricultural/later Holocene sites produced a strong correlation with dogs and pigs. In other words, PCA was able to 'predict' the subsistence base of sites based on a comparison of faunal composition.

The transition from hunting large bovids and deer to arboreal taxa was also evident in ISEA sites during the Terminal Pleistocene/Early Holocene boundary. Whereas, MSEA seems to continue with a heavy focus on large mammals during the Early and Mid Holocene, this is particularly evident in CCN and Dingsishan. In a similar vein, PCA was also useful in highlighting sites that are outliers, reflective of localised environments, group and individual choice.

12.3. Contributions to theoretical discourse in zooarchaeology and SEA

Aside from zooarchaeological analyses this project also aimed at connecting to theoretical discourse in wider research. Part of the motivation behind this goal was to encourage more theoretical development in the SEA region, where zooarchaeology is a relatively young discipline. Two broad approaches particularly influenced the theoretical framing of this thesis: niche construction theory, borrowed from biology, and interspecies asymmetrical relationships from post-humanist scholarship – particularly influenced by Donna Haraway (2008a). Although these approaches have developed independently in very different fields, throughout research for this thesis I found they are remarkably complementary, reflecting a wider academic zeitgeist (as outlined in Chapter four).

Within these frameworks, hunter-gathering and agriculture/domestication are not opposite ends of a scale, as this inherently implies progress and a promised trajectory. Instead, fluidity and permeability characterise subsistence patterns and interaction with animals. Domestication was argued to be a subtle shift in engagement with other animals and the environment – as Ingold (2000d) suggested. However, this engagement is not necessarily characterised by domination, though it may be asymmetrical. The role of pigs and dogs at MB do not easily fit into that model of dominated or oppressed animals, this denies their agency and is more characteristic of our modern industrial farming relationship.

The people of CCN and MB seem to have had a close relationship with animals. It was argued that both sites were not 'purely' middens as there is evidence of 'special' deposits and rituals involving animals. Both sites also have an interest in megafauna (whale, elephant) and large animals (deer, bovids, felids). Special deposits of these animals were argued to have a potential relationship to temporal boundaries (initial / terminal site use), since they are mostly present in the lower layers. However, the animals themselves also hold characteristics that probably held special meaning. Large felids, bovids, and deer are particularly present at CCN, where it was suggested that the high occurrence of severe trauma in human skeletons may be linked to hunting of dangerous fauna. For MB, the continued importance of hunting despite the introduction of domesticates suggests that hunting had taken on new roles and meanings. This was likely also the case with the animals themselves, both wild and domestic.

Though the role of animals was fluid and ambiguous, the increase in sedentism, construction of large cemeteries, and continued hunting of large 'dangerous' fauna at both sites was argued to represent a type of niche construction. These developments imply new concepts or understandings of territoriality, ownership, and the environment. At either site, the relationship with animals does not sit neatly within the role of domination or control, and indeed, the ambiguity of the relationship implies it was more complex. However nuanced the relationship between people and animals, there was a clear faunal transition between CCN and MB, and this ultimately portrays a transition from hunter-gathering to an increased reliance on domesticated animals.

12.4. Future directions and areas for improvement

Much more research in SEA is necessary, the more we learn about this region the more it continues to challenge our preconceived notions and ideologies. While there have been large scale projects in Thailand, Indonesia, and Malaysia, the rest of SEA has – to a certain extent – been lagging behind. Particularly essential is multidisciplinary teams in the field, not only for post-excavation analyses.

Specific to zooarchaeology (apart from more excavation), more reference materials are essential to building a better network and research base. Postcrania needs to be emphasised as equally important as crania, so they are available for researchers in major museums and university collections. Further, an online database summarising what is available and where the material is stored would be invaluable.

The biometric analysis of pig molars in Chapter eight highlighted issues with using modern samples of domestic and wild pigs as analogies for wild boar during the Early Holocene. There was considerable spread in molar size in the modern domestic (and to a lesser extent wild) samples which meant they were not particularly useful comparisons. Instead, sites such as Xipo were more useful comparisons of domestic archaeological pigs. Although a regional SEA comparison of how pig molar size shrinks during domestication is necessary, in the future when more data is available, it may be beneficial to constain analysis to regions. This is because I suspect a lot of the variation in molar size in the archaeological and modern reference samples is probably related to regional variations in size and shape.

Due to the (relative) youth of zooarchaeology in SEA both detailed and wide-scope research is essential to developing the field and contributing to our understanding of SEA. Methods such as PCA have great potential in helping to display wider regional patterns, and unexpected outliers. As mentioned previously, if Khok Phanom Di and Dingsishan were able to be separated between phases they may be able to show a transition between wild and domestic taxa. Further, if more sites were added to the PCA the picture would, no doubt, become more complex. Widening the PCA to include more sites from earlier and later periods would potentially show a number of other intriguing patterns.

Lastly, as suggested in the discussion chapter (section 11.6.7.), if Cohen's analogy of domestication in China evolving through community interaction and information exchange is applied to Vietnam, this begs the questions of how one-sided this engagement was. So far, scholarship on the Neolithic transition in MSEA has focused on the migration of people from southern China into northern Vietnam and has been characterised by seeing the engagement as largely one-sided. Little attention has been given to whether or how indigenous hunter-gatherer groups influenced, effected, and engaged with agricultural groups. This could be a potential research area of development for future studies of this period in Vietnam.

* * *

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Appendices

This section includes appendices on:

Appendix 1: Methodologies

- Ageing methodology for bovids and cervids
- Radiocarbon N% test

Appendix 2: MNE and BPR

- MNE and BPR methodology and results for pigs, dogs, cervids, and bovids

Appendix 3: Ageing results

- Dental wear results for bovids, cervids, and pigs
- Postcrania fusion results
- CCN: deer, bovids. MB: canids, pigs, bovids and deer

Appendix 4: Measurements

- Cranial and postcranial measurements for pigs, dogs, and bovids

Appendix 5: Cluster analysis of pig molars (Chapter eight)

- Levene's test and ANOVA tables for cluster analysis
- Summary of cluster groupings of each MB sample
- Summary of groupings for each site and sample
- Dendrograms from hierarchical cluster analysis

Unless otherwise stated, all skeletal measurements are outlined in Chapter five, or based on von den Driesch (1976) and are in mm.

Appendix 1. Methodologies

1.1. Ageing methods bovids

Table A-1 Grigson 1982 summary of eruption and wear stages

Stage	Age	Grant (1982)
M1 not yet erupting	<6 months	UNER
M1 erupting	6 months (9-12m)	A
M1 in wear, M2 not yet erupting	6-18 months (13-18m)	B-A
M2 erupting	18 months	A
M2 erupting, M3 not yet in wear	18m-2.25 yrs (21m-2yrs)	A-A
M3 erupting	2.25-3 years	A
M3 erupted, P4 erupting	2.5-3 yrs	A-A
M3 slightly worn	>3 years	B-D
M3 medium worn	>3 years	E-H
M3 strongly worn	>3 years	J-M

Table A-2 Summary of Higham 1967 dental wear stages

Stage	Development	Age	Grant
1	Deciduous undeveloped or erupting	fetal	
2	Deciduous in late eruption, unworn	birth-3 weeks	
3	Deciduous in early wear, M1 unerupted	1-4m	B-C/UNER
4	M1 in primary eruption	5-6m	
5	M1 in secondary eruption	6-7m	
6	M1 in tertiary eruption	7-9m	
7	M1 in primary wear, M2 unerupted	8-13m	B-C/UNER
8	M2 in primary eruption	15-16m	
9	M2 in secondary eruption	16-17m	
10	M2 in tertiary eruption	17-18m	
11	M2 in wear, M3 unerupted	18-24	B/UNER
12	M3 in primary eruption	24m	
13	M3 in secondary eruption	24-30m	
14	M3 in tertiary eruption	30m	
15	M3 in primary wear, PM2 and 3 in primary eruption	30-31m	B-D
16	M3 in primary wear, with cusp 3 untouched by wear. PM2-3 in secondary eruption.	31-32m	B-D
17	M3 in late primary wear, PM2-3 in secondary eruption	32-33m	D
18	M3 cusp 3 just in wear, PM4 in primary eruption	36m	E
19	M3 cusp 3 in primary wear, PM4 in tertiary eruption	38m	E
20	M3 cusp 3 in early secondary wear, PM4 in tertiary eruption	40m	F
21	PM4 in primary wear	40-50m	B-C

22	PM4 in secondary wear	50m	D-F
23	PM4 in tertiary wear	over 50m	G-J

Table A-3 Summary of Amorosi 1989 dental wear stage

Development	Age	Grant
M1 not yet erupting	<6m	
M1 erupting	6-12m	
M1 in wear, M2 not yet erupting	6-18m	B-C
M2 erupting	18m	
M2 erupted, M3 not in wear	18-30m	
M3 erupting	28-30m	
M3 erupting, P4 erupting	30-36m	
M3 slightly worn	>36m	B-D
M3 medium worn	>36m	E-H
M3 strongly worn	>36m	J-M

Table A-4 Postcrania fusion ages based on Viner-Daniels 2014, 25-6 and O'Connor 2003, 160

Postrcrania			
Earliest <1 yr	**Early 1-2 yrs**	**Intermediate 2-3 yrs**	**Late 3-4 yrs**
Pelvis	Distal humerus	Distal MC	Proximal humerus
Scapula	Proximal radius	Distal MT	Proximal femur
Phalanx 1		Distal tibia	Proximal tibia
Phalanx 2			Distal radius
			Distal femur
			Calcaneus

Table A-5 Cranial eruption phase based on Viner-Daniels 2014, 25-6 and O'Connor 2003, 160

Crania		
Category	**Description**	**Grant**
Neonatal	dp4 UNER or erupting	
Juvenile	dp4 in wear, M1 not in wear	
Immature	M1 in wear, M2 not in wear	
	M2 in wear, M3 not in wear	
Subadult	M3 forming or just erupting	
	M3 erupting to the occlusal plane	
	M3 in wear	
Adult	M3 in wear	A-B
	M3 with dentine exposure across central column	C-D
	M3 with dentine on distal column	E-H
Elderly	Dentine exposure beyond stage J	J

1.2. Ageing methods cervids

Table A-6 Dental wear for M1 and M2 based on Payne 1982 and Grant 1982

M1 and M2						
Description	**Payne**	**Grant**	**M1 Age**	**Category**	**M2 Age**	**Category**
No wear	1	A	3-5m	Young	9-15m	Young
Minimal wear on anterior cusp	2	B	5-8m		11-18m	
Minimal wear on posterior cusp	3	C	6-13m		12-20m	Subadult
Anterior dentine exposed buccal-lingually and starting to join to posterior	4	C-D	6-13m		14-28m	
Dentine connection between anterior and posterior cusp	5	D	8-14m		18-31m	
	6	E	9-17m	Subadult	20-39m	Adult
	7	F	11-20m		25-45m	
Islands of enamel	8	G	13-50m	Adult	28-90m	Adult
	9	H				
	10	J				
Anterior island gone	11	K			60++	
	12	K-L				
	13	L	35-75m			
No islands, outline of enamel	14	M	55m++	Elderly	70++	Elderly
No outline		N				
Two separate dentine pieces		O				

Table A-7 Dental wear for M3 based on Payne 1982 and Grant 1982

M3				
Description	**Payne**	**Grant**	**Months**	**Category**
No wear	1	A	<30m	Adult
Minimal wear on anterior cusp	2	B	25-39m	
Minimal wear on middle cusp	3	C	28-45m	
Anterior dentine exposed buccal-lingually	4	C-D	30-49m	
Minimal wear on posterior cusp	5	E	35-55m	
Dentine connection between anterior and middle cusp	6	E	39-65m	
	7	E		
Dentine connection with posterior cusp	8	F	40-70m	
	9	F		
Two enamel islands on anterior and middle cusps	10	G	50++	Elderly
Anterior island split in two	11	H		
	12	J		
Anterior island gone	13	K	>90m	
Middle island split in two	14	K	>90m	
	15	L		
No islands	16	M	>90m	

1.3 Radiocarbon, nitrogen test results

Table A-8 Summary of N% test results. *sample enamel dated; +sample collagen dated

Code	Lab ID	N%	C%	C:N	Result	Notes
	CCN-01	0	1.7	87.1	Fail	
13CCN-062	CCN-02	0	2	52.9	Fail*	*Cervus* UM3, L.
	CCN-03	0	1.6	176.3	Fail	
13CCN-407	CCN-04	0	1.7	89	Fail*	Bovinae lower molar
13CCN-408	CCN-05	0	1.7	105.7	Fail*	*Bubalus* lower molar
13CCN-409	CCN-06	0	1.2	127.7	Fail*	Bovinae LM3, L
	CCN-07	0	1.5	105.6	Fail	
	CCN-08	0	1.7	122.1	Fail	
	CCN-09	0	1.8	161.3	Fail	
	CCN-10	0	1.7	93.3	Fail	
	CCN-11	0	1.8	82.8	Fail	
	MB-01	0	1.1	50.6	Fail	
MB07-002	MB-02 (BONE)	0.1	3.5	47.5	Fail+	Dog mandible
	MB-02 (DENTINE)	0.1	2.6	25.1	Fail	Dog mandible
	MB-03	0.1	2.9	36.7	Fail	
	MB-04 (TOP OF DENTINE)	0.3	2.8	12.1	?	*Sus* molar
	MB-04(AT JUNCTION)	0.1	2.4	45.5	Fail	
	MB-06 (BONE)	0.2	2.2	13.3	?	*Sus* UM3, R
MB05-108	MB-06 (DENTINE)	0.4	2.5	6.6	?+	*Sus* UM3, R
	MB-08	0.1	2.6	23	Fail	
	MB-08	0.6	3.1	6.1	?	
	MB-09	0	1.7	52.7	Fail	
	MB-10 (BONE)	0.1	1.8	32.8	Fail	
	MB-10 (DENTINE)	0.1	1.6	27.2	Fail	
MB05-097	MB-11	0.7	3.7	5.9	Pass+	*Sus* molar
	MB-12	0.2	3.1	20.7	?	*Sus* molar
	MB-13	0	1.1	41.4	Fail	
	MB-14	0.2	2.6	19.8	?	
	MB-15	0.1	1.6	36.6	Fail	
MB07-046	MB-16 (BONE)	0.9	4.4	5.9	Pass+	*Sus* maxilla
	MB-16 (DENTINE)	0.3	2.5	8.9	?	*Sus* maxilla
	MB-17 (AT JUNCTION)	0.1	2.9	27.3	Fail	
	MB-17 (BONE)	0.1	2.6	31	Fail	
	MB-18	0.1	1.3	24.1	Fail	
	MB-19	0.1	1.2	28.8	Fail	
	MB-20	0.4	2.6	7.1	?	
	MB-21	0.1	1.1	16.6	Fail	

APPENDIX 2: MNE AND BPR METHODS

2.1. Pigs at MB

Table A-9 Postcranial MNE and BPR for pigs at MB

Element	R	L	Unsided	MNE Total	% total	NISP total	% total
Mandible	3	6	9	18	8.3	30	8.5
Maxilla	13	11	24	48	22.2	108	30.7
Cranial	9	2		11	5.1	47	13.4
Scapula	6	3		9	4.2	17	4.8
Humerus	8	8		16	7.4	21	6
Ulna	2	5		7	3.2	7	2
Radius	2	3		5	2.3	7	2
Axis			1	1	0.5	1	0.3
Atlas			2	2	0.9	2	0.6
UNID vert			11	11	5.1	11	3.1
Ribs			8	8	3.7	3	0.9
Sternum			1	1	0.5	1	0.3
Pelvis	1	2		3	1.4	5	1.4
Femur	1	3		4	1.9	9	2.6
Tibia	4	3		7	3.2	8	2.3
Fibula		1	1	2	0.9	2	0.6
Metapodials	14	10	4	28	13	30	8.5
Carpals		3	2	5	2.3	3	0.9
Tarsals	7	6		13	6	18	5.1
Phalanges			17	17	7.9	22	6.3
Totals	**70**	**66**	**80**	**216**	**100**	**352**	**100**

Table A-10 Loose teeth MNE and BPR for pigs at MB

Tooth	R	L	Unsided	MNE Total	% total
Incisors	21	21	12	54	39.7
Canines	6	2	7	15	11
Premolars	11	10	6	27	19.9
Molars	13	23	4	40	29.4
Totals	**51**	**56**	**29**	**136**	**100**

2.2. Canids at MB

Table A-11 Postcranial MNE and BPR of canids at MB

Region	R	L	Unsided	MNE	NISP
Mandible	1	1		2	2
Maxilla	2	1		3	3
Humerus	1			1	1
Ulna	1	1		3	3
Radius		1		1	1
Pelvis	1			1	2
Tibia	2			2	4
Metapodials	1	2	1	4	4
Tarsals	1	1		2	2
Totals	**10**	**7**	**2**	**19**	**22**

Table A-12 Loose teeth MNE and BPR for canids at MB

Loose teeth	Side	C unsided	I3	P4	M1
Upper	Right	1			
	Left			2	1
Lower	Right				
	Left		1		

2.3. Cervids at MB

Table A-13 Cervid MNE and BPR at MB

Region	R	L	Unsided	MNE Total	NISP total
Antler			3	3	8
Mandible	2	1		3	6
Scapula		2		2	4
Humerus	1			1	1
Radius	3		1	4	7
Ulna	1	4		5	6
Atlas			1	1	1
Pelvis	1	1		2	6
Femur		1		1	2
Tibia	1			1	2
Metapodials	1	1	4	6	11
Carpals/tarsals		2	1	3	3
Phalanges			9	9	10
Totals	**10**	**12**	**19**	**41**	**67**

Table A-14 Loose teeth BPR and MNE *Cervus* MB

		dp4	P UNID	P2	P3/4	M1	M2	M3
Upper	Right		1			1	1	1
	Left			1			1	
Lower	Right				2			1
	Left	1						

2.4. Bovids at MB

Table A-15 MNE and BPR for bovids at MB

Region	R	L	Unsided	MNE Total	% total	NISP total	% total
Ulna	1	1		2	14.3	3	15.8
Vertebrae			1	1	7.1	1	5.3
Rib			1	1	7.1	3	15.8
Femur		1		1	7.1	3	15.8
Tibia		1		1	7.1	1	5.3
Carpals/tarsals	3	2		5	35.7	5	26.3
Metapodials			2	2	14.3	2	10.5
Phalanges			1	1	7.1	1	5.3
Totals	**4**	**5**	**5**	**14**	**100**	**19**	**100**

2.5. Bovids CCN

Table A-16 MNE and BPR for bovids at CCN

Element	L	R	Unsided	MNE	NISP
Crania	2	2	1	5	8
Mandible	3	1		4	16
Scapula			2	2	3
Humerus	1	1		2	8
Radius	5	3		8	16
Ulna	1		1	2	4
Axis			2	2	2
Atlas			1	1	1
Vertbrae			7	7	17
Sacrum			1	1	1
Pelvis	1	1		2	6
Rib			3	3	7
Femur	1	1		2	4
Patella			1	1	1
Tibia	3	1	3	7	15
Metapodials	7	6	10	23	43
Carpals	17	7	8	34	34
Tarsals	11	10		22	26
Phalanges			49	49	86
Sesamoid			2	2	2
Totals	**52**	**33**	**91**	**179**	**300**

Table A-17 Loose teeth bovids MNE at CCN

Bovinae		dp4	I1	I2	I3	I UNID	I Unsided	P2	P3	P4	P4 Unsided	P3/4	M1/2	M2	M3	M UNID
Upper	Right								1					1		2
	Left							1	1	2					1	
Lower	Right	1	1	1	1	1	1				1			1		
	Left				1	1		1		1		1	1		1	

2.6. Cervids at CCN

Table A-18 Cervidae MNE and BPR at CCN

Element	R	L	Unsided	MNE	NISP
Antler			5	5	97
Mandible		1	1	2	3
Scapula			1	1	1
Humerus	1	1	2	4	7
Radius	1		1	2	3
Ulna	1	1	1	3	4
Atlas			1	1	1
Vertebrae			2	2	3
Pelvis	1	2		3	3
Sacrum			2	2	2
Femur	1	2	1	4	11
Patella		2	1	3	3
Tibia	5	2		6	10
Metapodials	4	9	10	23	39
Carpals	5	2	1	8	8
Tarsals	10	8		18	23
Phalanges			42	42	61

Table A-19 Cervidae loose teeth MNE at CCN

Loose teeth		dp4	I1/2	I3	I3	M UNID	M1/2	M1	M2	M2 UNID	M3
Upper	Right					1	2		3	1	
	Left							1	1		2
Lower	Right				1						
	Left	1	1	1					1		2

2.7. Pigs at CCN

Table A-20 Pig MNE and BPR at CCN

Element	R	L	Unsided	MNE	NISP
Mandible		1		1	5
Humerus		1		1	1
Ulna	1			1	1
Atlas			1	1	1
Rib			1	1	1
Femur		1		1	1
Tibia		1		1	1
MCs		3		3	4
MTs	1	2		3	4
Carpals			3	3	3
Tarsals	4	3		7	7
Phalanges			10	10	11

Table A-21 Pig loose teeth BPR and CCN

Loose teeth		C	C unsided	I1	M1 unsided	M2	M3
Upper	Right					1	
	Left	1		1			
Lower	Right	1	1		1		
	Left	2					1

APPENDIX 3. AGEING

3.1. Dental wear CCN

Table A-22 Upper dental wear for bovids from CCN, ageing method.

		Wear Stage (Grant 1982, 92)							Age (months)		
ID	**Side**	**P1**	**P2**	**P3**	**P4**	**M1**	**M2**	**M3**	**Grigson (1982, 23) & Higham (1967)**	**Amorosi (1989, 55)**	**O'Connor (2003)**
13CCN-516	R	F									
13CCN-471-2	L		H	G					>33		Adult
13CCN-743	L										
13CCN-1222	R								>33		Adult
13CCN-406	R			G					>33		Adult
13CCN-063	R				G				>50	>36m	Elderly
13CCN-1134	L				E				50m	>30	Elderly
13CCN-1559	R				G				>50m	>30m	Elderly
13CCN-2119	L				C				40m	>30	Adult
13CCN-2032	R						H/J		>13m	>18m	
13CCN-080	R						K		>24m	>30m	Adult
13CCN-161	L						B		18-24m	18-30m	Subadult
13CCN-188	R						K		>24m	>30m	Adult
13CCN-162	R						B		18-24m	18-30m	Subadult
13CCN-758	R						J		>24m	>30m	Adult
13CCN-162	R						B		18-24m	18-30m	Subadult
13CCN-297	L							UNER	<24	<30m	Subadult 2
13CCN-1072	R							K	>40m	>36m	Elderly

Table A-23 Lower dental wear for bovids from CCN, ageing method.

		Wear Stage (Grant 1982, 92)							Age (months)		
ID	**Side**	**dp4**	**P2**	**P3**	**P4**	**M1**	**M2**	**M3**	**Grigson (1982, 23) & Higham (1967)**	**Amorosi (1989, 55)**	**O'Connor (2003)**
13CCN-466	R	J								<36m	Juvenile-Subadult
13CCN-470	R		D								
13CCN-1011	R		E/F						>32		Adult
13CCN-469	R			E							
13CCN-468	R				E				50m		Elderly
13CCN-654	L				UNER					<36m	
13CCN-676	L				F				50m		Elderly
13CCN-849	R				F				50m		Elderly
13CCN-1255	R				F				50m		Elderly
13CCN-1599	R				UNER					<36m	
13CCN-1398	R				D/E				50m		Elderly
13CCN-653	L				UNER					<36m	
13CCN-800	L				G				>50m		Elderly
13CCN-189	R					G			>13m	>18m	
13CCN-081	R					K			>13m	>18m	
13CCN-467	R					E			>13m	>18m	
13CCN-509	L					E			>13m	>18m	
13CCN-510	L					UNER			>13m	>18m	
13CCN-1225	L					F?					
13CCN-134	R					E			>13m	>18m	
13CCN-303	L						D		18-24m	18-30m	Subadult
13CCN-405	R						D		18-24m	18-30m	Subadult
13CCN-464	L						G		>18m	>18m	Adult

13CCN-554	R						J		>18m	>18m	Adult
13CCN-624	L						G		>18m	>18m	Adult
13CCN-1049	L						K		>18m	>18m	Adult
13CCN-1113	L						G	C	>40m	>36m	Adult
13CCN-064	R						J		>18m	>18m	Adult
13CCN-220	R							F	>40m	>36m	Adult
13CCN-360	R							F	>40m	>36m	Adult
13CCN-1221	L							H	>40m	>36m	Adult
13CCN-1665	L							K	>50m	>36m	Elderly

Table A-24 Dental wear for cervids from CCN, ageing method.

			Grant (1982)			Months		
ID	Element	Side	M1	M2	M3	Payne (1982)	Age	Category
Upper dentition								
13CCN-061	M2	R		F		7	25-45m	Adult
13CCN-062	M3	L			G	10	50++	Elderly
13CCN-292	M1	L	H			9	13-50m	Adult
13CCN-511	M2	L		G		8	28-90m	Adult
13CCN-719	M2	R		G		8	28-90m	Adult
Lower dentition								
13CCN-760	M3	L			F	8-9	40-70m	Adult
13CCN-1254	M2	L		UNER			<11 or 2-7m	Young
13CCN-2777	M3	L			B-C	2-4	25-49m	Adult

3.2. Dental wear MB

Table A-25 Pig upper dental wear based and scores based on Grant (1982) and Lemoine et al. (2014), ageing method.

			Grant (1982) wear stage							Lemoine et al. (2014)						
ID	**Element**	**Side**	**dp2**	**dp3**	**dp4**	**P4**	**M1**	**M2**	**M3**	**Score**	**Specific**	**Age specific**	**System A**	**Age System A**	**System B**	**Age System B**
MBANU-033	mx frag w P4, M1	L				D	K			10,16	8	52-72m	F	52-96m	III	52-96m
MBANU-034	mx frag w dP3, dP4	L		B	C					8,9	2	3-5m	B	3-8m	I	0-12m
MBANU-039	M2	L						UNER		6	4	8-12m	C	8-12m	I	0-12m
MBANU-042	mx w dP2-4, M1	R	n/a	E	D		A			11,10,7	3	6-8m	B	3-8m	I	0-12m
MBANU-043	M2	L						C		9			D-E	12-52m	II	12-52m
MBANU-046	M3	L							A	7			E-F	18-96m	II-III	12-96m
MBANU-047	dp3-4, M1	R		F	D		A			12,10,7	2	3-5m	B	3-8m	I	0-12m
MBANU-048	dp2-4	L	A	D	C					7,10,9	2	3-5m	B	3-8m	I	0-12m
MBANU-050	P4, M1-2	R				A	D*	A		7,10,7	4	8-12m	C	8-12m	II	12-52m
MBANU-051	M2-3	L						D-E*	A-B	10-11,7-8			E-F	18-96m	II-III	12-96m
MBANU-052	M1-2	R					E	A		11,7			C-D	8-16m	II-III	12-96m
MBANU-054	M2	R						UNER		6	4	8-12m	C	8-12m	I	0-12m
MBANU-059	dp4, M1-2	R			H		D	A		14,10,7	4	8-12m	C	8-12m	I	0-12m
MBANU-061	P4, M1-3	R				B	F	D	UNER	8,12,10,5	6	18-30m	E	18-52m	II	12-52m
MBANU-066	dp4, M1	R			E		A			11,7	3	6-8m	B	3-8m	I	0-12m
MBANU-070	P3-4, M1-3	R				B	H	E	UNER	8,14,11,6	7	30-52m	E	18-52m	II	12-52m
MBANU-071	M3	R							D	10			F	52-96m	III	52-96m
MBANU-072	M1, M2	R					G?	B		13,8	7	30-52m	E	18-52m	II	12-52m
MBANU-073	M2	R						E		11			E-F	18-96m	II-III	12-96m
MBANU-074	M1	R					UNER			5	2	3-5m	B	3-8m	I	0-12m
MBANU-076	M2	L						UNER		6	4	8-12m	C	8-12m	I	0-12m

MBANU-077	M2	L						UNER		6	4	8-12m	C	8-12m	I	0-12m
MBANU-078	P4	R				A				7	4	8-12m	C	8-12m	I	0-12m
MBANU-079	dp4	R			B					8	2	3-5m	B	3-8m	I	0-12m
MBANU-080	M1	L					A			7	3	6-8m	B	3-8m	I	0-12m
MBANU-091	P4, M1-3	L				C	H	D	A	9,14,10,7	7	30-52m	E	18-52m	II	12-52m
MBANU-092	dp4, M1	L			N		NA			19	4	8-12m	C	8-12m	I	0-12m
MBANU-093	P4	L				C				9			D-E	12-52m	II	12-52m
MBANU-117	dp2-4	R	A	D	C					7,10,9	2-3	3-8m	B	3-8m	I	0-12m
MBANU-119	M1	L					A			7	3	6-8m	B	3-8m	I	0-12m
MBANU-120	P2	R														
MBANU-125	P3	R								8					II-III	12-96m
MBANU-126	P4	L				A*				7	4	8-12m	C	8-12m	I	0-12m
MBANU-134	M3	R							UNER	6			E	18-52m	II	12-52m
MBANU-135	M2	L						A		7			C-D	8-16m	I-II	0-52m
MBANU-136	M2	R						A		7			C-D	8-16m	I-II	0-52m
MBANU-137	dp3	R		E-F						11-12			B-C	3-12m	I	0-12m
MBANU-212	M2	R						A		7			C-D	8-16m	I-II	0-52m
MBANU-214	M3	L							UNER	6			E	18-52m	II	12-52m
MBANU-215	M2	L						A		7			C-D	8-16m	I-II	0-52m
MBANU-218	M3	L														
MBANU-225	P4, M1-3	L				N/A	N/A	C	UNER	9,6			E	18-52m	II	12-52m
MBANU-226	P3-4	R				A				7,7	4	8-12m	C	8-12m	I	0-12m
MBANU-227	dp4, M1	L				E	A?			11,7	3	6-8m	B	3-8m	I	0-12m
MBANU-228	dp4	R													I	0-12m
MBANU-229	dp3-4	L		D	C					10,9			B	3-8m	I	0-12m
MBANU-230	M2	L						F		12			F	52-96m	III	52-96m

MBANU-236	M1	L					A?			7	3	6-8m	B	3-8m	I	0-12m
MBANU-239	dp2	L	A							7			B	3-8m	I	0-12m
MBANU-247	M3	L							B	8			E-F	18-96m	II-III	12-96m
MBANU-248	M2	L						C		9			D-E	12-52m	II	12-52m
MBANU-253	M2	L						D		10			E-F	18-96m	II-III	12-96m
MBANU-262	dp3-4	L											B-C	3-12m	I	0-12m
MBANU-263	dp4,M1	R											B-C	3-12m	I	0-12m
MBANU-411	dp2,3,4, M1	R											B-C	3-12m	I	0-12m

Table A-26 Pig lower dental wear based and scores based on Grant (1982) and Lemoine et al. (2014), ageing method.

			Grant (1982)									Lemoine et al. (2014)						
ID	Element	Side	dp2	dp3	dp4	P2	P3	P4	M1	M2	M3	Score	Specific	Age specific	System A	Age System A	System B	Age System B
MBANU-036	M2	L			E							11			E-F	18-96m	II-III	12-96m
MBANU-045	dp3-4, M1	L		A	E				A			7,11,7	3	6-8m	B	3-8m	I	0-12m
MBANU-049	P2-4	R						D				10			D-F	12-96	II-III	12-96m
MBANU-060	M2-3	R								M	A	18,7	8-9	52-96m	F?	52-96m	III	52-96m
MBANU-062	C, P3	R					A					7			D-E	12-52m	II	12-52m
MBANU-063	P3-4	L					B	NA				8			D-E	12-52m	II	12-52m
MBANU-068	i1-2, dp2-4, M1	L	A	B	D				A			7,8,10,7	3	6-8m	B	3-8m	I	0-12m
MBANU-069	i1-2, dp2-4, M1	R	A	B	D				A			7,8,10,7	3	6-8m	B	3-8m	I	0-12m
MBANU-104	M1	R							A			7	3	6-8m	B	3-8m	I	0-12m

MBANU-116	M3	R									A	7			E-F	18-96m	II-III	12-52m
MBANU-127	M1	R							UNER			6	2	3-5m	B	3-8m	I	0-12m
MBANU-198	M3	R									A	7			E-F	18-96m	II-III	12-96m
MBANU-205	M3	L									C	9			E-F	18-96m	II-III	12-96m
MBANU-231	M1	R							D			10			C-E	8-52m	I-II	0-52m
MBANU-232	P4	R						A?				7			B-C	3-12m	I	0-12m
MBANU-237	P2	R				B						8			D-F	12-96	II-III	12-96m
MBANU-251	M1	L							B			8	3	6-8m	B	3-8m	I	0-12m
MBANU-255	M3	L									C	9			E-F	3-12m	II-III	0-52m
MBANU-265	p2,4,M1,2,3	L						B	E	D	B	8,11,10,8	6		E	18-52m	II	12-52m
MBANU-415	M2	R								B		8			D-E	12-52m	II	12-52m
MBANU-416	M2-3	L								E	A	11,7			E-F	18-96m	II-III	12-96m
MBANU-1716	M3	L									B	8			E-F	18-96m	II-III	12-96m
MBANU-1717	M2	L								F		12			F	52-96m	III	52-96m
MBANU-1720	dp4	L			D							10			B	3-8m	I	0-12m

3.3 Postcranial fusion CCN

Table A-27 Deer postcranial fusion data

Element	ID	Side	Proximal F/U	Distal F/U	Mariezkurenna (1983)	Munro et al. (2009)	Category
Humerus	13CCN-2833	R		F	>32m	>18m	Adult
Radius	13CCN-049	R		U	<32m		Subadult
	13CCN-1735		U		<20m	<7m	Young–Subadult
Ulna	13CCN-358	L		F	32m+	>18m	Adult
	13CCN-364	L	F		32m+	>18m	Adult
Metacarpals	13CCN-653			F	32m+	>18m	Adult
	13CCN-1118	R	F		32m+	>18m	Adult
	13CCN-2168			F	32m+	>18m	Adult
Metapodials	13CCN-1196			U		<18m	Subadult
	13CCN-1739			F	32m+	>18m	Adult
	13CCN-2202	L		U		<18m	Subadult
	13CCN-2546			F	32m+	>18m	Adult
	13CCN-2865			F	32m+	>18m	Adult
	13CCN-2905			U		<18m	Subadult
Femur	13CCN-496	L		U	<32	<18m	Subadult
	13CCN-923	L	F		32+	>18m	Adult
	13CCN-924	L		F	32+	<18m	Adult
	13CCN-1724	R		U	<32	<18m	Subadult
	13CCN-2153	R	F		32+	>18m	Adult
	13CCN-2549	R	F		32+	>18m	Adult
Tibia	13CCN-359	R	F			>18m	Adult
	13CCN-495	R	F			>18m	Adult
	13CCN-555	R		F	>32m	>18m	Adult
	13CCN-669	L	U			<18m	Subadult
	13CCN-1117	R		F	>32m	>18m	Adult
	13CCN-1848	R	U			<18m	Subadult
Calcaneus	13CCN-501	L	(dorsal) F			>18m	Subadult
	13CCN-502	R	(dorsal) U			<18m	Subadult
	13CCN-2047	R	(dorsal) F			>18m	Subadult
Metatarsals	13CCN-1868	L	U		Young		Juvenile
	13CCN-2548	L	F				Adult
Pelvis (acetabulum)	13CCN-2033	L	F		32+	>18m	Adult
	13CCN-2034	R	F		32+	>18m	Adult
	13CCN-2773	L	F		32+	>18m	Adult
Phalanages: Basal	13CCN-265		F			>18m	Adult
	13CCN-332		U			<18m	Subadult
	13CCN-915		U			<18m	Subadult
	13CCN-938		F			>18m	Adult
	13CCN-1022		F			>18m	Adult

	13CCN-1179	F	>18m	Adult
	13CCN-2071	F	>18m	Adult
	13CCN-2235	F	>18m	Adult
	13CCN-2410	F	>18m	Adult
	13CCN-2530	F	>18m	Adult
	13CCN-2547	F	>18m	Adult
	13CCN-2595	U	<18m	Subadult
	13CCN-3134	F	>18m	Adult
	13CCN-3173	U	<18m	Subadult
Phalanges: SubTerminal	13CCN-166	F	>18m	Adult
	13CCN-1350	F	>18m	Adult
Phalanages: Terminal	13CCN-222	F		Adult
	13CCN-2707	F		Adult
	13CCN-2722	F		Adult

Table A-28 Bovids postcrania fusion data

Element	**ID**	**Side**	**Proximal F/U**	**Distal F/U**	**Amorosi (1989)**	**O'Connor (2003)**	**Category**
Humerus	13CCN-112	L	F		>42m		Adult
	13CCN-435		F		>42m		Adult
Radius	13CCN-095		F		>12m		
	13CCN-102			F	>42m		Adult
	13CCN-146		F		>12m		
	13CCN-285		U		<12-18m	<1–2 yrs	Younger
	13CCN-326			U	<48m		
	13CCN-344		F		>12m		
	13CCN-457		F		>12m		
	13CCN-1129			U	<48m		Adult
Metacarpals	13CCN-026		F		F before birth		
	13CCN-105			F	>24m	>2-3 yrs	Adult
	13CCN-286			F	>24m	>2-3 yrs	Adult
	13CCN-1975			F	>24m	>2-3 yrs	Adult
Femur	13CCN-622		U		<48m	<2–3 yrs	
Tibia	13CCN-103	R		F	>30m	>2-3yrs	Adult
	13CCN-110		U		<48m	<3-4yrs	
	13CCN-151	L	F		>42-48m	>3-4yrs	Adult
	13CCN-165	R	F		>42-48m	>3-4yrs	Adult
	13CCN-323	R	U		<48m	<3-4yrs	
	13CCN-330	L	U		<48m	<3-4yrs	
	13CCN-355	L		F	>30m	>2-3yrs	Adult
	13CCN-356	?	F		>42-48m	>3-4yrs	Adult

	13CCN-551	L	U		<48m	<3-4yrs	
	13CCN-1663	?	U		<48m	<3-4yrs	
	13CCN-1723	L		F	>30m	>2-3yrs	Adult
Calcaneus	13CCN-281		(dorsal) F		>36m	>3-4yrs	Adult
	13CCN-331		(dorsal) F		>36m	>3-4yrs	Adult
	13CCN-623		(dorsal) F		>36m	>3-4yrs	Adult
	13CCN-1009		(dorsal) U		<36m	<3-4yrs	
	13CCN-2638		(dorsal) F		>36m	>3-4yrs	Adult
Metatarsals	13CCN-147			F	>30m	<2–3 yrs	
	13CCN-2409		F		F at birth		
Phalanages: Basal	13CCN-043		F		>18m		Adult
	13CCN-096			F	>18m		Adult
	13CCN-269		U		<24m	<1 yr	Subadult
	13CCN-447		F		>18m		Adult
	13CCN-630		F	F	>18m		Adult
	13CCN-703		U		<24m	<1 yr	Subadult
	13CCN-982		F		>18m		Adult
	13CCN-1064		F		>18m		Adult
	13CCN-1146		U		<24m	<1 yr	Subadult
	13CCN-1562		F		>18m		Adult
	13CCN-1584		F		>18m		Adult
	13CCN-1737		F		>18m		Adult
	13CCN-1885		U		<24m	<1 yr	Subadult
	13CCN-2351		F		>18m		Adult
	13CCN-2374		F		>18m		Adult
	13CCN-2482		F		>18m		Adult
	13CCN-2515		F		>18m		Adult
Phalanages: SubTerminal	13CCN-041		F	F	>15m		
	13CCN-238		F	F	>15m		
	13CCN-299		F		>15m		
	13CCN-324		F	F	>15m		
	13CCN-448		F	F	>15m		
	13CCN-450		F		>15m		
	13CCN-1038		F		>15m		
	13CCN-1237		F		>15m		
	13CCN-1257		F		>15m		
	13CCN-1351		F	F	>15m		
	13CCN-1790		F	F	>15m		
	13CCN-1950		F	F	>15m		
	13CCN-1952		F		>15m		
	13CCN-1968		U		<18m	<1 yr	Subadult
	13CCN-2155		F		>15m		

	13CCN-2167	U		<18m	<1 yr	Subadult
	13CCN-2381	F		>15m		
	13CCN-2481	F		>15m		
	13CCN-2718	F	F	>15m		
	13CCN-2750	F		>15m		
	13CCN-2808	U		<18m		Subadult
Phalanages: Terminal	13CCN-042	F		>18m		Adult
	13CCN-344	F	F	>18m		Adult
	13CCN-449	F	F	>18m		Adult
	13CCN-1010	F	F	>18m		Adult
	13CCN-1138	F	F	>18m		Adult
	13CCN-1558	F	F	>18m		Adult
	13CCN-2018	F	F	>18m		Adult

Section 3.4 Postcranial fusion MB

Table A-29 Pig postcranial fusion data. Methodology based on Zeder et al. (2015), see section 5.6 and Table 5-3 in the Chapter five for further detail. 1=unfused; 2=fusing; 3=fused.

	C (≤1m)		D (7–8m)			E (8–18m)	
ID	Axis	Atlas	Pelvis	Scapula	P Radius	SubT Phalanx	D Humerus
MBANU-014	3						
MBANU-345		3					
MBANU-559		1					
MBANU-149			3				
MBANU-490			3				
MBANU-557			1				
MBANU-558			1				
MBANU-012				1			
MBANU-013				1			
MBANU-057				1			
MBANU-335				1			
MBANU-339				3			
MBANU-481				1			
MBANU-556				1			
MBANU-017					3		
MBANU-259					1		
MBANU-826					1		
MBANU-001						3	
MBANU-003						3	
MBANU-004						3	
MBANU-005						3	
MBANU-146						1	

	E (8–18m)		F (18–24m)	
ID	SubT Phalanx	D Humerus	Basal Phalanx	D Tibia
MBANU-154	3			
MBANU-250	3			
MBANU-344	3			
MBANU-835	1			
MBANU-1239	3			
MBANU-1240	3			
MBANU-007		3		
MBANU-008		2		
MBANU-201		3		
MBANU-207		1		
MBANU-210		3		
MBANU-211		3		
MBANU-258		3		
MBANU-429		3		
MBANU-565		1		
MBANU-1575		1		
MBANU-002			1	
MBANU-141			3	
MBANU-338			3	
MBANU-581			1	
MBANU-626			3	

Table A-29 Continued. Pig postcranial fusion data. 1=unfused; 2=fusing; 3=fused.

	F (18–24m)		G (24–36m)	
ID	Basal Phalanx	D Tibia	MCs	MTs
MBANU-009		2		
MBANU-010		3		
MBANU-015		3		
MBANU-200		3		
MBANU-261		1		
MBANU-346		3		
MBANU-561		1		
MBANU-143			3	
MBANU-340			3	
MBANU-341			3	
MBANU-342			3	
MBANU-571			1	
MBANU-573			1	
MBANU-574			1	
MBANU-577			1	
MBANU-578			1	
MBANU-579			1	
MBANU-1456			1	
MBANU-019				3
MBANU-398				1

	G (24–36m)		H (36–48m)		I (48–60m)					
ID	MCs	MTs	Calcaneus	P femur	D radius	P ulna	D femur	P tibia	P fibula	Humerus head
MBANU-572		1								
MBANU-575		1								
MBANU-576		1								
MBANU-580		1								
MBANU-494			1							
MBANU-523			1							
MBANU-1127			1							
MBANU-1166			3							
MBANU-260				1						
MBANU-259					1					
MBANU-964					1					
MBANU-496						1				
MBANU-554						1				
MBANU-555						1				
MBANU-600						3				
MBANU-209							3			
MBANU-562							1			
MBANU-261								1		
MBANU-561								1		
MBANU-560									1	
MBANU-257										1

Appendix 4. Measurements

4.1. Pig dental biometrics from MB

Table A-30 Pig biometrics for upper premolars from MB.

ID	Context	Element	Side	dP2 L	dP2 B	dP3 L	dP3 B	dP4 L	dP4B	P2L	P2B	P3L	P3B	P4l	P4B
Maxilla/upper															
MBANU-033	05 MB L4.1 f3	mx frag w P4, M1	L											n/a	14.44
MBANU-034	07 MB H2 L12.2 b3	mx frag w dP3, dP4	L			13.39	9.37	15.25	11.43						
MBANU-042	07 MB H2 L10.2 d2	mx w dP2-4, M1	R	11.47	7.36	12.15	9.57	15.46	13.41						
MBANU-047	04MB L7 (I) b3	dp3-4, M1	R			14.19	9.58	13.84	12.15						
MBANU-048	05MB H1 L13 (II) b1	dp2-4	L	11.6	6.89	13.22	9.6	13.88	12.28						
MBANU-050	04MB H1 L10 (II) C3	P4, M1-2	R											12.61	13.61
MBANU-059	H2 L15 (III) C1	dp4, M1-2	R					13.29	12.26						
MBANU-061	07MB H2 L11 (II) d4	P4, M1-3	R											12.02	12.89
MBANU-066	07MB H2 L7 (I)	dp4, M1	R					14.05	12.59						
MBANU-070	01MB L5-1 B2	P3-4, M1-3	R									13.67	11.14	12.22	13.83
MBANU-078	01MB L2-4 A2	P4	R											11.94	14.12

MBANU-079	01MB L3-1 C2	dp4	R					14.71	13.07						
MBANU-091	05MB HI L13 (II) b1	P4, M1-3	L											12.46	15.23
MBANU-092	04MB H1 L4 (I) e3	dp4, M1	L					12.67*	12.5*						
MBANU-093	05MB H1 L14 (II) b1	P4	L											11.97	14.76
MBANU-117	05MB H1 L9 (I) a3	dp2-4	R	9.56	6.4	11.76	8.6	13.01	11.93						
MBANU-120	05MB H1 L10+11 (II) a4	P2	R							12.06	8.36				
MBANU-125	05MB H1 L10+11 (II) a4	P3	R									12.06	11.97		
MBANU-126	04MB H1 L9 (I) d1	P4	L											12.34	11.82
MBANU-137	L7 (I) e6	dp3	R			13.48	9.36								
MBANU-225	04MB H1 L7 (I) b5	P4, M1-3	L											11.71	13.44
MBANU-226	05MB H1 L6 (I) f4	P3-4	R									13.04	12.35	12.63	14.93
MBANU-227	04MB H1 L7 (I) b5	dp4, M1	L					13.33	12.66						
MBANU-228	04MB H1 L7 (I) b5	dp4	R					13.62	12.67						
MBANU-229	04MB H1 L6 (I) d6	dp3-4	L			12.8	9.13	13.79	11.6						

MBANU-239	04MB H1 L7 (I) b5	dp2	L	10.59	6.13				
MBANU-262	01MB L4-2 A2	dp3-4	L			14.06	9.61	15.61	12.47
MBANU-263	01MB L4-2 A2	dp4,M1	R					15.78	12.43
MBANU-411	04MBL6-1 E2	dp2,3,4, M1	R	11.14	8.03	13.88	10.35	15.54	14.59

Table A-31 Pig biometrics for upper molars from MB.

ID	Context	Element	Side	M1l	M1Ba	M1Bp	M2l	M2Ba	M2Bp	M3l	M3Ba	M3Bm	M3Bp
Maxilla/upper													
MBANU-033	05 MB L4.1 f3	mx frag w P4, M1	L	14.18	13.84	15.95							
MBANU-039	07 MB H1 L7.2 ag	M2	L				23.18	17.71	16.87				
MBANU-042	07 MB H2 L10.2 d2	mx w dP2-4, M1	R			15.82							
MBANU-043	07 MB H2 L11.2 a1	M2	L				21.59	18.51	17.56				
MBANU-046	05 MB H1 L14 (II) a1	M3	L							33.81	19.06	17.9	11.21
MBANU-047	04MB L7 (I) b3	dp3-4, M1	R	16.19	14.94	14.63							
MBANU-050	04MB H1 L10 (II) C3	P4, M1-2	R	NA	NA	14.86	19.74*	18.03	NA				
MBANU-051	L10 (II) a5	M2-3	L				NA	NA	17.24	32.58	19.37	17.57	11.17

MBANU-052	05MB H1 L10+L11 (II) a4	M1-2	R	15.8	14.59	14.53	20.94	18.76	16.52				
MBANU-054	05MB H1 L9 (II) a6	M2	R				20.72	19.44	17.93				
MBANU-059	H2 L15 (III) C1	dp4, M1-2	R	16.41	15.21	15.37	22.13	18.76	19.14				
MBANU-061	07MB H2 L11 (II) d4	P4, M1-3	R	15.5	15.06	15.6	19.8	18.72	19.5	34*	20.39	18.4	NA
MBANU-066	07MB H2 L7 (I)	dp4, M1	R	18.9	15.17	15.67							
MBANU-070	01MB L5-1 B2	P3-4, M1-3	R	16.88	15.6*	15.25*	19.77	18.54	18.93	35.02	20.28	18.84	13.95
MBANU-071	01MB L2-3 C2	M3	R							33.07	20.37	16.82	11.06
MBANU-072	01MB L5-7 A1	M1, M2	R	NA	NA	16.23	21.53	19.94	19.73				
MBANU-073	01MB L3-1 B1	M2	R				21.81	19.58	19				
MBANU-074	01MB L3-2 A1	M1	R	19.12	15.53	15.2*							
MBANU-076	01MB L2-3 B2	M2	L				21.5	19.91	19.54				
MBANU-077	01MB L3-1 C2-1	M2	L				20.84	19.39	19.79				
MBANU-080	01MB L4-2 A2	M1	L	16.8	14.75	15.04							
MBANU-091	05MB HI L13 (II) b1	P4, M1-3	L	15.7	14.14	16.03	20.85	19.55	19.6	37.31	23.58	20.51	15.96

MBANU-092	04MB H1 L4 (I) e3	dp4, M1	L	NA	NA	NA							
MBANU-119	05MB H1 L8 (I) f2	M1	L	14.8	13.15	14.25							
MBANU-134	L7 (I) a3	M3	R							34.44	20.3	19.11	NA
MBANU-135	L8 (I) a3	M2	L				20.18	18.21	18.12				
MBANU-136	L7 (I) a4	M2	R				19.53	NA	18.94				
MBANU-212	L7 (I) a4	M2	R				19.9*		18.49				
MBANU-214	04MB L8 (I) a3	M3	L							NA	20.56	NA	NA
MBANU-215	04MB L8 (I) a3	M2	L				21.42	17.93	17.96				
MBANU-218	04MB L7 (I) b3	M3	L							NA	NA	NA	15.02*
MBANU-225	04MB H1 L7 (I) b5	P4, M1-3	L	16.92*	16.44*	16.4*	25.59	19.3	20.16				
MBANU-227	04MB H1 L7 (I) b5	dp4, M1	L	15.04	14.35*	14.59*							
MBANU-228	04MB H1 L7 (I) b5	dp4	R										
MBANU-230	04MB H1 L6 (I) c2	M2	L				18.37	17.72	18.31*				
MBANU-236	04MB H1 L7 (I) b5	M1	L	15.4	14.94	14.83							
MBANU-247	05MB H1 L14-15 (III) a2 b2	M3	L							37.55	22.1	20.23	11.97
MBANU-248	05MB H1 L17 (III) c2	M2	L				19.08	17.73	17.92				
MBANU-253	05MB H1 L12 (III) d2	M2	L				NA	NA	15.91				
MBANU-263	01MB L4-2 A2	dp4,M1	R	19.14	15.12	14.68							

MBANU-411	04MBL6-1 E2	dp2,3,4, M1	R	17.61	16.91	16.74							
MBANU-1714	07MB H2 L12 (II) b1	M1	L	16.53	NA	14.49							
MBANU-1715	L12 (II) d1	M3	R							32.48*	19.11	17.97	11.44

Table A-32 Pig biometrics for lower premolars from MB.

Mandible/lower	Context	Element	Side	dP2 L	dP2 B	dP3 L	dP3 B	dP4 L	dP4 aB	dP4 pB	P2L	P2B	P3L	P3B	P4l	P4B
MBANU-045	05 MB H1 L10 (II) C1	dp3-4, M1	L			11.45	5.86	19.53	7.9	10.28						
MBANU-049	04MB H1 L7 (I) C1	P2-4	R								12.19	6.27	12.85	8.31	13.23	10.24
MBANU-062	07 MB H2 L9 (II) b3	C, P3	R			12.62	7.77									
MBANU-063	07MB H2 L12 (II) d4	P3-4	L										12.76	7.82	NA	NA
MBANU-068	01MB L4-2 A2	i1-2, dp2-4, M1	L	9.44	4.6	10.87	5.61	19.84	7.22	9.57						
MBANU-069	01MB L4-2 A2	i1-2, dp2-4, M1	R	10.13	4.47	10.89	5.6	19.69	7.31	9.68						
MBANU-232	04MB H1 L7 (I) d1	P4	R												14.63	10.67
MBANU-237	04MB H1 L6 (I) b6	P2	R								12.6	8.02				
MBANU-265	01MB L5-1 B2	p2,4,M1,2,3	L												16.86	10.91
MBANU-1720	07MB H2 L9.2 e3	dp4	L						NA	NA	9.38					

Table A-33 Pig biometrics for lower molars from MB.

Mandible/lower	Context	Element	Side	M1l	M1Ba	M1Bp	M2l	M2Ba	M2Bp	M3l	M3Ba	M3Bm	M3Bp
MBANU-036	07 MB H1 L14.3 a3	M2	L			11.54							
MBANU-045	05 MB H1 L10 (II) C1	dp3-4, M1	L	15.59	12.73								
MBANU-060	07MB H2 L8 (I) d3	M2-3	R				20.39	15.2*	16.6*	38.03	17.45	18.33	15.33
MBANU-068	01MB L4-2 A2	i1-2, dp2-4, M1	L	17	10.68	12.25							
MBANU-069	01MB L4-2 A2	i1-2, dp2-4, M1	R	18.38	10.76	12.3							
MBANU-104	05MB H1 L10-11 C2	M1	R	17.09	NA	12.72							
MBANU-116	05MB H1 L10-11 (II) a2	M3	R							42.06	16.87	17.16	15.91
MBANU-127	04MB H1 L9 (I) a2	M1	R	18.48	11.53	12.09							
MBANU-198	01MB L2-3 A1	M3	R							34.41	15.57	15.82	14.1
MBANU-205	01MB L5-1 B1	M3	L							43.2	17.47	16.87	15.73
MBANU-231	04MB H1 L7 (I) d1	M1	R	16.06	11.32	12.29							
MBANU-251	05MB H1 L12 (III) a5	M1	L	16.56	11.77	12.45							
MBANU-255	01MB L5-1	M3	L							41.85	16.8	16.57	15.35
MBANU-265	01MB L5-1 B2	p2,4,M1,2,3	L	18.08	12.22	13.27	23.88	16.39	17.2		18.68	18.37	
MBANU-415	05MBL6-1 F3	M2	R				22.13	15.42	16.75				
MBANU-416	05MBL6-1 F1	M2-3	L				21.03	14.94	15.89	43.82	16.47	17.2	
MBANU-1716	H2 L10.1 d4	M3	L							43.8	18.14	18.16	16.1
MBANU-1717	H2 L10.1 d4	M2	L				20.95	15.46	15.71				
MBANU-1728	H1 L10-11(II)a2	M2	R?				NA	NA	16.09				

4.2. Pig postcranial measurements MB

Table A-34 Summary of postcranial measurements for pigs from MB

Femur

ID	Portion	Side	SD	Notes
MBANU-113	Proximal + shaft	L	22.32	Missing femoral head

Tibia

ID	Portion	Side	Dd	Bd	Fusion
MBANU-010	Distal	L	27.7	34	F
MBANU-015	Distal	L	27.6	35.35	F
MBANU-009	Distal	R	29.99	39.2	F

Humerus

ID	Portion	Side	Bd	Bt	SD	Dd	Fusion	Notes
MBANU-008	Distal	R	51.14	40.35	NA	NA	F	
MBANU-007	Distal + shaft	L	48.71	39.22	23.03		F	Cutmarks
MBANU-133	Distal	L	41	NA	15.32			Trochlear and capitulum broken
MBANU-201	Distal	L	47.63			45.3	F	AT-064
MBANU-343	Distal + shaft	R	NA	NA	15.32*	NA		Broken just above facets

Radius

ID	Portion	Side	Bp	BFacetp	LFacetProx-Medial	LFacetProximalLateral	Fusion	Notes
MBANU-017	Proximal	L	34.48		20.92	14.55	F	Cutmarks

Ulna

ID	Portion	Side	BPC	Notes
MBANU-516	Proximal + shaft	L	28.39	Gnaw marks

Scapula

ID	Side	SLC	LG	GLP	BG	Fusion	Notes
MBANU-339	R	36.46	39	46.87	33.02	F	Articulation end

Metacarpals

ID	Element	Side	GL	SD	Bd	Bp	Dd	Dp	Fused	Notes
MBANU-067	MC3	R	NA	NA	NA	18.24	NA	NA	F	Previously has been cut transversely for sampling
MBANU-143	MC?	R	57.98	6.82	10.85	6.6	14.7	10.21	?	AT-006
MBANU-340	MC3	L	76.65	14.94	18	17.33	18.54	16.9	F	Robust condition
MBANU-341	MC4	L	77.96	15.35	19.67	20.93	18.54	NA	F	Some damage to prox facet
MBANU-342	MC3	R	78.07*	16.7*	19.34	NA	18.37	NA	F	Previously sampled which has damaged half of the proximal end

Astragalus

ID	Side	G Length M	G Length L	Dm	Dl	Notes
MBANU-011	R	Broken	43.08	Broken	22.95	
MBANU-016	L	40.34	44.18	18.6	21.96	
MBANU-249	R	40.68	43.65	21.51	21.9	
MBANU-495	L	29.27	31.26	17.95	17.34	Juvenile
MBANU-505	R	35.63	39.65	21.56	20.55	
MBANU-531	R	28.7	29.88*	15.77*	NA	
MBANU-649	R	37.1	42.44		20.39	AT-305

MBANU-670	R	40.89	44	27.57	22.51	AT-326

Calcaneus

ID	Side	GL	GB	Notes
MBANU-494	L	45.72	23.94	Juvenile, unfused

Phalanges basal

ID	Element	GL	SD	Bd	Bp	Dd	Dp	Fusion	Notes
MBANU-141	Basal	33.03	16.08	16.9	19.29	10.19	19.8	F	AT-004
MBANU-338	Basal	36.9	15.12	17.77	18.6	11.7	184	F	
MBANU-262	Basal	35.4	15.27	16.48	19.96	12.34	19.44	?	AT-282

Phalanges subterminal

ID	Element	GL	SD	Bd	Bp	Dd	Dp	Fusion	Notes
MBANU-001	SubT	24.32	15.68	17.64	19.08	14.48	18.01	F	Proximal end almost finished fusing
MBANU-004	SubT	NA	13.91	13.21	NA	13.55	NA	F	Proximal end is broken
MBANU-005	SubT	26.07	14.25	15.53	16.93	14	16.98	F	
MBANU-003	SubT	25.03	15.41	16.64	18.32	14.37	17.5	F	
MBANU-250	SubT	26.97	13.92	15.11	17.59	16.7	16.09*	F	Bite marks
MBANU-344	SubT	23.7	16.75	18.61	18.91	15.4	19.94	F	
MBANU-1239	SubT	24.2	16.84	18.43	18.06	14.39*	17.73	F	
MBANU-1240	SubT	NA	13.03	NA	NA	NA	NA	F	Two small holes

MBANU-154	SubT	24	13.88	16.88	13.55	16.2	F	AT-017

4.3. Dog dental biometrics from MB

Table A-35 Dog maxilla biometrics, based on von den Driesch (1976, 60–1).

Maxilla	Context	Element	Side	P3L	P3B	P4L	P4B	M1L	M1B	M2L	M2B	P4-M2L	M1-M2L (16)	Notes
MBANU-021	07 MB H2 LII.2, e2	Maxilla frag	L	10.02	4.76	18.22	11.01	10.43	15.1	6.03	9.97	33		wear on tips of crowns, fully erupted
MBANU-095	05MB H1 L14.2, e1	M1	R					11.78	14.93					Tooth is still embedded in mx frag. Anterior alevolar for M2 visible. Anterior cusp damaged. Some wear on cusps.
MBANU-115	05MB H1 L10.2, C4	P4	L			14.26*	6.75*							Quite fragmented
MBANU-213	04MB H1 L7.1, d4	M1-2	R					11.02	13.52	6.78	9.83		16.47	Two posterior cusps on M1
MBANU-244	04MB H1 L7.I, b5	M1	L					9.5	10.79					

Table A-36 Dog mandible biometrics, based on von den Driesch (1976, 60–1).

Mandible	Context	Element	Side	P2L	P2B	P3L	P3B	P4L	P4B	M1L	M1B	M2L	M2B	P4-M2L	P1-P4L (11)	M1-M2L (10)	Thickness below M1 (17)	Height behind M1 (19)	Notes
MBA-NU-044	07 MB H2 L10.2, f2	Mandible w C, P1-4, M1-2	L	7.62	3.95	9.17	4.4	5.52*	5.5	20.27	8.42	8.49	6.71	37.98	33.35	28.43	10.94	24.81	Sampled for C14. Fully erupted, a small amount of wear on cusps M1 and M2, no wear on Ps or C

4.4. Dog postcrania measurements

Table A-37 Dog postcranial measurements from MB

Humerus					
ID	**Element**	**Side**	**SC**	**Bd**	**Fusion**
MBANU-1642	Distal + shaft	R	12.66	32.12	F

Metatarsal					
ID	**Element**	**Side**	**GL**	**Bd**	**Fusion**
MBANU-1635	MT4	R	64.03	6.98	F

Astragalus		
ID	**Side**	**GL**
MBANU-1519	L	22.68

Calcaneus				
ID	**Side**	**GL**	**GB**	**Notes**
MBANU-321	R	42.4	15.17	
MBANU-1381	R	36.99	12.97	Pathology
MBANU-1430	L	37.08	12.07	Pathology

4.5. Bovid dental measurements

Table A-38 Bovid upper dentition measurements from CCN

ID	Side	P1L	P1B	P2L	P2B	PM3L	PM3B	PM4L	PM4b	M2l	M2Ba	M2Bp	M3l	M3Ba	M3Bp
13CCN-063	R							18.05	23.03						
13CCN-080	R									31.7	26.34	24.96			
13CCN-161	L									33.53	21.05	20.87			
13CCN-188	R									32.68	26.63	27.19			
13CCN-162	R									29.65	24.02	22.85			
13CCN-297	L												31.57	18.58	18.3
13CCN-406	R					17.73	18.81								
13CCN-471-2	L			16.88	13.07	18.15	14.93								
13CCN-758	R			16.9	10.84					30.17	22.62	23.31			
13CCN-1072	R												32.12	28.25*	22.34*
13CCN-1134	L							20.33	18.7						
13CCN-1222	R					18.9	15.05								
13CCN-1559	R							19.65	22.76						
13CCN-2032	R									29.95	25.86	25.02			
13CCN-2119	L							20.78	18.2						
13CCN-162	R									29.65	24.02	22.85			
13CCN-516	R	20.54	15.55												
13CCN-743	L					20.52	14.76								

Table A-39 Bovid lower dentition measurements from CCN

ID	Side	dp4l	dp4Ba	dp4m	dp4B	P2L	P2B	P3L	P3B	P4L	P4b	M1l	M1Ba	M1Bp	M2l	M2Ba	M2Bp	M3l	M3Ba	M3Bm	M3Bp
13CCN-189	R											30.84	18.9	18.63							
13CCN-220	R																	40.11	16.22	15.75	8.67
13CCN-303	L														35.46*	16.15	16.09				
13CCN-360	R																	42.62	16	15.85	13.26
13CCN-405	R														33.6	17.21	17.62				
13CCN-464	L														32.09	17.14	18.6				
13CCN-466	R	33.16	13.63	15.57	15																
13CCN-467	R														34.38	14.68	14.75				
13CCN-468	R									21.17	13.3										
13CCN-469	R							20.56	11.5												
13CCN-509	L											31.74	16.19	16.25							
13CCN-510	L											31.35	15.29	15.16							
13CCN-554	R														31.16	15.76	15.44				
13CCN-624	L														34.56	15.78	16.57				
13CCN-654	L									25.97	14.76										
13CCN-676	L									22.25	12.98										
13CCN-849	R									26.35	14.68										
13CCN-1011	R					16.44	11.05														
13CCN-1049	L														32.28	15.45	16.04				
13CCN-1221	L																	44.93	18.56	18.57	13.2
13CCN-1225	L														33.73	15.48	15.11				
13CCN-1255	R									23.92	13.86										
13CCN-1599	R									26.77	14.45										

13CCN-1665	L											41.16	15.84	16.68	9.09
13CCN-1113	L								31.34	15.73	15.8	44.59	14.91	16.21	10.18
13CCN-1398	R			22.3	12.88										
13CCN-081	R					33.55	15.57	14.86							
13CCN-064	R								29.17	14.38	14.37				
13CCN-134	R					27*	16.36	13.66*							
13CCN-653	L			25.11	14.04										
13CCN-470	R	16.67	9.64												
13CCN-800	L			22.39	14.2										

4.6. Bovid postcrania measurements

Table A-40 Summary of Bovid postcranial measurements from CCN

Radius

ID	Portion	Side	Bp	BFacetp	Length Facet-ProxMedial	Length Facet Proximal-Lateral	Notes
13CCN-146	Proximal	L	97.8	91.81	54.52	35.72	Cutmarks
13CCN-457	Proximal	R	95.22	86.55	47.7	35.08	Fused

Tibia

ID	Portion	Side	Bp	Length-ProxFacet-Lateral	LengthProx-FacetMedial	Bd	Dd	Fusion
13CCN-151	Proximal	L	86.55	52.49	NA	NA	NA	F
13CCN-165	Proximal	R	120.05	64.93	66.55	NA	NA	F
13CCN-355	Distal	L	NA	NA	NA	63.92	47.58	F

Metacarpals

ID	Side	GL	Bp	Dp	SD	Bd	Dd	Fusion
13CCN-286		NA	NA	NA	NA	89.36	47.2	F
13CCN-105	L	NA	NA	NA	NA	82.5	42.53	F
13CCN-1975		NA	NA	NA	NA	82.62	44.12	F

Calcaneus

ID	Side	GL	GB	Notes
13CCN-623	R	160*	69.1*	GL measured with ruler
13CCN-631	R		63.98*	proximal portion missing
13CCN-281	L	NA	58.69	can’t measure GL

Astragalus

ID	Side	Dm	Dl	G Length M	G Length L
13CCN-283	L	37.49*	41.96	NA	77.23
13CCN-219	R			56.28	59.95
13CCN-635	R	47.11	46.67	73.06*	89.42
13CCN-636	R		43.22	75.59	81.87
13CCN-665	L	50.77	49.68	81.73	88.74
13CCN-708	L	51.58	50.71	77.62	84.52
13CCN-1045	L	39.92*	44.35	74.27	81.97
13CCN-1063	R	50.12	49.15	75.77	83.64
13CCN-1587	L	48.15	41.12	72.99	80.47
13CCN-1168	L	46.67	47.68	79.4	85.52
13CCN-1162	R	44.6	44.85	73.28	81.54

Scapho-cuboid/cuboid-navicular

ID	Side	GB	GL
13CCN-329	R	73.91	59.85

13CCN-152	R	75.53	62.95

Captio-trapezoid

ID	Side	GB	GL
13CCN-1936	L	47.55	47.36
13CCN-248	L	42.74	44.99
13CCN-858	L	42.98	48.4
13CCN-403	R	46.55	44.3
13CCN-458	L	39.94	44.13

Basal phalanges

ID	GL	SD	Bd	Bp	Dd	Dp	Fusion
13CCN-447	NA	40.91*	NA	43.63	NA	42.83	F
13CCN-982	NA	38.49*	NA	39.84	NA	40	F
13CCN-1562	NA	38.58*	NA	42.17	NA	41.22	F
13CCN-1584	NA	36*	NA	41.78	NA	43.71	F
13CCN-1737	NA	39.84	NA	42.36	NA	39.58	F
13CCN-282	75.93*	NA	NA	41.25*	NA	49.88	F
13CCN-447	NA	41.28*	NA	43.14	NA	44.08	F
13CCN-269	NA	NA	NA	38.3	NA	41.38	U
13CCN-043	NA	NA	NA	38.34*	NA	39.05	F
13CCN-1064	74.77*	NA	NA	34.86*	NA	NA	F
13CCN-703	NA	NA	NA	37.9	NA	36.59	U
13CCN-1885	NA	26.66	29.59	NA	24.71	NA	U
13CCN-1146	NA	NA	NA	35.35	NA	38.19	U
13CCN-630	79.37*	37.52	39.7	41.58	27.91	42.89	F
13CCN-2351	NA	NA	NA	21.45	NA	25.91	F
13CCN-2374	NA	21.37	NA	26.19	NA	30.89	
13CCN-2482	NA	NA	NA	41.09	NA	38.88*	
13CCN-2515	78.2*						
13CCN-2261	NA	18.71*	20.58	NA	19.22	NA	
13CCN-2653	NA	NA	39.58	NA	29.27	NA	
13CCN-2798	NA	19.76	22.43	NA	19.03	NA	
13CCN-2830	NA	NA	NA	40.15	NA	41.78	

Subterminal phalanges

ID	GL	SD	Bd	Bp	Dd	Dp	Fusion
13CCN-041	56.91	34.56	33.99	41.01	38.49	39.72	F
13CCN-238	53.42	32.03	32.5	39.8	41.36	38.39	F
13CCN-324	57.9	NA	32.26	NA	34.97*	NA	F
13CCN-448	59.62	30.3	30.36	39.96	34.97	37.62	F
13CCN-1038	55.01	30.67	30.39	40.6	36.72	39.26	F
13CCN-1257	NA	NA	NA	37.5	NA	40.17	F
13CCN-1790	63.09	38.22	36.47	47.85	38.59	42.96	F
13CCN-1950	43.95	21.06	23.94	28.8	27.62	27.75	F
13CCN-1952	63.13	32.96	32.6	42.72	36.95	44.01*	F
13CCN-1237	60.02	32.17	31.68	42.22	36.93	43.38	F

13CCN-1968	NA	22.51*	NA	NA	30.21*	NA	U
13CCN-2155	58.3	31.05	31.69	42.64	34.29	41.59	F
13CCN-2167	NA	20.98	21.18	NA	28.8	NA	U
13CCN-2381	58.36	29.81	29.71	39.94	33.88	39.52	
13CCN-2718	59.06	31.06	30.71	38.51	34.81	40.99	
13CCN-2750	NA	NA	NA	36.17	NA	35.73	F
13CCN-2808	NA	25.05	22.88	NA	28.83	NA	U

Terminal phalanges				
ID	**GL**	**Bp**	**Dp**	**Fused**
13CCN-1010	98.12	37.84	57.6	F
13CCN-1558	62.97	31.52*	NA	F
13CCN-2018	88.13	34.22	59.01	F
13CCN-1138	NA	31.92	NA	F
13CCN-042	NA	35.75*	NA	F
13CCN-344	81.65	30.97	48.9*	F
13CCN-449	88.1	28.42*	51.69	F

Appendix 5. Cluster analysis of pig molars

5.1. Levene's test and ANOVA post-hoc test results

5.1.1. Lower M1s

Table 38 shows the results from Levene's test, and notes that anterior breadth failed the test of homogeneity. For this reason, Welch and Brown-Forsythe tests were conducted for anterior breadth. The independent between-groups ANOVA yielded a statistically significant effect for length and posterior breadth and robusticity tests for anterior breadth also produced significant results (Table 39). Thus, the null hypothesis of no difference between the four groups was rejected. To evaluate the nature of the differences between groups Tukey HSD post-hoc tests were conducted. In all cases the difference between groups was statistically significant (between p=<0.001-0.008). Specifically, Tukey HSD showed significant differences between means in length and posterior breadth. For anterior breadth the wide and large groups were significant but there was some overlap between the small and narrow groups. This can be easily understood when viewing Figure 8-1, as there is some overlap in the anterior breadth between the small and narrow groups. However, overall the statistics support the presence of at least four groups within the data.

Table A-41 Levene's results *indicates variable that failed homogeneity test. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Test of Homogeneity of Variance (Levene's test)				
	F	**df1**	**df2**	***p***
LM1L	2.52	3	165	0.6
LM1Ba	4.97	3	165	0.002*
LM1Bp	0.18	3	165	0.91

Table A-42 Summary of ANOVA and Robusticity tests of significance. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

ANOVA	***F***	**df**	***p***
LM1L	136.64	3	<0.0001
LM1Bp	18.67	3	<0.0001
Robusticity test			
LM1Ba	***F***	**df**	***p***
Welch	49.63	3, 32.87	<0.0001
Brown-Forsythe	51.39	3, 25.8	<0.0001

5.1.2. Lower M2s

Table 40 shows the results from Levene's test, which shows that length failed the homogeneity test. For this reason, Welch and Brown-Forsythe tests were conducted for length. The independent between-groups ANOVA yielded a statistically significant effect for anterior and posterior breadth and robusticity tests for length also produced significant results (Table 41). Thus, the null hypothesis of no difference between the three groups was rejected. Tukey HSD post-hoc tests showed length was the most statistically significant factor influencing the grouping (between p=<0.0001-0.014). Anterior and posterior breadth specifically for the large group was also significant (p=<0.0001). Conversely, there was an overlap in means between small and medium groups in anterior (p=0.18) and posterior (p=0.64) breadths. Figure 8-2 shows the overlap in anterior and posterior breadth between small and medium groups, while there is more difference with length between the three groups.

Table A-43 Levene's results *indicates variable that failed homogeneity test. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Test of Homogeneity of Variance (Levene's test)				
	F	**df1**	**df2**	***p***
LM2L	7.74	2	111	<0.001*
LM2Ba	0.86	2	111	0.43
LM2Bp	0.16	2	111	0.86

Table A-44 Summary of ANOVA and Robusticity tests of significance. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

ANOVA	***F***	**df**	***p***
LM2Ba	60.12	2	<0.0001
LM2Bp	106.68	2	<0.0001
Robusticity test			
LM2L	***F***	**df**	***p***
Welch	52.78	2, 38.86	<0.0001
Brown-Forsythe	38.53	2, 47.98	<0.0001

5.1.3. Lower M3s

Table 42 shows the results from Levene's test, both length and anterior breadth pass. The independent between-groups ANOVA yielded a statistically significant effect for length and anterior breadth (Table 43). Thus, the null hypothesis of no difference between the three groups was rejected. Tukey HSD post-hoc analysis shows length was the most statistically significant variable influencing all three groups (p=<0.0001). Anterior breadth was significant for the small group (p=<0.001). There was an overlap in means for the anterior breadth in the medium/wide and large groups (p=0.29).

Table A-45 Levene's results, both variables passed. L = length, Ba = anterior (mesial) breath.

Test of Homogeneity of Variance (Levene's test)				
	F	df1	df2	*p*
LM3L	1.7	2	68	0.35
LM3Ba	1.13	2	68	0.33

Table A-46 Summary of ANOVA test of significance. L = length, Ba = anterior (mesial) breath.

ANOVA	*F*	df	*p*
LM3L	133.98	2	<0.0001
LM3Ba	14.6	2	<0.0001

5.1.4. Upper M1s

Table 44 shows the results from Levene's test, length passed but anterior and posterior breadth failed. Thus, Robusticity tests were conducted for breadth measurements. The independent between-groups ANOVA yielded a statistically significant effect for length (Table 45). Robusticity tests for anterior and posterior breadths also yielded statistically significant results (Table 8-19). Thus, the null hypothesis of no difference between the three groups was rejected. Tukey HSD post-hoc analysis suggested that posterior breadth was overall the most significant contributing variable to group clustering (p=<0.0001-0.001). For length there was an overlap between the small and wide groups (p=0.23), though not for the large group (p=<0.0001). For anterior breadth there was some overlap in the large and wide groups (p=0.02), but not for the small group (p=<0.0001).

Table A-47 Levene's results, *indicates the variable failed the homogeneity test. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Test of Homogeneity of Variance (Levene's test)				
	F	df1	df2	*p*
UM1L	0.64	2	136	0.53
UM1Ba	4.87	2	136	0.009*
UM1Bp	3.07	2	136	0.05*

Table A-48 Summary of ANOVA and Robusticity tests of significance. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

ANOVA	*F*	df	*p*
UM1L	108.87	2	<0.0001
Robusticity tests			
UM1Ba	*F*	df	*p*
Welch	34.73	2, 34.18	<0.0001
Brown-Forsythe	39.05	2, 46.7	<0.0001
UM1Bp	*F*	df	*p*
Welch	47.11	2, 35.8	<0.0001
Brown-Forsythe	47.7	2, 56.98	<0.0001

5.1.5. Upper M2s

Table 46 shows the results from Levene's test, all three variables passed. The independent between-groups ANOVA yielded a statistically significant effect for all three variables (Table 47). Thus, the null hypothesis of no difference between the three groups was rejected. Tukey HSD post-hoc analysis shows a mixture of results for each variable. For length, the medium/wide and small groups overlap (p=0.8), while the large group is significant (p=<0.0001). Anterior and posterior breadths of the large and medium/wide groups overlap (p=0.73, 0.76 respectively), while the small group is significant for both breadths (p=<0.0001). This suggests that although statistically there are at least three significant groups within the data, there is also some overlap in the means in each variable. This overlap in size between groups can be seen in Figure 8-5.

Table A-49 Levene's results, all variables passed. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

Test of Homogeneity of Variance (Levene's test)				
	F	**df1**	**df2**	***p***
UM2L	0.38	2	93	0.69
UM2Ba	0.12	2	93	0.88
UM2Bp	1.17	2	93	0.32

Table A-50 Summary of ANOVA test of significance. L = length, Ba = anterior (mesial) breath, Bp = posterior (distal) breadth.

ANOVA	***F***	**df**	***p***
UM2L	48.42	2	<0.0001
UM2Ba	76.12	2	<0.0001
UM2Bp	53.81	2	<0.0001

5.1.6. Upper M3s

Table 48 shows the results from Levene's test, both length and anterior breadth passed. The independent between-groups ANOVA yielded a statistically significant effect for both length and anterior breadth (Table 49). Thus, the null hypothesis of no difference between the three groups was rejected. Tukey HSD post-hoc analysis showed that both length and anterior breadth were significant contributing factors to the group clusters (between p=<0.0001-0.003).

Table A-51 Levene's results, both variables passed. L = length, Ba = anterior (mesial) breath.

Test of Homogeneity of Variance (Levene's test)				
	F	**df1**	**df2**	***p***
UM3L	1.99	2	53	0.15
UM3Ba	1.4	2	53	0.26

Table A-52 Summary of ANOVA test of significance. L = length, Ba = anterior (mesial) breath.

ANOVA	***F***	**df**	***p***
UM3L	104.87	2	<0.0001
UM3Ba	17.55	2	<0.0001

5.2. Grouping of MB pig molars

Table A-53 Results of cluster analysis per MB sample, summary of groupings organised by K-means. For mandibles and maxillae; Green = molars agreed, red = molars disagreed between sample groups.

ID	Small	Narrow	Medium/Wide	Large
13CCN-1411			LM 3	
MBANU-033			UM 1	
MBANU-039				UM 2
MBANU-043			UM 2	
MBANU-046	UM 3			
MBANU-047			UM 1	
MBANU-051	UM 3			
🟩 MBANU-052			UM 1, 2	
MBANU-054			UM 2	
🟥 MBANU-059			UM 1	UM 2
🟥 MBANU-060			LM 3	LM 2
🟩 MBANU-061			UM 1, 2, 3	
MBANU-066				UM 1
MBANU-068		LM 1		
MBANU-069		LM 1		
🟩 MBANU-070			UM 1, 2, 3	
MBANU-071	UM 3			
MBANU-072			UM 2	
MBANU-073			UM 2	
MBANU-074				UM 1
MBANU-076			UM 2	
MBANU-077			UM 2	
MBANU-080			UM 1	
🟩 MBANU-091			UM 1, 2	UM 3
MBANU-116				LM 3
MBANU-119			UM 1	
MBANU-127				LM 1
MBANU-134			UM 3	
MBANU-135			UM 2	
MBANU-198			LM 3	
MBANU-205				LM 3
MBANU-215			UM 2	
🟥 MBANU-225			UM 1	UM 2
MBANU-227			UM 1	
MBANU-230			UM 2	
MBANU-231			LM 1	
MBANU-236			UM 1	
MBANU-247			UM 3	
MBANU-248			UM 2	
MBANU-251			LM 1	
MBANU-255				LM 3

MBANU-263				UM 1
MBANU-265				LM 1, 2
MBANU-411			UM 1	
MBANU-415				LM 2
MBANU-416				LM 2, 3
MBANU-1716				LM 3
MBANU-1717				LM 2

5.3. Groupings of molars in pig cluster analysis

Table A-54 Summary groupings of each molar samples per sites in cluster analysis. Sites roughly arranged from oldest to youngest.

	Sample	Small	Narrow	Medium &/ or Wide	Large	Subtotal
Archaeological	Lobang Hangus		1	11	17	29
	Gan Kira	5	1	9	21	36
	Dingsishan	1		10	14	25
	Cishan				1	1
	Shishanzi				1	1
	CCN			1		1
	Xipo	64	76	64	64	268
	Shouling			1		1
	Jiangzhai			1		1
	Banpo			1		1
	MB	3	2	35	19	59
	An Son	3	4	7	7	21
	Rach Nui	7	2	10	1	20
	Nagsabaran	3	1	21	7	32
	Anaro	3	2	2	11	18
	Savidug	6		13	2	21
	Vasino	6				6
	Pre Khmeng	8		2		10
	Phum Lovea	2		2		4
	Pacung	9		4	5	18
	Sembiran	6				6
	Yinxu	1				1
Wild				18	12	30
Domestic		10	4	14	7	35
Subtotal		**137**	**93**	**226**	**189**	
Total						**645**

5.4 Dendrograms from pig cluster analysis

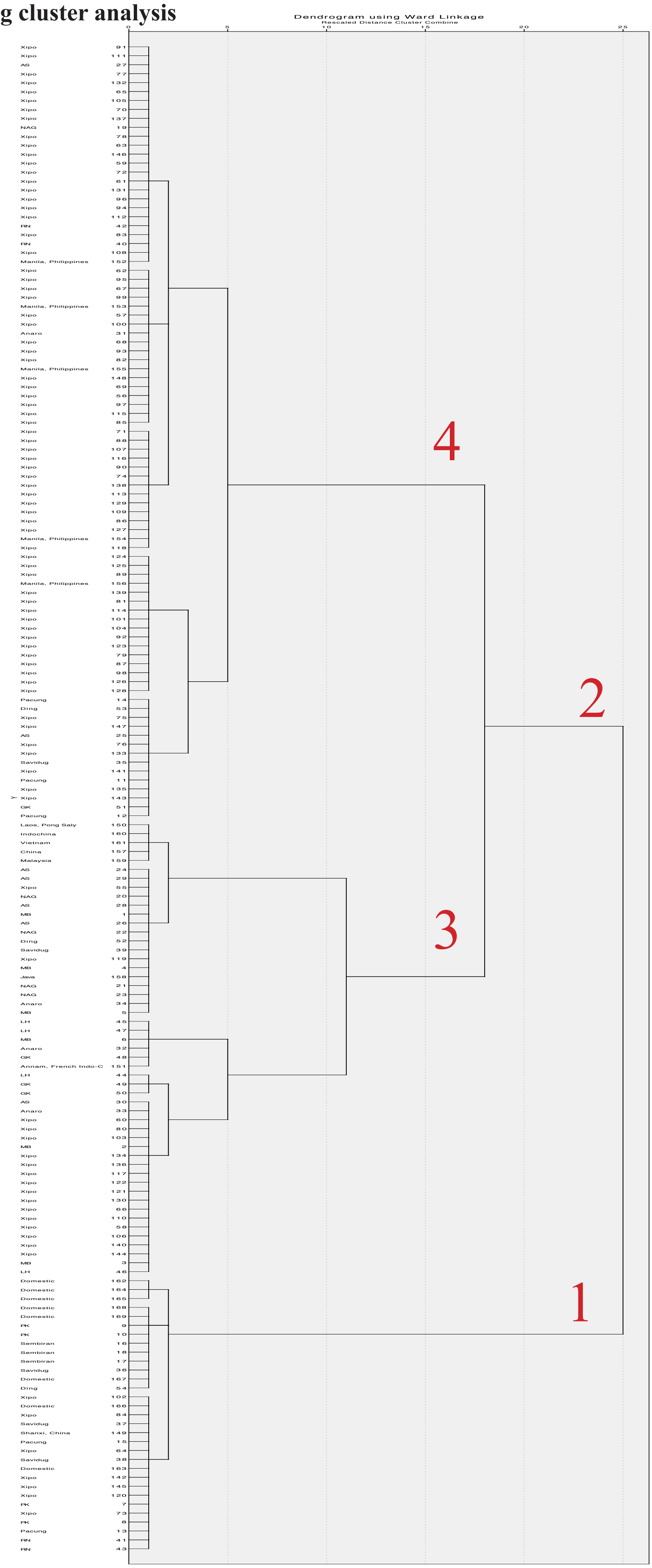

Figure A-1 Pig LM1s dengrogram using Ward linkage. Four clusters are indicated.

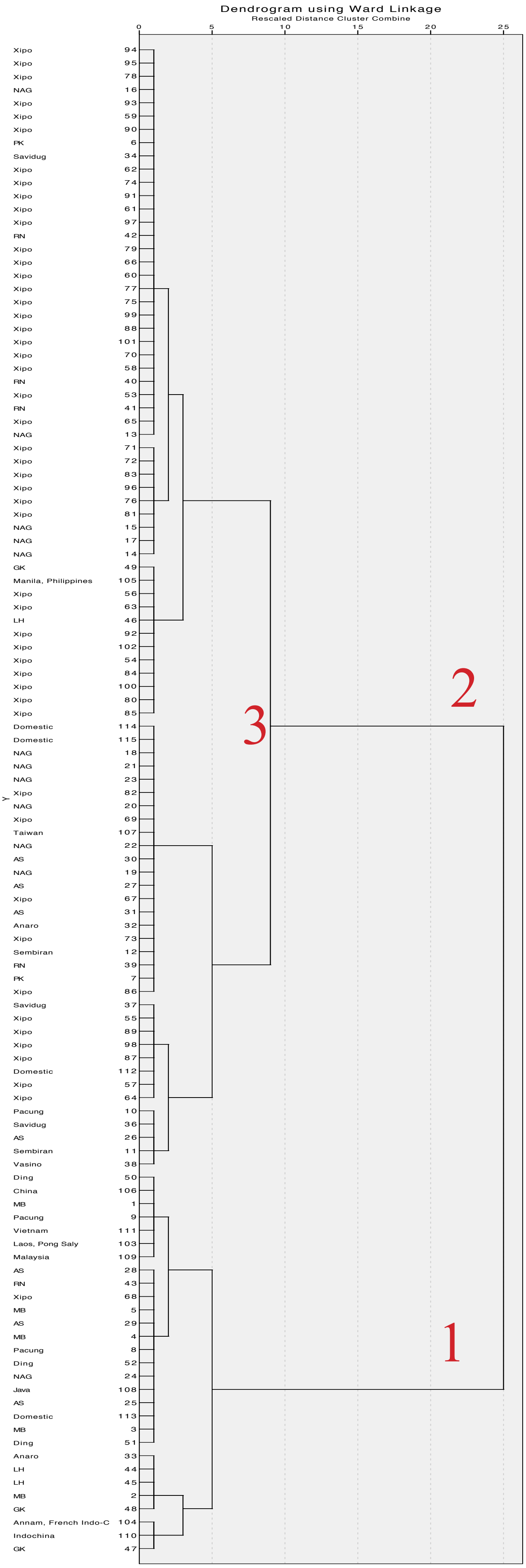

Figure A-2 Pig LM2s dengrogram using Ward linkage. Three clusters are indicated.

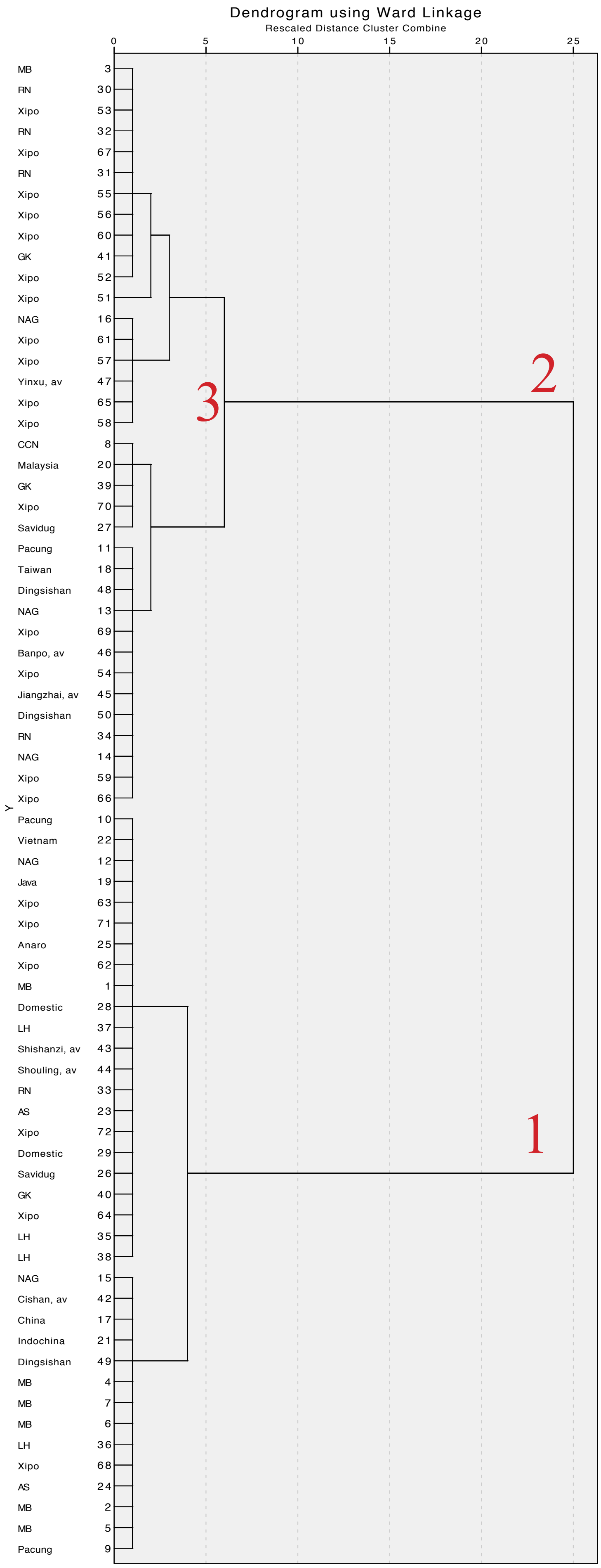

Figure A-3 Pig LM3s dengrogram using Ward linkage. Three clusters are indicated.

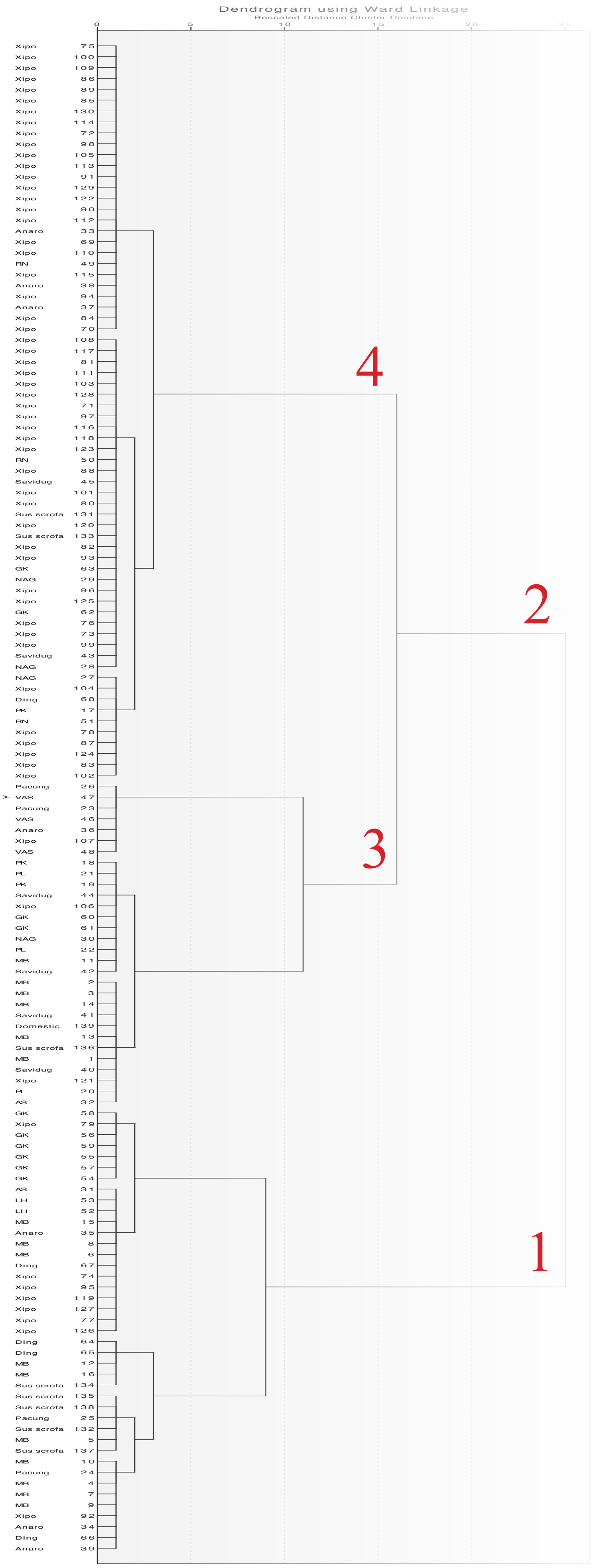

Figure A-4 Pig UM1s dendrogram using Ward linkage. The hierarchical cluster analysis indicated four clusters (as shown here), but when Kmeans and ANOVA was performed there was too much overlap between the groups, and the groupings were not significant (using Tukey post-hoc tests). Thus, three groups were run for Kmeans and ANOVA to produce the best results.

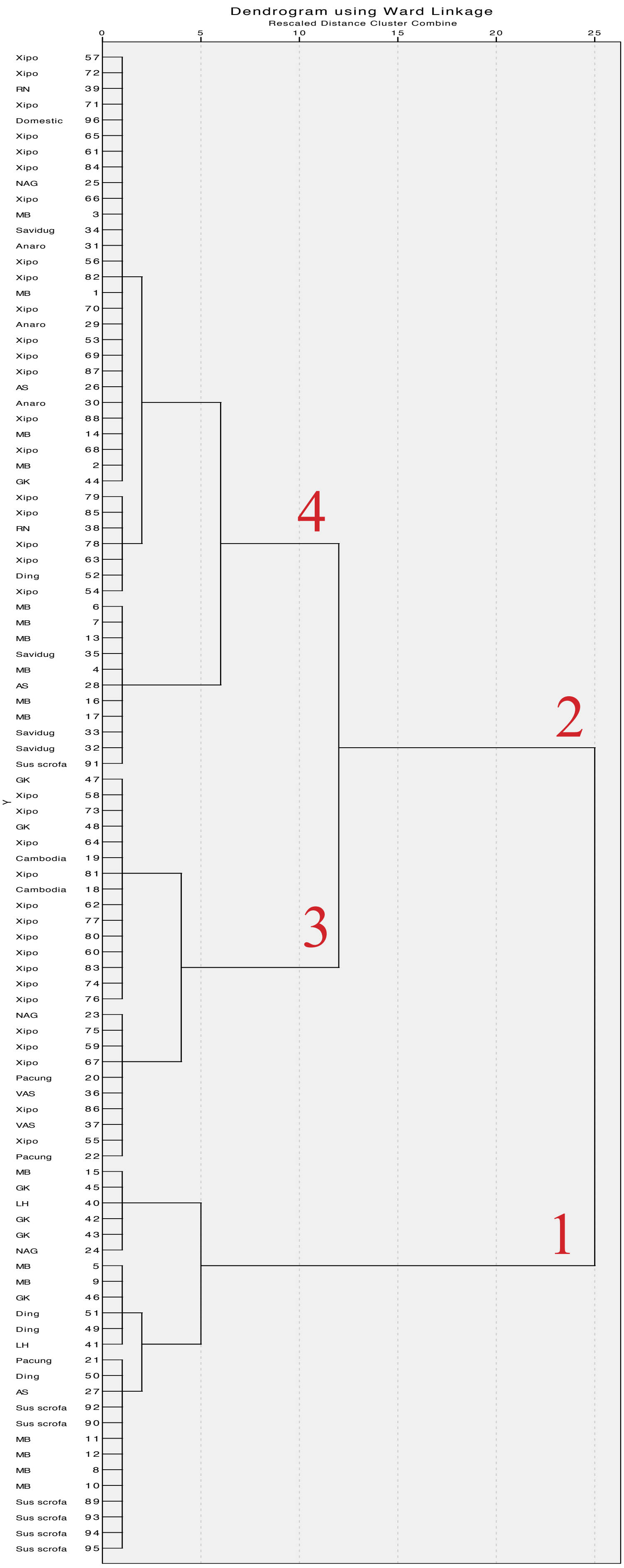

Figure A-5 Pig UM2s dendrogram using Ward linkage. As with the UM1s, the hierarchical cluster analysis indicated four groups (as shown), but when Kmeans and ANOVA was performed there was too much overlap between groups. Three clusters were used as this produced better results.

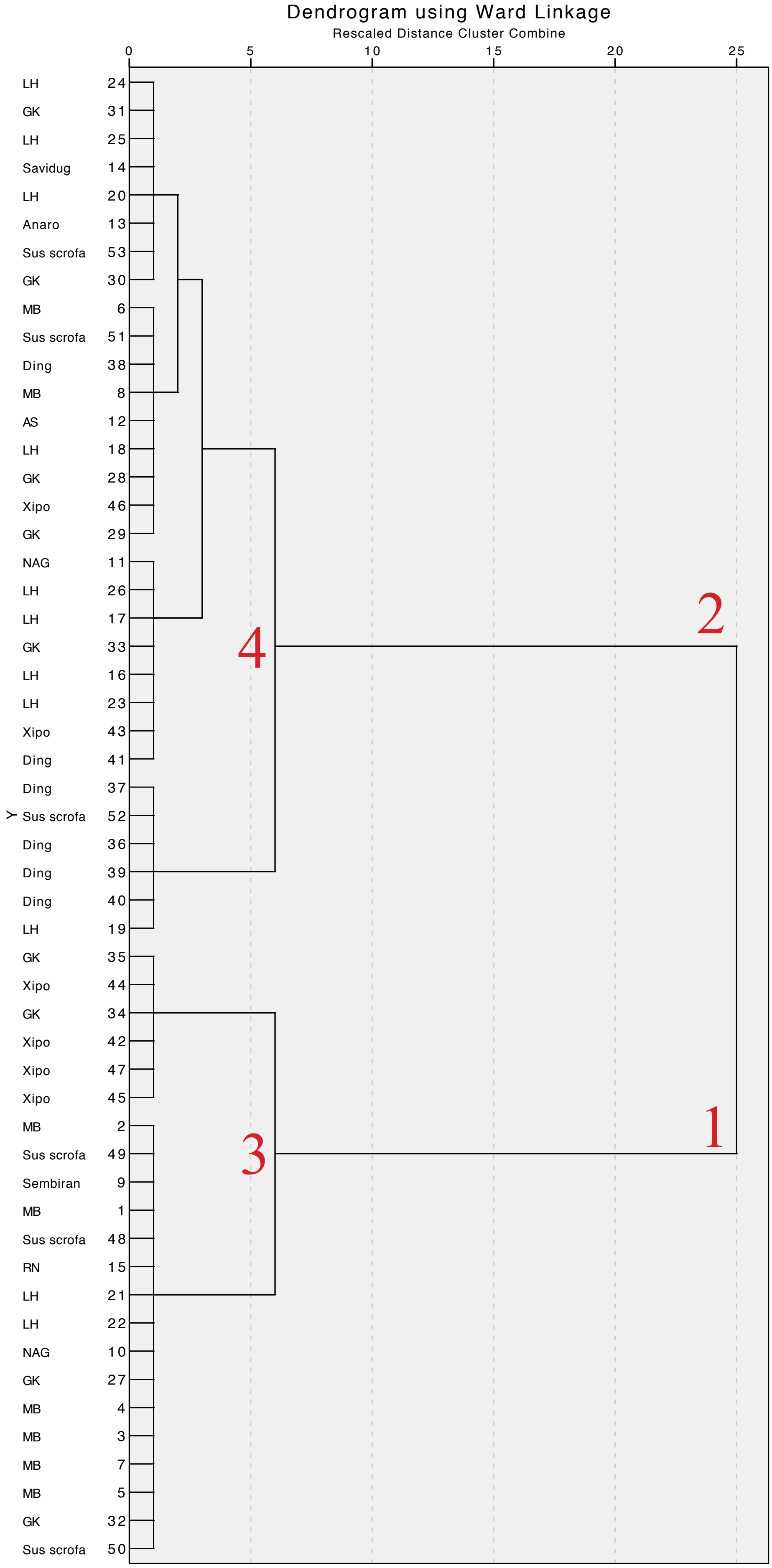

Figure A-6 Pig UM3s dendogram using Ward linkage. Hierarchical analysis indicated either two or four groups. However, the results for the Kmeans analysis and the hierarchical analysis were quite different, Kmeans suggested three groups. Since the groupings were significant with Kmeans and they made more intuitive 'sense', three groups were used.