Leonor Soares Carreiro Gonçalves Filipe

Use and Abandonment:

Interpreting a Mesolithic structure through faunal analysis (Cabeço da Amoreira shell midden, Muge)

Uso e Abandono:

Interpretação de uma estrutura mesolítica através da análise faunística (concheiro do Cabeço da Amoreira, Muge)

UAlg FCHS
UNIVERSIDADE DO ALGARVE
FACULDADE DE CIÊNCIAS HUMANAS E SOCIAIS

Faro, 2024

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Master in Archaeology

Work carried out under the guidance of
Doctor Anna Rufà Bonache and Doctor Célia Gonçalves

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Declaration of authorship of work

I declare myself to be the author of this work, which is original and unpublished.

Consulted authors and works are duly cited in the text and are included in the list of references included.

Aos meus avós e pais.

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Resumo

As alterações climáticas do Holoceno marcaram o início de uma transição drástica nas estratégias de subsistência das comunidades humanas, alterando paisagens e criando novos nichos ecológicos que poderiam ser explorados e aproveitados. Na Europa, as últimas comunidades de caçadores-coletores demonstraram um crescente interesse na exploração de recursos aquáticos, como representado pela variedade e quantidade de concheiros encontrados em áreas costeiras e ribeirinhas ao longo da costa atlântica e do sul da Escandinávia (Gutiérrez-Zugasti, et al., 2011). Os concheiros de Muge (Salvaterra de Magos, Santarém) são um exemplo desse fenômeno e têm sido um dos grandes focos dos estudos mesolíticos em Portugal nos últimos 160 anos. Através de uma extensa coleção arqueológica, estes concheiros representam a complexa relação que as últimas comunidades de caçadores-coletores da bacia do Tejo tinham com sua paisagem e os recursos disponíveis.

Depois de mais de um século e meio de investigação e múltiplas campanhas arqueológicas foi criada uma impressionante coleção arqueológica e paleoantropológica. Do ponto vista faunístico, uma longa lista taxonómica de mamíferos, anfíbios, répteis, aves, peixes e invertebrados, tem vindo a ser identificada. Estes foram objeto de vários estudos, como os de Lentacker (1986), Detry (2007), Pereira (2014) e Dias (2017). Em 2008 iniciou-se um projeto que instigou escavações arqueológicas anuais no concheiro do Cabeço da Amoreira, disponibilizando assim a oportunidade de estudos extensivos e comparativos, com o auxílio de novas metodologias colocadas em prática. As escavações em curso incluem atualmente georreferenciação da maioria (ver seção 3.1 Metodologia: Escavação e Materiais) dos materiais arqueológicos, o que fornece um amplo conhecimento sobre a distribuição especial de artefactos. Esses dados mostraram-se úteis na identificação de ações como o arrastamento de sedimentos (Aldeias & Bicho, 2016), acumulação de líticos (Belmiro, et al., 2020), eventos de deposição únicos, como a Feature A (Gonçalves, et al., 2018a).

Após o trabalho de Pereira (2014) nos níveis mais altos do concheiro, e comparando com o extenso estudo das faunas em toda a estratigrafia por Detry (2007), visa-se compreender a história diacrônica deste sítio arqueológico através da análise de materiais provenientes dos níveis inferiores. Adicionalmente, beneficiando de novas metodologias de escavação e documentação dos últimos projetos que têm ajudado a identificar numerosos contextos bem definidos espacialmente estruturados, esta dissertação propõe a análise dos restos faunísticos da estrutura denominada de Feature C. Este estudo procura compreender a funcionalidade da estrutura, e testar como os dados espaciais podem ser essenciais para entender a distribuição

faunística em nível intra-estrutura em relação a processos deposicionais e pós-deposicionais. O conjunto faunístico será analisado em termos anatómicos e taxonómicos, e será realizada uma análise tafonómica. É esperado que os dados recuperados desta análise poderão ser enquadrados dentro das estratégias de subsistência reconhecidas em estudos anteriores e explorar a utilização de certas espécies pela comunidade que habitava o amontoado de conchas. Além disso, visa-se compreender os processos pós-deposicionais pelos quais os restos faunísticos passaram, ilustrando o ambiente de abandono da Feature.

A Feature C foi identificada dentro da camada 9 devido a uma aparente concentração de restos faunísticos, carvões e termoclastos nos quadrados de escavação A1 e B1 durante as campanhas de 2022 e 2023. Observações *in situ* sugeriam uma possível funcionalidade como estrutura de combustão, e ficou evidente através dos perfis que a estrutura se estendia para os quadrados A2 e B2 escavados em 2016 e 2018, respetivamente. Em A2 e B2, outras estruturas e depósitos tinham sido identificados (Feature Be Bone Cluster), mas uma relação entre os mesmos não tinha sido identificada. Tronou-se evidente graças a documentação das intervenções anteriores que a Feature C, Feature B e o Bone Cluster eram um único contexto. Como estes depósitos não tinham sido inicialmente identificados como partes de uma estrutura de combustão nem mesmo relacionados entre si até a terceira campanha arqueológica (2022), os materiais das campanhas anteriores tiveram de ser reanalisados seguindo os parâmetros do estudo atual (ver Capítulo 3. Metodologia), e análises espaciais foram realizadas para compreender o relacionamento entre os depósitos identificados, bem como estabelecer o tamanho total da estrutura. Além disso, uma vez que todos os quadrados mencionados foram individualmente escavados, os artefactos exumados poderiam ter sido suscetíveis à degradação dos perfis arqueológicos. Consequentemente, a análise espacial também é importante para entender o grau de erosão que poderia ter afetado a Feature e como isso poderia ter afetado a distribuição de artefactos.

Esta estrutura, como possível estrutura de combustão, permitirá novas interpretações sobre o consumo animal nos níveis inferiores do concheiro e demonstrará a eficácia das novas metodologias na recontextualização de materiais durante o trabalho de laboratório. Com os dados coletados, o objetivo é identificar um padrão de consumo animal que possa integrar ou diferir das estratégias de subsistência previamente estudadas do local; bem como, compará-la com outras estruturas identificadas neste sítio arqueológico. Além disso, espera-se que a análise faunística realizada forneça informações valiosas em termos de tafonomia – permitindo que um segundo objetivo seja alcançado: a identificação de agentes acumuladores não humanos e a representação da história pós-deposicional da estrutura.

Os resultados são comparados com análises faunísticas anteriores para enriquecer as descobertas deste estudo, pois uma abordagem comparativa ajudará a obter uma perspetiva mais ampla sobre o conjunto faunístico e alcançar uma perspetiva diacrónica da ocupação do local e do uso destas estruturas. Esses objetivos permitiram uma melhor compreensão das mudanças comportamentais ao longo do tempo e mostrarão como os restos faunísticos podem ser cruciais para entender a história da acumulação e pós-deposicional das estruturas arqueológicas, iluminando os papéis desempenhados por agentes antrópicos, carnívoros e naturais, que influenciam este sítio.

Este estudo reforçou os dados paleoecológicos já conhecidos e descobriu dois possíveis momentos de atividade dentro da estrutura: um primeiro de origem antrópica (o uso do recurso), que fornece dados dietéticos, e o abandono da estrutura pelos humanos, evidenciado pela extensa atividade carnívora. Através desses objetivos, esperamos contribuir para uma compreensão mais profunda das relações entre as comunidades humanas mesolíticas e seu ambiente, bem como os processos de preservação e alteração que moldaram o registo arqueológico no Cabeço da Amoreira.

Palavras-chave: Vertebrados terrestres; Zooarqueologia; Subsistência; Tafonomia;

Abstract

The Mesolithic is a chronological period characterized by the climate and environmental changes associated with the end of the Pleistocene and the early Holocene (c.8.5-6 kyr BP in the Iberian Peninsula). These changes create new ecological niches with resources that could be exploited, which has been repeatedly observed in archaeological and paleoenvironmental records. It is now widely accepted that the exploitation of marine and riverine resources intensified during the Mesolithic. Nevertheless, it remains less clear how these changes affected the consumption of smaller terrestrial vertebrates.

When examining the shift in subsistence strategies among the last hunter-gatherers of the Tagus basin, the Muge shell middens stand out as an excellent example of complex resource exploitation. Their extensive collection of terrestrial and aquatic fauna, of which a substantial amount remains to be analyzed, provides the opportunity to conduct comprehensive studies not only on human subsistence behavior but also on the complex depositional history of the site. With this goal in mind, this study examines the terrestrial vertebrates found in Feature C of the Cabeço da Amoreira shell midden during the 2016-2023 archaeological campaigns.

Feature C's uncommon spatial preservation and concentration of archaeological materials suggested it may be a combustion structure. The feature is expected to yield valuable insights regarding this community's dietary habits by analyzing the remains of terrestrial vertebrates encompassing taxonomical, anatomical, and taphonomical aspects. Additionally, this study will fill a gap regarding the scarcity of taphonomic records and analyses done on this site, providing important information regarding the feature's accumulation processes and post-depositional history –particularly on anthropic, carnivorous, and other natural agents.

The results will be compared to prior faunal studies conducted in the Muge shell middens to understand how they might integrate and complement previous interpretations of the sites.

Keywords: Terrestrial vertebrates, Zooarchaeology, Subsistence, Taphonomy

1. Contents

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1. Introduction

The evolution of human societies along coastal regions during the Mesolithic period was marked by the exploitation of aquatic resources and, ultimately, the creation of shell middens. These middens, characterized by their deposits predominantly composed of shells with thin sedimentary matrices, are emblematic of recurrent coastal resource exploitation and represent significant transformations in foraging strategies. Shell middens have since been used as a proxy for social complexity, reflecting shifts in subsistence strategies, environmental adaptations, and climate changes (Hockett & Haws,2003; Bicho & Esteves, 2022; Hocket & Haws, 2004).

The climate changes of the Pleistocene-Holocene transition marked the beginning of a drastic shift in the subsistence strategies of human communities. These climatic fluctuations profoundly affected the environment, raising temperatures, expanding forests, increasing biodiversity, and reshaping the landscape, creating favorable conditions for the emergence of new ecological niches. This period of environmental flux, punctuated by warm and cold phases, spurred adaptation strategies among hunter-gatherer communities across Europe's varied biomes. Overall, the last hunter-gatherer communities showed a growing interest in the exploitation of aquatic resources, as represented by the variety and quantity of shell middens found in coastal and riverside areas along the Atlantic coast and southern Scandinavia. These middens can be found along the Atlantic façade, the Cantabrian coast of the Iberian Peninsula, the French coastline, the British Isles, and northern Europe, and they represent early manifestations of established coastal adaptations in Europe, illuminating the intricate interplay between human societies and coastal environments (Gutiérrez-Zugasti, et al., 2011). One of Portugal's most renowned examples of this behavioral evolution is the Muge shell middens (Salvaterra de Magos, Santarém). These mounds have been at the heart of Mesolithic studies in Portugal for the past 160 years and have spurred countless researchers and projects.

The latest sequence of projects and research at these sites started in 2008 when a research team from the University of the Algarve, led by Nuno Bicho, started annual archaeological field seasons funded by Foundation for Science and Technology (FCT). Currently, research at the archaeological site is funded by the EarthWatch Foundation, coordinated by Célia Gonçalves, allowing the continuation of archaeological interventions. Since then, an extensive collection of archaeological materials has been uncovered, permitting a greater understanding of the last hunter-gatherers of the Tagus basin. The faunal assemblage has amounted to a vast taxonomic list comprised of mammals, amphibians, reptiles, birds, fish, crustaceans, and invertebrates. As the collection continues to grow with recent excavations, so does the need for analysis.

Studies such as those developed by Lentacker (1986), Detry (2007), Pereira (2014), and Dias (2017) have significantly advanced the knowledge of the complex relationship that the hunter-gatherer communities of the Tagus basin had with their landscape and the resources available. Together, they have laid the foundation for studies contemplating the middens' inter-site and intra-site diachronic history. Additionally, new methodologies such as georeferenced documentation of materials have permitted the development of more precise spatial analysis, permitting the identification of complex actions such as the dragging of sediments (Aldeias & Bicho, 2016), lithic accumulation (Belmiro, et al., 2020), single accumulation events (Gonçalves, et al., 2018a).

Excavation from the lower levels in recent years has augmented the faunal collection. The analysis of these faunal remains, as well as studies conducted by Detry (2007), Pereira (2014), and Dias (2017), have provided additional insights into the diachronic history of the site. The presented study benefits from these studies for comparative analysis and the new excavation and documentation methodologies from the latest projects, which have aided in identifying numerous well-defined spatially structured contexts. As such, this dissertation proposes the analysis of Feature C of Cabeço da Amoreira.

Feature C was identified within layer 9 due to an apparent concentration of faunal remains, charcoals, and fire-cracked rocks in the A1 and B1 excavation quadrants during the 2022 and 2023 campaigns. *In situ* observations acknowledged it as a possible combustion structure, and it was made evident through the quadrant profiles that the feature extended into the A2 and B2 squares excavated in 2016 and 2018, respectively. In A2 and B2, other features and deposits had been identified (Feature B/Animal 2 and Bone Cluster), but their relationship with Feature C was made clear by georeferenced data and have since then been renamed Feature C as well. Since these deposits were not initially identified as parts of a combustion feature nor related to one another until the third field season (2022), materials from these previous campaigns had to be re-analyzed following the current study's parameters (see Chapter 3. Methodology). Additionally, since all mentioned quadrants were individually intervened, the exhumed artifacts could have been susceptible to degradation of archaeological profiles. Consequently, spatial analysis is also essential to understand the degree of erosion that could have affected the Feature and how it may have affected artifact distribution.

This study aims to analyze and interpret the faunal remains found in Feature C with the hopes of addressing the need for analysis of the materials recovered in recent years and testing how spatial data could be essential for understanding faunal distribution on an intra-feature level regarding depositional and post-depositional processes.

The faunal assemblage will be analyzed in anatomical and taxonomic terms, and taphonomic analysis will be conducted. The recovered data will be compared with previous faunal analyses to enrich this study's findings, as a comparative approach will help gain a broader perspective on the site's faunal assemblage and achieve a diachronic perspective of the site's occupation. This comparative approach is expected to contextualize the faunal remains within the paleo-environmental and paleo-economic contexts identified in previous studies, either proving a continuity within the site or disproving it.

Anatomic and taxonomic identifications will prove helpful in evaluating the subsistence strategy employed. Aspects such as prey selection will be analyzed to analyze the age profiles of hunted prey and understand hunting strategies. Other factors in animal consumption include preferential transport of body parts, which may relay information regarding the distance of prey from the site. Additionally, this data will provide insights into the roles of small and large game in the subsistence economy.

Taphonomic analysis is expected to identify the accumulating agents by discerning patterns of human and carnivore activity within the site and assessing the impact of post-depositional processes on the preservation and distribution of faunal remains within the archaeological feature. This step will help identify different phases of occupation and abandonment of the structure; it will also provide information regarding human-carnivore relationships, whether commensal or domesticated.

Aside from the previously stated objective, the spatial analysis also provides information regarding patterns of dispersion, specific taxa, and taphonomic modifications, which might relay important information regarding the use of the feature and its abandonment, such as identifying possible areas of activity or intentional depositions.

In the most extensive faunal studies on the site, spatial analysis has not, for the most part, been sufficiently acknowledged. It is, then, the hope of this research to also demonstrate how effectively these new methodologies have aided in the recontextualization of materials during lab work. With the gathered data, the goal is to identify a pattern of animal consumption that might integrate or differ from previously studied subsistence strategies of the site. Additionally, it is expected that the faunal analysis undertaken to achieve that goal will also provide valuable insights in terms of taphonomy – allowing a second objective to be met: the identification of non-human accumulating agents and the portrayal of the post-depositional history of the feature.

This study aimed to analyze the faunal assemblage of the feature, focusing on the primary fundamental goals of this research, such as interpreting the archaeological record, discussing issues related to the diachronic history of the site, and examining human behavior over time, as well as interpreting the post-depositional processes to understand the history of the feature, it is functionality, accumulating agents and post-depositional history.

2. State of the Art

2.1. Coastal Adaptations

One of the factors that prompted the recognition of marine resources in the diet of early modern humans (*c.* 300 ka) was the vital role of their nutritional contribution to the development of cognitive complexity. Some nutritional values necessary for the development of the nervous system, pregnancy, and early childhood are not internally produced and are, therefore, a testament to the pivotal role the consumption of aquatic resources had on the evolution of the human brain and nervous system (Bicho & Esteves, 2022; Hockett & Haws,2003, 2004; Will, et al., 2019).

In South Africa, Marean (2011, 2014) suggests that exploiting marine resources already portrays complex cognitive abilities, as their exploitation requires knowledge of their availability, accessibility, and lunar and tidal cycles. This researcher added that shellfish provided a predictable coastal resource, allowing for reduced mobility and higher population densities, inciting prosocial behaviors to approach an increasingly complex social structure, and minimizing intergroup conflicts (Marean, 2011, 2014).

A recurrent problem in the study of coastal adaptations is the absence of a consensus among researchers on the definition of the term itself. Several authors have tried to mitigate this issue by proposing definitions. However, these proposals can be loosely interpreted and applied subjectively, as they are stated without a proper hierarchization of resource exploitation (Bicho & Esteves, 2022). Authors such as Beaton (1995) pointed out that proximity to coastal areas or residual remains of marine and riverine resources does not indicate a coastal adaptation and that the site's location does not prove systematic use of these resources.

Effectively mitigating the issue regarding subjectively appliable terms, Marean (2014) proposed a hierarchical approach that distinguished between degrees of coastal resource exploitation. Despite the focus on sea-related resources, this researcher acknowledges that coastal adaptations refer to aquatic resources, whether marine or riverine/lacustrine.

Marean's (2014) focus is distinguishing the **Systematic Use of Coastal Resources** from **Coastal Adaptation.** Systematic use of coastal resources refers to the regular consumption of these resources, making them a significant part of these communities' diets and, consequently, their foraging systems; however, in these cases, human settlements and economics are not altered by coastal resource exploitation.

> *"So, systematic use of coastal resources is when coastal resources are part of a plan, occur regularly and recurrently, but the use of these resources is not transforming. A 'coastal adaptation' is when the adaptation has been transformed to revolve around the sea."*
>
> (Marean, 2014, p. 20)

For coastal adaptation to be proven, Marean claims that the mobility system must have been adapted for exploring coastal resources. These foods become a significant portion of a community diet, and henceforth, mobility either accounts for recurrent returns to that specific ecological niche or the communities become somewhat sedentary with permanent settlements in coastal areas (Bicho & Esteves, 2022; Marean, 2014).

How to distinguish between systematic use and coastal adaptation in the archaeological record is more complex; Marean (2014) proposes that the only unequivocal representation of coastal adaptation is shell middens. These middens are deposits of varied shape and size, whose sediment is comprised mainly of shells, with a thin sedimentary matrix that fills the negative spaces between them (Bicho & Esteves, 2022). Marean (2014, p. 23) claims, "*With shell middens, the deposition of the shell was so fast that it exceeded the deposition of sediment,*" making them unequivocal proof of recurrent exploitation of coastal resources and of the significant transformation of foraging strategies – the parameter that differentiates coastal adaptation and systematic use of resources.

Marean (2014) also mentions the **Sporadic Use of Coastal Resources**, referring to communities not organized around a body of water to a local or regional degree. In these groups, mobility is higher, and resource exploitation of coastal resources is not recurrent, regular, or cyclical (daily or monthly). The occasional use of these resources in no way reflects a coastal adaptation, as there is no indication of scheduled or recurrent foraging. Therefore, a singular deposit with a small number of shells is not an indicator of even systematic consumption.

Archaeologically and ethnographically, coastal environments have proven optimal for sustained habitation, fostering the development of complex human societies characterized by elements such as social inequality, group identity, and territoriality – apparent by the establishment of territorial landmarks (Bicho & Esteves, 2022). In this regard, shell middens serve as a proxy for social complexity and coastal adaptations, making them remarkable sources of information about human behaviors concerning the shift in subsistence strategies and human lifeways, environmental adaptations, and climate changes. Using Marean's (2014) definitions, it may be concluded that the first significant signs of established coastal adaptations in Europe were the Mesolithic shell middens found along the Atlantic façade and the Cantabrian coast of the Iberian Peninsula, the French coastline, the British Isles, and northern Europe.

Coastal adaptation and extensive exploitation of aquatic resources do not equate to the abandonment of other resources, such as terrestrial vertebrates. The "*Adaption to marine resources can not be separated from the role played by terrestrial game and plants*" (Jonsson, 1995, p. 147) – it is evident in archaeological assemblages that hunting continued to be prevalent and that meat was a significant part of diets.

2.2. The Mesolithic

2.2.1. A General Overview

The Mesolithic is a chronological period proposed by Hodder Westropp in 1872 that is characterized by the climate and environmental changes associated with the end of the Pleistocene and the early Holocene. These changes correspond with the incremental heat that is associated with the end of the last Ice Age, which, through rising sea levels, forest growth, and increased biodiversity, created an optimal setting for new ecological niches with resources that could be exploited, such as repeatedly observed in the archaeological and paleoenvironmental records (Pereira, 2014; Zander & Gehlen, 2020).

The general rising temperature during the final stages of the Pleistocene was interspersed with warm (interstadial) and cold (stadial) episodes (Table 2.1) until it stabilized into the warm period known as the Holocene (Naughton, et al., 2016; Rodriges, et al., 2010). These phases (interstadial and stadial) affected the reforestation of some European areas, namely the northwestern portion. The accelerated pace of climate changes meant that hunter-gatherers had to continuously adapt to the fluctuating climate, which spawned distinct adaptation strategies across a wide range of European biomes (Zander & Gehlen, 2020).

The Mesolithic is currently divided into several periods. Other terminologies are applied, such as Early Mesolithic in reference to the pre-boreal and boreal periods and Late Mesolithic for the Atlantic period until the early Neolithic (Carvalho, 2009). Other researchers, such as Nuno Bicho (1993), have also proposed the term "Epipaleolithic" to denote Holocene sites that show elements of continuity from the Late Upper Paleolithic (10.5-8 ka). In that sense, the Mesolithic would be applied to sites from the Atlantic period (8.5-6 ka.) based on the lack of continuity regarding technologies, subsistence economies, and settlement patterns compared to the Late Upper Paleolithic. Other researchers, such as Arnaud (1987), showed a preference for an "early" and a "late" Mesolithic terminology based on similar criteria (Clark, 2000).

TABLE 2.1
List of climatic episodes during the Pleistocene-Holocene transition. Table adapted from Silva (1993, p.121)

Climatic Periods (Pollen zonation of N. Europe)		**Dates (BP)**	**Climate Characteristics**
Post Glaciar (Holocene)	Sub-Atlantic	3000-(…)	Current
	Sub-boreal	5000-3000	Warm and dry
	Atlantic	8000-5000	Warm and humid
	Boreal	9000-8000	Warm/hot and dry
	Pre-boreal	10000-9000	Transition cold/warm
Late Glaciar (Pleistocene)	Dryas III	10800-10000	Cold period (stadial)
	Allerod	11800-10800	Interstadial period
	Dryas II	12400-11800	Cold period (stadial)
	Bolling	13000-12400	Interstadial period

Authors have pointed out that there was an inherent passivity in the first designations of the Mesolithic period:

> *"Clark's (1932: 5) definition of the period as 'between the close of the Pleistocene and the arrival of the Neolithic' (...), the period appears to be caught between two apparently inexorable and inescapable event, the first environmental and the second cultural."*
>
> (Spitkins, 2008, p. 4)

Initial presumptions of this period were that of severe hardships – the Mesolithic hunter-gatherers were said to have struggled as megafaunas' population density fell or migrated, attested by the disappearance of complex cultural behavior such as cave art (Silva, 1993). Shell middens and the apparent shift to marine and riverine resources were seen in the academic community as a fallback subsistence strategy, and therefore, the adaptation to marine and riverine environments was a consequence of demographic stress and low resource availability (Bicho & Esteves, 2022). Renown authors, such as Gordon Child and Mortimer Wheeler, viewed Mesolithic communities as impoverished, lacking social/cultural complexity, and of little consequence to European civilization – which, in their view, was kickstarted by the migration of Neolithic societies (Spitkins, 2008).

Academic perceptions of the Mesolithic changed throughout the second half of the 20th century. New theoretical frameworks, together with the development of novel methodologies, such as radiocarbon dating and extensive research in Mesolithic sites, provided the baseline of Mesolithic knowledge. Continuous work on Northwestern European sites revealed socially complex communities living in permanent villages, with specialist groups, food storage, social hierarchy, funerary areas, and high population density comparable to early farming societies – the last hunter-gatherers were now seen as complex and stable, relatively large, groups of individuals who had mastered hunter-gatherer strategies entirely (Silva, 1993; Spitkins, 2008). Through these findings, the Mesolithic was no longer considered a passive and stagnant period in human history, and new interests arose in understanding the Mesolithic communities' complex resource exploitation and the Mesolithic-Neolithic transition (Spitkins, 2008). The Mesolithic's intensification of the exploitation of marine and riverine resources and the adaptation to aquatic environments is now acknowledged to have had an essential role in the reduced mobility of communities and increased human demographics. These are also possible factors for the development of increasingly complex technologies, economic structures, social structures, and subsistence strategies (Bicho & Esteves, 2022; Dias, et al., 2016).

Mesolithic coastal adaptations are reflected throughout Europe (Figure 2.1). The first shell midden ever found was in Denmark during the first half of the 19th century (Gutiérrez-Zugasti, et al., 2011). This is the site Krabbesholm, which was initially subject to much speculation regarding its anthropic origin due to the abnormal concentration of shells. The Danish shell middens were henceforth called Køkkenmødding. This term applies to coastal sites with cultural deposits spanning over an area of at least $10m^{2,}$ in which around 50% of the anthropic layers consist of shells. Sites that did not meet these criteria were called "shell-bearing sites." The oldest Danish midden found dates to c. 5600 cal BC. However, shell middens were not exclusively a Mesolithic phenomenon, as some Køkkenmødding date to the Early Neolithic (Gutiérrez-Zugasti, et al., 2011). In northern Europe, extensive research has shown a diverse taxonomic representation in faunal assemblages with significant variations between sites. Although the prevalence of fish remains within coastal sites, meat continued to contribute to the dietary habits of the Mesolithic communities (Ritchie, et al., 2014).

In the British Isles, shell midden research started in the 19th century. These shell middens of various sizes tend to be open-air sites, except for the shell deposits in caves and rock shelters along the west coast of Scotland. The anthropic origin of some of the larger sites has been debated due to the absence of artifacts in the layers. The Scottish middens date back to *c.* 8000 BC, whereas the Irish middens date to the 6th and 5th millennium BC. These middens are not exclusively used by Mesolithic communities; some Scottish and Irish middens remained in use until historical times. These sites appear to have been temporary occupations (Gutiérrez-Zugastiet, et al., 2011).

Figure 2.1 – Map of the distribution of Mesolithic shell-middens and sites with shell-layers in Atlantic Europe. Authorship: C. Dupont. Source: Gutiérrez-Zugasti, et al., 2011, p.71.

In France, shell middens often date to the 7th and 6th millennium BC and are found on dunes on the coast of Brittany. Most were brown shell-rich layers spread over approximately 100 m^2, between 0.5 to 1 m thick. However, these sites can be seriously affected by erosion from the dunes, which, in addition to rising sea levels, could mean the loss of archaeological sites throughout time. The consumption of terrestrial mammals does not appear significant in these sites. The isotope analysis of human remains in the Téviec and Hoedic shell middens (the only two that contain burials) supports a low meat consumption hypothesis. Some middens display signs of habitational use, such as hearth and paved surfaces, whereas others do not display any anthropic structures.

Little is known about the seasonality of occupation of the sites (Gutiérrez-Zugasti, et al., 2011). In Spain, mollusk in archaeological deposits can be dated to the Middle Paleolithic, and systematic exploitation of coastal resources was first identified in the Upper Paleolithic. Research on shell middens, and by extension, coastal adaptations (using Marean's definitions described in chapter 2.1 - Coastal Adaptations), began in the 20th century with the excavation of the Mesolithic sites of El Penicial and Cueto La Mina. These middens were "large accumulations of shells built up, filling cave entrances to the roof" (Gutiérrez-Zugasti, et al., 2011, p. 76), a phenomenon exclusively found in the western region of Cantabria. In these sites, faunal assemblages mainly comprise marine resources, although terrestrial game is still present (Gutiérrez-Zugasti, et al., 2011).

2.2.2. Mesolithic in the Atlantic Iberia

Environmental stress brought on by the return of colder weather during Younger Dryas led to a greater reliance on small game, particularly lagomorphs, in specific areas of Iberia (*e.g.*, Hockett & Haws, 2007; Villaverde, et al., 1996). In most cases, this shift in subsistence strategies was not accompanied by cultural discrepancies. (McLaughlin, et al., 2021). These climatic oscillations also affected settlement patterns. Late Pleistocene settlement patterns were diverse, having been identified with various coastal and inland occupations. In the Holocene, the archaeological record shows an increased preference for aquatic environments in response to new subsistence strategies that heavily employ aquatic resources. In the Mesolithic, occupations became more common in riverine and estuarine environments than in preceding periods (Bicho, 1994; Dias, et al., 2016).

Located in the westernmost region of the Eurasian continent, the Iberian Atlantic coast seemed less affected by climate changes than the northern areas of Europe. Regardless, the Iberian Peninsula saw a gradual rise in sea levels, changes in flora distribution, and increased forest density (*c*. 8.5-6 ka BP in the Atlantic Period of the Iberian Peninsula) (Clark, 2000). The modifications to landscape and vegetation provided optimal conditions for stable habitats for most faunal populations, especially small species such as lagomorphs and microfauna. The importance of these animals can be seen growing steadily since the Middle Paleolithic and reaching its peak in the Mesolithic diet. These changes in landscape and biodiversity impact not only subsistence strategies but also technologies, settlements, and mobility of communities (Dias et al., 2016).

The most significant signs of diverging cultural elements such as subsistence, technology, and settlement patterns in the Atlantic façade occurred around 8200 cal. BP. A higher dependency on marine and riverine resources and the adoption of geometric microlithic technology became telltale signs of Mesolithic cultures. Aquatic resource exploitation is represented in sites commonly found in paleo-estuaries such as the Muge and Sado shell middens. Despite cultural discrepancies, DNA evidence has proved genetic continuity from the late Pleistocene populations (Bicho & Esteves, 2022).

Modern approaches and theoretical frameworks in Mesolithic research seem to have been relatively recent in Iberia compared to other regions - in the Vasco-Cantabrian region, it dates to the 1970s, whereas in the Atlantic façade of Portugal, only in the 1980s. Clark (2000, p.18) identified a pattern among the first and most relevant comprehensive analyses and syntheses of the Mesolithic in the Iberian Peninsula, claiming they "(…) *share a central "package" of research biases that can broadly be defined as "ecological" and "adaptationist, " and are characterized by research protocols that represent a departure from the lithic- and site-centered typological approaches of earlier generations."*).

In Portugal, Mesolithic research started with discovering the Tagus Valley shell middens of the Muge and Magos rivers. These were first identified in 1863 by Carlos Ribeiro and have undergone over 160 years of research, proving to be invaluable sources of information regarding the last hunter-gatherers in the region. In the Sado Valley, multiple sites are categorized as shell middens, such as Cabeço do Pez and Porças de Sao Bento, which have undergone extensive research since the mid-XIX century. In addition, several projects took place in the Mira Valley (Alentejo), including those at Medo Tojeiro and Samouqueira (Clark, 2000).

In his 2000 paper, Clark described the research efforts stated above as being "*still in the descriptive stages, with much effort expended on chronology building, paleoenvironmental reconstructions, lithic-based time-space systematics* (…), *studies of settlement patterns and subsistence strategies, and dietary reconstructions*" (Clark, 2000, p. 22). Since then, the Muge shell middens have undergone extensive research and excavations. Further efforts have also been made to understand stratigraphic relationships and accumulation and post-depositional processes since the implementation of new excavation methodologies that allow a better spatial understanding of the site.

2.3. The Muge Shell Middens

The shell middens of the Mesolithic complex in the Ribeira de Muge represent seven of the fifteen shell middens located on the Quaternary low and medium fluvial terraces of the left bank of the Tagus River. The remaining ones are located in the Ribeira de Magos (Cabeço dos Môrros, Cova da Onça, Monte dos Ossos, Cabeço da Barragem, Magos de Cima, and Magos de Baixo) and Fonte da Moça (Vale da Fonte da Moça I and Vale da Fonte da Moça II) (Gonçalves, 2014) (Figure 2.2). As mentioned, this area is rich in Mesolithic settlements, which are repeatedly found on Miocene fluvial terraces, areas with easy access to watercourses to explore various resources. These shell middens would be integrated into a brackish water ecosystem, providing access to abundant marine, fluvial, and terrestrial resources (van der Schriek, et al., 2007).

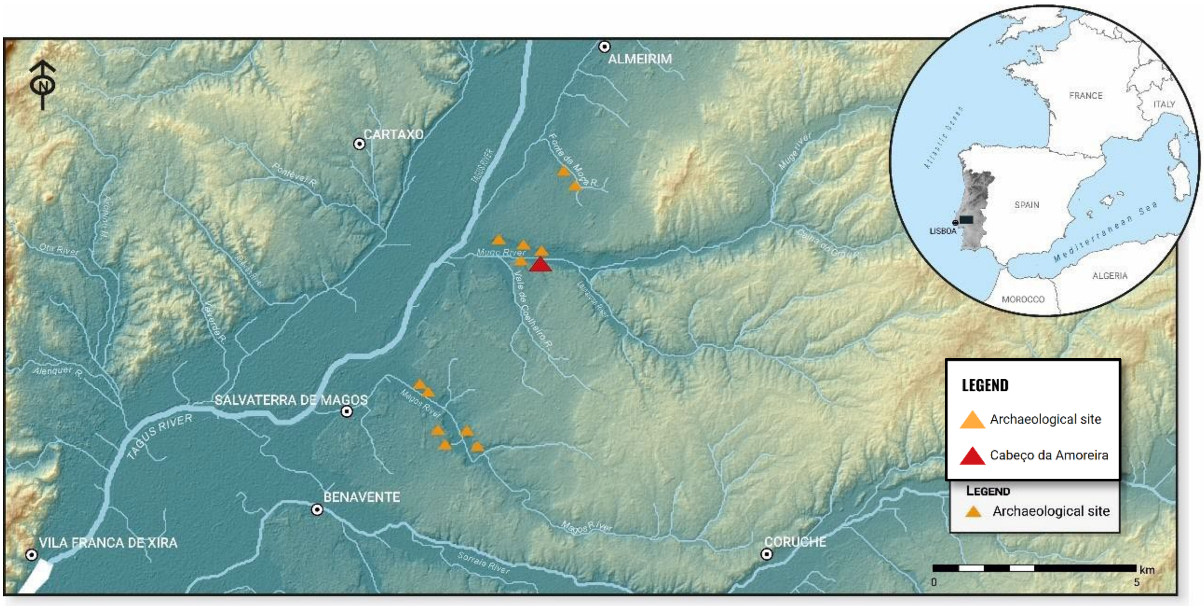

Figure 2.2 -Map displaying the dispersion of the Muge, Magos, and Fonte da Moça shell middens within the Tagus Basin and the Iberian Peninsula. Authorship of Célia Gonçalves. Adapted by Leonor Filipe.

The shell middens are a hallmark of the European Mesolithic. However, some had occupations that extended beyond this chronological period, including signs of Neolithic (Cabeço da Amoreira), pre-Roman, and Roman (Fonte do Padre Pedro) (Bicho, et al., 2015; Cardoso & Rolão, 1999/2000).

2.3.1. *Administrative Context*

The territory encompassed by the civil township of Muge has stood out due to its enormous archaeological potential, as evidenced by the great variety and impressive antiquity of the archaeological sites already identified. Among these, the most internationally renowned are the Muge shell middens, which have been key players in the narrative of the Portuguese Mesolithic since their discovery in 1863 by Carlos Ribeiro (Cardoso, 2023).

The first administrative documentation of Muge dates to 1304, when D. Dinis declared a sovereign charter to facilitate the region's settlement[1]. Over the centuries, it changed several times regarding administrative divisions, such as county and parish. Muge eventually lost its status as a county, being integrated into Salvaterra de Magos as a parish in 1837 by a decree of Queen D. Maria II. Later, it decreased in size when, in 1928, 1966, and 1988, the populated areas of Marinhais, Glória do Ribatejo, and Granho (respectively) became independent, forming their own parishes[2].

Currently, Muge is one of the four parishes that make up the Municipality of Salvaterra de Magos in the district of Santarém. This parish covers an area of 52.03 km^2 and a population of 1,270 inhabitants, according to the 2011 census, corresponding to a population density of 24.4 inhabitants/km^2.[2]

2.3.2. Geological Context

When studying a region to understand the factors that led to successive and prolonged settlements of populations, it is necessary to consider the geographic and geological characteristics that define the area under study. These characteristics reveal elements favorable or unfavorable to its settlement, including geological features, soil type, relief, natural resources, vegetation, and climate (Gonçalves, 2014). These topics will be briefly addressed in the current chapter.

The civil parish of Muge is part of the Cenozoic Tagus-Sado Basin, a Miocene tectonic depression that encompasses the valleys of the Tejo and Sado rivers. This basin is characterized by flat relief at low altitudes, forming a staircase of fluvial terraces with few altimetric variations. It is on these Miocene terraces that most of the Mesolithic human occupations are found, which is crucial for the archaeological study of this region. In the study area, the fluvial and aeolian sand sediments that characterize the fluvial terraces were deposited during the Holocene, forming a flat relief with few altimetric oscillations (Gonçalves, 2014).

The rise in mean sea levels at the beginning of the Holocene was essential in creating

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[1] Sovereign charter that, regulating the administration of a locality, granted certain privileges, in Priberam Dictionary of the Portuguese Language [online], 2008-2023, https://dicionario.priberam.org/foral.

[2] Information available online at: http://www.jf-muge.pt/gp.asp?p=2040751766 [Consulted 15 of February 2024]

deep estuarine environments, as with the Tagus River, allowing areas relatively distant from the coastal zone to benefit from marine influence. This determinant element of the coastal landscape has proven to be one of the most important features that make Muge suitable for successive occupations since prehistoric times, as it reveals a prosperous location concerning available natural resources. The estuary provides the region with rich access to marine, fluvial, and terrestrial resources, benefiting activities such as hunting and agriculture. Additionally, the estuary has been a crucial focal point from prehistoric times to today (Gonçalves, 2014).

The region's climate possesses both Atlantic, temperate, and humid characteristics, as well as Mediterranean features. Therefore, the area is characterized by strong seasonal contrasts (Gonçalves, 2014).

2.3.3. Archaeological History

The first shell middens in the Tagus Valley were identified in the Ribeira de Magos in 1863 by Carlos Ribeiro during a systematic exploration initiative of the Tagus and Sado basins. This initiative began in 1857 under his co-direction at the Geological Commission of Portugal (CGP). Among the discoveries of multiple shell middens, the knapped stone tools were also identified and collected, and stones were initially attributed to the "Tertiary Man." These themes would constitute two major archaeological debates that would become important topics during the IX Session of the International Congress of Anthropology and Prehistoric Archaeology in Lisbon (Cardoso & Rolão, 1999/2000).

Among the multiple archaeological sites identified by this action of the CGPs was Arneiro do Roquete (otherwise known as Quinta da Sardinha) shell midden, the first of its kind to be studied. However, due to the landowner's rejection of archaeological interventions, Carlos Ribeiro's efforts turned to the Ribeira de Muge and the archaeological sites there, effectively initiating archaeological activity in the region (Cardoso & Rolão, 1999/2000).

Thus, in the same year, the first Tejo Valley shell midden was discovered, and the first shell midden in Muge, Cabeço da Arruda, was identified and intervened. Later, it became possible to locate Moita do Sebastião (1863), Cabeço da Amoreira (1864), Fonte do Padre Pedro (1964), and Flor da Beira (1964) (Cardoso & Rolão, 1999/2000; Gonçalves, 2014). In 2014, for her doctoral thesis, Célia Gonçalves identified two additional two shell middens, namely ID15 and ID20, in the Ribeira de Muge.

Early efforts were made to conduct archaeological work at the sites identified by Ribeiro. Consequently, archaeological campaigns were carried out at Cabeço da Arruda in

1863/64, 1880, 1884, and 1885. At Fonte do Padre Pedro, a sondage was conducted in 1880. Campaigns took place at Moita do Sebastião in 1880, 1884, and 1885, and sondages were carried out at Cabeço da Amoreira at an unknown date before 1885. From the interventions at Moita do Sebastião and Cabeço da Arruda, over 120 funerary deposits were identified, an unprecedented number in Europe at that time (Cardoso & Rolão, 1999/2000).

Associated with these discoveries is one of the earliest monographs of Portuguese archaeology. In 1865, Pereira da Costa wrote the first reference work on these shell middens, marking an important moment in the development of archaeology in Portugal (Cardoso & Rolão, 1999/2000).

A significant milestone in the research history of this parish is the visit that the congress participants of the IX Session of the International Congress of Anthropology and Prehistoric Archaeology, held in Lisbon in 1880, made to Cabeço da Arruda and Moita do Sebastião. During this visit, Carlos Ribeiro showcased the archaeological work conducted and these sites' extensive archaeological and anthropological potential. The success of this visit was accompanied by the presentation of the results obtained thus far and the proposal of a prehistoric occupational complex of much larger proportions with multiple sites yet to be discovered and studied - sites that, whether due to natural or anthropic actions, could be currently damaged or even lost (Cardoso & Rolão, 1999/2000).

The municipality of Salvaterra de Magos is known for its archaeological richness, which has attracted prominent figures in Portuguese archaeology during the 20th century. In the 1930s, Hipólito de Cabaço discovered 26 Paleolithic and Mesolithic stations in the municipality, which earned him international recognition (Raposo, 2015). Professor Dr. António Mendes Corrêa also began his archaeological work at Cabeço da Amoreira with the support of the Institute of Anthropology of the Faculty of Sciences of Porto during the summers of 1930, 1931, and 1933. In 1937, he began work at Cabeço da Arruda (Cardoso & Rolão, 1999/2000). In 1952, Mendes Corrêa, as the director of the Institute of Anthropology at the University of Porto, assigned Jean Roche and Octávio da Veiga Ferreira of the Geological Services of Portugal with emergency interventions at the Moita do Sebastião shell midden after it was substantially destroyed for rice cultivation (Alvim, 2009/2010). Mendes Corrêa revisited Cabeço da Amoreira in the 1960s with new archaeological campaigns, entrusting Jean Roche and Octávio da Veiga Ferreira, and funded by the Geological Services of Portugal (Cardoso & Rolão, 1999/2000)

In the 1980s and 1990s, researchers under the direction of Farinha dos Santos, such as José Manuel Rolão, were able to identify and subsequently excavate the Fonte da Moça I shell midden, as well as Cabeço de Morros in the Magos River further south. Rolão and Roksandic highlighted that after 140 years of research, "*(...) there were no systematic studies of the palaeoenvironment, the publication of the documentation and different archaeological materials from these early excavations were patchy, and the analyses of micro- and macro-spatial contexts of the sites were practically non-existent (...).*" (Rolão & Roksandic, 2007, p. 78). These concerns were why, in a project that took place between 1999 and 2004, Dr. José Manuel Rolão carried out two field seasons at Cabeço da Amoreira (2001, 2002). This project aimed to fill in the gaps regarding site formation processes, the stratigraphic relationship between structures, and the overall knowledge of the last hunter-gatherers and landscapes of the lower Tagus valley (Gonçalves, 2014; Rolão & Roksandic, 2007).

Since then, the Foundation for Science and Technology (FCT) funded the project proposed by Nuno Bicho in 2006, *The last hunter-gatherers of the Tagus Valley – The Muge shell middens* (PTDC/HAH/64185/2006), and in 2011, *The last hunter-gatherers of Muge (Portugal): the origins of social complexity* (PTDC/HIS-ARQ/112156/2009). Since 2018, archaeological excavations have been funded by the project *MUGEPORTAL - The Muge Shell middens Project: A new Portal to the Last Hunter-gatherers of the Tagus Valley* (ALG-01-0145-FEDER-29680) and by the EarthWatch Foundation with the project *Discovering ancient societies in Central Portugal: The Muge Shell middens*, under the direction of Célia Gonçalves.

Radiocarbon dating

The first carbon dating of the Muge shell middens was done in 1954, pioneering the application of this methodology in Portuguese archaeological research. The samples dated were from a batch of charcoals from Moita do Sebastião estimated to originate from 7350 ± 350 years BP. Samples from this same batch were subsequently re-dated in 1971 and were estimated to date from 7080 ±130 years BP. Further samples were sent for dating over the decades, including from osteological remains from Moita do Sebastião, Cabeço da Arruda, and Cabeço da Amoreira (Detry, 2007; Roksandic, 2006). More recently, the projects led by Nuno l and Célia Gonçalves have submitted many samples for radiocarbon dating, allowing for a better understanding of the site's occupation (Bicho, et al., 2013a).

2.3.4. Cabeço da Amoreira

The site is located on top of a river terrace about 20 meters above the current sea level. It has an elliptical shape with approximately 90 meters in length (N-S) and 50 meters in width (E-O) (Belmiro, et al., 2020). Cabeço da Amoreira stands out for its horizontal and stratigraphic extension, as well as its layers rich in archaeological materials and a high frequency of human burials (Bicho, et al., 2011; Cunha, et al., 2003)

Extensive excavations took place in the 1930s by Mendes Corrêa, with the support of the Instituto de Antropologia of the Faculdade de Ciências do Porto, during the summer of 1930, 1931, and 1933 (Cardoso & Rolão, 1999/2000).

Between 1958 and 1967, Jean Roche excavated a 25m trench, until a depth of 3.20m, with a stratigraphic sequence of 39 layers. These layers were grouped within three occupation phases. The first phase (layers 33-39) corresponds to its earliest occupation (*c.* 7030± 350 BP) with some negative structures such as pits. The second phase of occupation (layers 32-8) corresponds to a habitation area on the NW and a domestic waste area on the SE; layers in this phase are described as mostly parallel with few disturbances, such as pits. During the last phase (layers 7-2), the shell midden was flattened, and sediment was dragged mostly SE; some pits are documented. Layers 3-4 were carbon dated to *c.* 6050 ± 300 BP (Roche, 1989). Roche observed similar patterns in occupation amongst the Cabeço da Arruda and, possibly, Moita do Sebastião shell middens and poses the question, "*To what extent was the Mesolithic Population of Muge a nomadic one*?" (Roche, 1989, p. 612).

Bicho and colleagues (2011) suggest that the site initially served as a residential area, probably simultaneously but spatially separated from funerary function. After this period, there is little evidence of residential occupations, and the site likely served as a location for resource exploitation, mainly shellfish. The radiocarbon dating obtained from various samples suggested that the approximately 2-3 meters of shell-rich layers were deposited relatively quickly, possibly in several short phases, between *c.* 7900 and 7500 cal BP. Following this, the midden was closed by a cairn of river pebbles and seemingly abandoned. The identification of pottery fragments and human burials on top of the shell midden and traces of excavated areas around the midden also revealed a significant Neolithic occupation of the site (Bicho, et al., 2011; 2013b).

The presence of varied structures and their stratigraphic location in the site, the vertical accumulation and reshaping of shell layers, and the multiple human burials indicate that the site did not serve a single function. This shell midden changed roles through time, with a clear residential phase in the beginning, probably simultaneously but spatially separated, with the funerary function. After that, there is very little evidence for *in situ* habitation, and the site may only represent a space for resource exploitation and deposition of food waste (Bicho, et al., 2011)

Recent studies demonstrate the complexity of the occupations and layers of the midden, providing the opportunity to test how it may be reflected in material culture. By using spatial data obtained during excavations, it has been possible to correlate lithic technology with other data, such as the frequency of faunal remains or charcoals, to understand better the occupations' characteristics, such as the activities taking place (Belmiro, et al., 2020). Through micromorphological analysis of sediments Aldeias and Bicho (2016) highlighted complex occupation patterns, including the redeposition and dragging actions of sediment and archaeological materials.

Despite concluding that the archaeological site was a non-residential space for most of its occupation, there is still a need to understand the possible uses and activities that took place within the various stratigraphic layers, which may reflect behavior patterns and how these may change or perdure through time.

2.3.5. Hearths, Structures and Deposits

At the time of the first archeological interventions, stratigraphical studies were not commonplace. Instead, the archaeological sequence was divided into three broad categories: the "Upper," "Middle," and "Lower" levels. A growing interest in stratigraphic complexity and the relationship between layers and structures became evident with the Jean Roche interventions of multiple shell middens between 1952 and 1973 (Alvim, 2009/2010; Roche, 1989).

In 1989, Roche wrote a publication on the spatial organization within the Moita do Sebastião, Cabeço da Arruda, and Cabeço da Amoreira shell middens. At Cabeço da Amoreira (1958-1967), as previously mentioned, the three phases of occupation were all rich in negative features, such as pits, though not extensively detailed (Roche, 1989).

Multiple structures were identified in Roche's excavations of Moita do Sebastião, namely 96 negative structures (35 pits and 61 post holes) and combustion areas. Negative structures were separated into five types: post holes, flat pits (*fosses plates*), deep pits (*fosses profondes*), shell silos, and holes (*trous*) – the distinction of typologies was made based on morphology, dimensions, dispersion, and (apparent) function. The relationship among negative structures identified in these excavations was Roche's target of great speculation. However, little literature has been found concerning the fire pits/hearths or areas that appear to be altered by combustion. Some pits of the flat variety seemed to have been used for food waste (*e.g.*, pit 86 of Moita do Sebastião) due to the characteristics of the sediment and artifacts. In the case of pit 86, it appeared to be filled with "(…) *terra negra, muito dura, com ossos calcinados e* *termoclastos, areias com cinzas e bolsas de brecha com cinzas* (…)" (Alvim, 2009/2010, p. 22)[3].

Only recently, more specifically with the research groups led by José Rolão at the turn of the century and Nuno Bicho since 2008, were the stratigraphic relationships between structures and artifacts more thoroughly analyzed to finally answer all the relevant questions that previous interventions raised regarding the origin of the archaeological materials and the stratigraphic dynamics themselves (Bicho, et al., 2013b).

During Nuno Bicho's first project, hearths were found in a newly excavated area and the area previously excavated by Mendes Corrêa. In 2010, a test pit uncovered two hearths characterized by the disposition of mainly thermally altered cobbles in circular or semi-circular shapes and charcoals. This same year, Bicho's team uncovered two hearths in the area previously excavated by Mendes Corrêa in the 30s: Lareira 1 and Lareira 2. Both Lareira 1 and 2 were built on top of pits (Figure 2.3), Lareira 2 being composed of thermally altered clasts and a depth of around 10cm (Bicho, 2010). In 2011, Bicho and colleagues described hearths at Cabeço da Amoreira as "*less than 50 cm in diameter, structured by a series of cobbles set in a circular or semi-circular position. They are usually fire-cracked and charcoal-stained with a few quartzite flakes around or within them. Few shells seem to be associated with them*" (Bicho, et al., 2010, p.10).

The 2014 archaeological field season allowed the identification of well-defined spatially structured contexts, such as Feature A. This context comprised a high density of red deer (*Cervus elaphus*) bones, lithics, charcoals, and fire-cracked rocks within an area of approximately 1m^2. Analyzing and refitting the faunal and lithic assemblages and examining georeferenced spatial information allowed researchers to define spatial limits and establish density patterns within the layers and the structure (Gonçalves, et al., 2018a).

In recent years, fieldwork has identified other features and deposits that show spatial complexity. For example, Feature C, a possible combustion structure such as a hearth, will allow new interpretations regarding animal consumption in the lower levels of the midden and demonstrate how these new methodologies have aided in identifying features and re-contextualizing materials.

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[3] Proposed translation: "(…) *dark earth, very hard, with calcined bones and thermoclasts, sands with ashe and pockets of breccia with ashe* (…)".

2.3.6. Faunal Studies

The most systematic and informative studies regarding the fauna of Cabeço da Amoreira were first by Lentacker (1986) and then by Detry (2007). Lentacker analyzed the faunal assemblage, vertebrates, and invertebrates from Cabeço da Amoreira and Cabeço da Arruda in the Instituto de Antropologia Prof. Mendes Corrêa of the Faculdade de Ciências of the Universidade do Porto (Lentacker, 1986). Detry reviewed all vertebrate and invertebrate remains, focusing on mammal taxa of three shell middens (including Cabeço da Amoreira). The remains from Cabeço da Amoreira were in possession of the Museu Geológico (Geological Museum). The Museu de História Natural (Natural History Museum) and the Faculdade de Ciências of the Universidade do Porto were originally keeping the materials from the 1930s and 1960s excavations and from João Rolão's fieldwork at the turn of the 21st century (Detry, 2007).

Detry's research was the first to provide critical information regarding subsistence strategies and paleo-environmental and paleo-economic contexts of the Muge and Magos shell middens. However, the contextual relationship between these faunal findings and the site's stratigraphy dynamics was less explored. With the 20th-century assemblages, stratigraphic dynamics were difficult to ascertain. Therefore, the focus was on the materials from João Rolão's excavations. Detry concluded that faunal remains were often concentrated in certain areas and could be spread over many archaeological layers. This suggests continuity in occupation over many generations, a semi-permanent site occupation (Detry, 2007).

Detry's and Lentaker's studies revealed a diverse range of terrestrial and aquatic fauna. Amongst the terrestrial vertebrates, the most represented taxa were the rabbit (*Oryctolagus cuniculus*) - though other lagomorphs, such as hares (*Lepus* sp.), are also present (Detry, 2007). Less prevalent in the archaeological record were species such as red deer (*Cervus elaphus*) and the wild boar (*Sus scrofa*), followed by the roe deer (*Capreolus capreolus*), the aurochs (*Bos primigenius*), and the horse (*Equus* sp.), as well as carnivores, such as the Iberian lynx (*Lynx pardina*), fox (*Vulpes vulpes*), and dogs (*Canis* sp.) (Lentacker, 1986; Detry, 2007). The faunal assemblage also included badgers (*Meles meles*), polecats (*Putorius putorius*), otters (*Lutra lutra*), martens (*Martes* sp.), wild cats (*Felis silvestris*), in addition to other rodents and micromammal species, and a wide variety of mollusks, crustaceans, fishes, amphibians, and reptiles. Over 25 bird taxa were present in assemblages (Lentacker, 1986; Detry, 2007), which, according to Clark (2000), is relatively abundant and might suggest that they may have been regularly consumed. These extensive findings not only identified hunting strategies but also provided a comprehensive picture of the ecological resources available to the ancient inhabitants of this site (Lentacker, 1986; Detry, 2007).

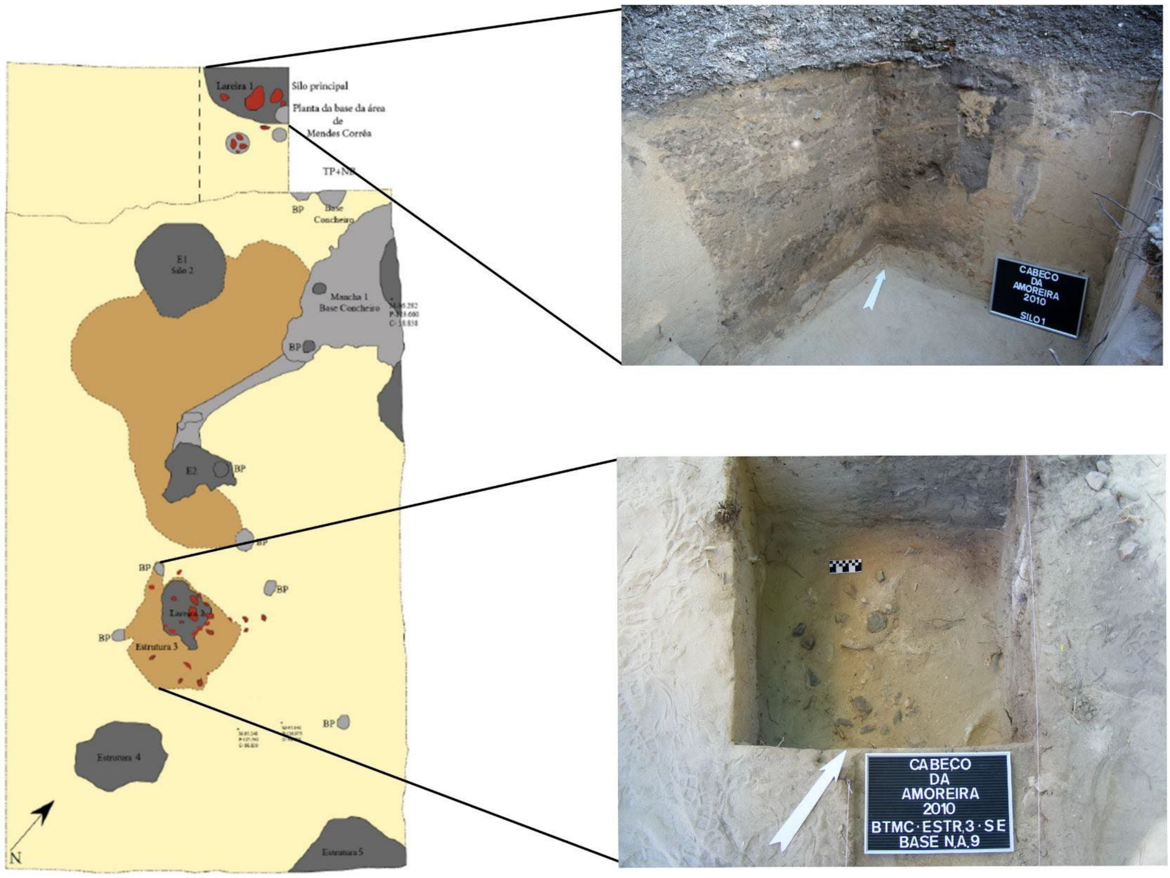

Figure 2.3 – Image displaying the profiles of Lareira 1 and Structure 3 (the pit that laid beneath Lareira 2). Map and Photographs from the 2010 field report provided by Célia Gonçalves.

These works showed that the shell midden was strategically located where different environments converged. It was evident that while some species were easily found in the site's surroundings, others were more suited to forested areas or open landscapes. Aquatic birds, fishes, crustaceans, and mollusks represent the nearby water environment. The ecological diversity, seemingly greater in Cabeço da Amoreira than in other sites, indicates the multifaceted activities at the site and the complex dynamics of the exploitation of resources (Detry, 2007; Lentacker, 1986). Additionally, Lentaker (1986, p.22) points out that most species are non-migrating but that some "*are hunted more efficiently in certain periods of the year. Red deer, for example, was hunted from January to March and wild boar from November to March*" suggesting a semi-permanent or permanent occupation of the site year-round.

Muge canids were initially identified as undomesticated individuals due to the absence of gnawed bones. In 1986, Lentaker's faunal assemblage contained a few gnawed specimens; however, in the proposed taxonomic listing, the researcher did not distinguish between wolf and dog due to the high fragmentation of remains. In Lentaker's interpretations of the site, he proposed that dogs could have served as possible hunting partners or were commensal opportunists but does not exclude wolves from the assemblage. Later, Detry and Cardoso's (2010) research allowed her to identify canid remains within the Geological Museum of Lisbon collection, retrieved from the 1880s Cabeço da Arruda excavations. Their study used osteometric data to distinguish domesticated individuals (dogs) and their wild counterparts (wolves). Other than the almost complete skeleton of Cabeço da Arruda, canid remains from the 1930s and 1960s excavations of Cabeço da Amoreira were also analyzed. Osteometric results concluded that the individuals from both shell middens were significantly smaller than wolves and, therefore, most likely were domesticated individuals. Additionally, the burial of a complete skeleton and the absence of taphonomic modifications such as cut marks, fractures, and thermal alterations suggested that these individuals were not consumed.

In 2008, Detry also analyzed materials from the Cabeço de Môrros shell midden in the Magos River and discovered that recovery methods of the materials influenced results and interpretations of the faunal assemblage. She observed: "*Mammals, amphibians, and reptiles dominate the faunal assemblage, a pattern which contrasts with that observed by Lentacker (1986) for Cabeço da Arruda and Cabeço da Amoreira. This disparity is probably due to differences in recovery methods and highlights the importance of using a fine mesh when water screening*" (Detry, 2008, p. 54).

The 2008 project and subsequent excavations significantly increased the assemblage. They aimed toward understanding the site's stratigraphic dynamics, creating the need to implement new excavation methodologies that enabled rigorous stratigraphic control (Bicho, et al., 2011) - revealing structured contexts that had never been observed before and allowing a new interpretative approach to faunal studies (*e.g.*, Gonçalves, et al., 2018a).

With this in mind and building on the work of Detry (2007), Pereira (2014) performed the first faunal identification of the large mammalian taxa from the new uppermost layers (1 and 2). Her analysis identified beaver (*Castor fiber*). It also reinforced the prevalence of red deer and wild boar, and, to a lesser extent, roe deer, aurochs, horses, and some small carnivores already documented in past studies (Pereira, 2014).

In 2017, Dias' doctoral research regarding aquatic and small terrestrial vertebrates expanded the taxonomic list for rodents, birds, and fishes (Dias, 2017). The discrepancies in the proportions of small taxa within the assemblage, such as birds and fish, could be correlated to previous excavation retrieval methods (Dias, et al., 2016). These findings on small vertebrate remains were a substantial element to the theory that indicated that the occupations at the site might not be as continuous as previously thought, revealing gaps in human presence that the seasonal availability of specific resources may justify (Dias, et al., 2019)

3. Methodology

3.1. Excavation and Materials

3.1.1. Excavation

The excavations at the Cabeço da Amoreira site started in 2008 and have resulted in numerous field seasons, producing a varied collection of artifacts. The excavation area was split into an alpha-numerical grid and performed in 5 cm increments following the natural and anthropogenic stratigraphic layers (Belmiro, et al., 2020; Bicho, et al., 2011).

The provenance of archaeological materials was registered using Total Stations to create three-dimensional plots of artifacts larger than 2cm, documenting their dispersion and spatiality. Complete bones, bladelets, microliths, and adornments were plotted individually, regardless of size. Larger artifacts, like long bones, had multiple coordinates recorded to document their spatial disposition and orientation. Each artifact was assigned an alphabetical or alphanumeric code linked to a barcode for easier access to information (Belmiro, et al., 2020; Bicho, et al., 2011).

Excavated sediment was stored in ten-liter buckets for subsequent sieving (1mm and 3mm meshes). The sediment's origin and materials found within were spatially documented from a central point of the excavated area. Small mesh sieving permitted the retrieval of remains from smaller animals (Belmiro, et al., 2020; Bicho, et al., 2011).

Feature C

Materials recovered from the shell-rich layers of the midden were often found randomly distributed, probably due to a complex set of anthropogenic activities and post-depositional processes. Although not unheard of, complex spatial organization and preservation are considered uncommon within the site (Gonçalves, et al., 2018a).

The abnormal spatial preservation and high concentration of fire-cracked and large-sized bones (identified horizontally and in the archaeological profile) permitted the isolation of Feature C during the excavation of Layer 9 in the A1 and B1 squares in 2022 (Figure 3.1). The feature was covered by a shell-rich layer (Figure 3.2) and, through the archaeological profile, appeared to be delimited at its lowest point by a row of fire-cracked rocks, which continued to the A2 and B2 squares (Figure 3.3). It was concluded that it connected with another feature found in 2016 named Feature B (first named Animal 2; Figure 3.4) and with a Bone Cluster discovered in 2018 (Figure 3.5) (Gonçalves, et al., 2018b). All deposits were promptly renamed Feature C.

Figure 3.1 – Example of archaeological materials found in Feature C in 2022. Photo: Célia Gonçalves.

Figure 3.2 – Shell-rich layer delimiting the top of Feature C. Photo: Célia Gonçalves.

Figure 3.3 – Archaeological profile of the A1 and B2 squares in 2022. Photo: Célia Gonçalves

Figure 3.4 – Example of materials recovered from the Feature C in 2016. Photo: Célia Gonçalves

Figure 3.5 – Example of materials recovered from Feature C from 2018. Photo: Célia Gonçalves.

3.1.2. Faunal assemblage

The faunal assemblage analyzed comes from the 2016-2023 seasons and corresponds to remains recovered from Feature C. The sample was first sorted in the field lab, where faunal remains were separated from other artifacts, and later at the Interdisciplinary Center for Archaeology and Evolution of Human Behaviour (ICArEHB). Here, sieved faunal remains were individualized whenever taxonomic or anatomical identification was possible or significant taphonomic alterations were exhibited. Only materials found *in situ* or individualized faunal remains were considered for this analysis.

This approach attributed 322 bones to Feature C. The faunal assemblage underwent two phases of examination. The first phase focused on taxonomic and anatomical identification, then analyzed taphonomic characteristics using a Euromex stereomicroscope (NexiusZoom ESD, up to 45x). In contrast, the second phase aimed to interpret the spatial data retrieved.

3.1.3. Radiocarbon Dating

Following the first phase of analysis, selected materials were sent to Curt- Engelhorn-Zentrum Archäometrie gGmbH in Manheim (Germany) for radiocarbon dating. The bones selected for carbon dating were chosen based on cortical bone surface preservation and animal size, favoring medium-sized animals[4]. Animals of very small size, such as rabbits (the most common taxon of very small size in the assemblage), were not considered for this type of analysis due to their burrowing nature and the potential contamination of recent inputs to the structure.

Three samples from Feature C were sent for dating, each from different depths of the structure—one from the top, one from the middle, one from the base, and one from the southwest area (B2). Additionally, another sample was selected from outside the feature. This was done to provide information on the chronological relationship between the feature and the layer it integrates (layer 9).

No sample was sent from the southeast section of Feature C since it had already been dated in 2021. This sample was sent to the University of Waikato's Radiocarbon Dating Laboratory (Hamilton, New Zealand).

Samples sent are summarized in Table 3.1.

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[4] Animal size and weight categories are described in the next section: Anatomic and Taxonomic Analysis.

TABLE 3.1
List of samples sent for Carbon Dating from Feature C. MSA stands for medium-sized animal; for weight categories, see 3.2 Anatomic and Taxonomic Analysis

Lab Code	Unit	ID	Context	Taxon	Skeletal Element	Taphonomic Observations
Wk-50404	A2	946	Southeast	MSA	Humerus	-
MAMS-6692	B2	1038	Southwest	MSA	Vertebra	Dispersed root etching
MAMS-6693	B1	1064	Top of Center	MSA	Long Bone	Dispersed root etching
MAMS-6694	B1	1528	Base of Center	*Cervus Elpahus*	Mandible	Calcium Carbonate
MAMS-6695	B1	1153	Middle of Center	MSA	Long bone	-
MAMS-6696	A1	4573	Layer 9	cf. *Cervus Elpahus*	Vertebra- Cervical	Pit or Puncture

3.1.4. Documentation

All data acquired were input into a spreadsheet using MS Excel (version 2312). These included all anatomic and taxonomic information, as well as other taphonomic modifications observed on bones. Cut marks, pits, punctures, and notches were measured using a digital caliper ruler (Fixpoint 77001).

Photographic documentation was done using the Canon EOS 6D Mark II camera with a 24-105mm lens at ICArEHB facilities. Detailed images of some modifications observed on bones were taken at Institut Català de Paleoecologia Humana i Evolució Social (IPHES) in Tarragona using a HIROX 3D Digital Microscope, with the lens SP-MXG-5000, with a low-range resolution of up to x35.

3.2. Anatomic and Taxonomic Analysis

The anatomical and taxonomic identification was carried out using the reference collection of ICArEHB's Osteoarcheology Lab, with support from auxiliary literature (*e.g.,* Barone, 1972, 2010; Barone, et al., 1973; France, 2009; Hillson, 2005; Pales & Garcia, 1981; Pales & Lambert, 1971; Schmid, 1972; Varela & Rodriguez, 2004) the 3D Atlas authored by the Max Planck Institute[5]. Additional taxonomic identifications required consultation with the

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[5] Accessed online through the Max Planck Institute for Evolutionary Anthropology: https://www.eva.mpg.de/evolution/downloads

Laboratório de Arqueociências reference collection of the Património Cultural, I.P. (LARC).

When anatomical determination was not possible, bones were classified according to shape parameters, distinguishing among long, flat, or irregular/articular bones. Elements whose taxonomic identification was not possible were classified as taxon undetermined and characterized by size: Animals of Very Small Size (<10Kg = VSSA), Small Size Animal (<100Kg = SSA), Medium Size Animal (100-300Kg = MSA), Large Size Animal (300-1000Kg = VSA), or Very Large Size Animal (>1000Kg = VLSA). When anatomical identification was not possible, elements were characterized as long bone, flat bone, or articular bone.

The sample fragmentation affected the possibility of calculating the estimated age at the time of death - therefore, it was considered only the state of matureness of the individual (infant, juvenile, adult, senile) considering surface porosity, epiphysis fusion, or tooth wear.

3.2.1. Quantification

Despite diverging terminologies within the zooarchaeological academic community, for the purpose of this study and to give continuity with previous analysis of the site (*e.g.*, Detry, 2007; Pereira, 2014), the terminology defined by Poplin (1976) was used. This pertains to the definition of the fragment as a portion of bone or tooth that is isolated from its original anatomical element - which is, by definition, a complete bone or tooth. The terms remain(s) or specimen(s) are used synonymously to fragment in the course of this study (Detry, 2007).

The quantification of remains was carried out using the following indexes.

- **Total Number of Remains (NR)**

The NR corresponds to the entire analyzed collection, summing up the number of identified and undetermined remains (Detry, 2007; Pereira, 2014). This quantification index allows for a better understanding of the degree of fragmentation of the remains. It is helpful for comparison of the proportion of taxa, elements, and taphonomic alterations within the broader spectrum of the assemblage.

- **Number of Determined Remains (NDR)**

The NDR follows Valente's (1997) considerations by distinguishing between the Anatomically Determined Number of Remains (**NDRa**) and the Taxonomically Determined Number of Remains (**NDRt**).

For NDRt, remains were identified to the species level. When this was not possible, genus and order approximations were considered (Detry, 2007; Pereira, 2014). On the other hand, NDRa includes any remains whose anatomical element could be identified even when unable to determine laterality. Vertebrae were considered determined remains if it was possible to identify whether they were cervical, dorsal, lumbar, or caudal.

- **Minimum Number of Elements (MNE)**

The MNE is the minimum number of anatomical elements within a taxon, calculated by adding the preserved portions and surfaces of each element. This calculation is helpful in later determining MNI and supplying data regarding the frequency of anatomical elements within the feature.

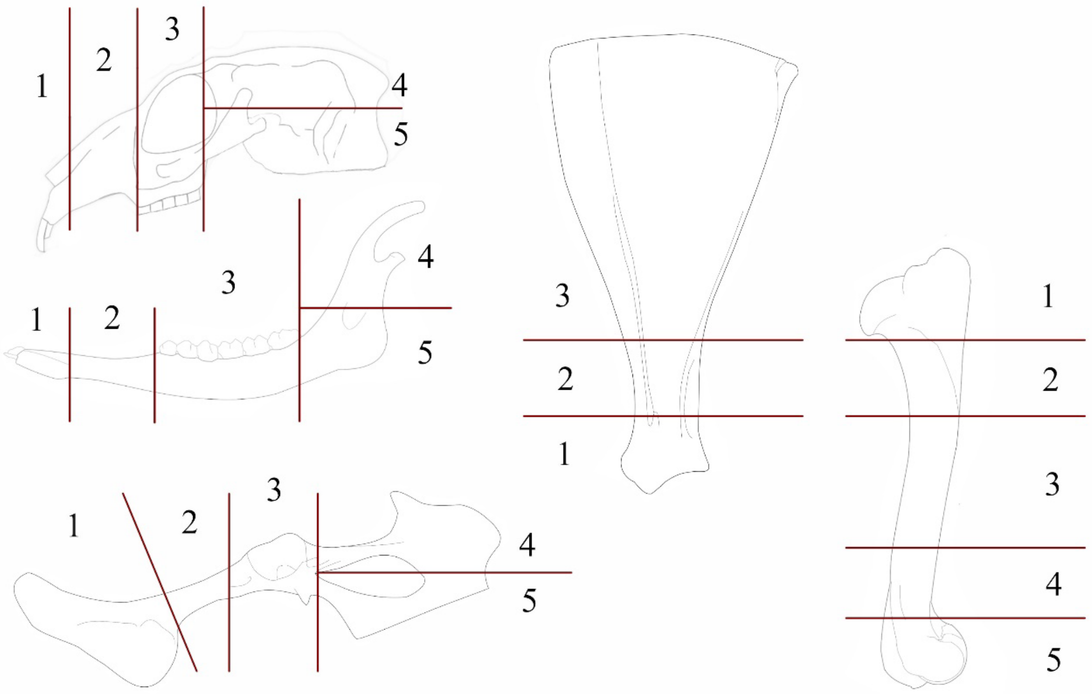

Figure 3.6 – Exemplification of portion division on the skull, mandible, coxal and long bones. Drawings from Coutureau & Forest (Inrap, France) & Dessin (Muséum de Genève, Switzerland).

Bone portions were established before the analysis and considering bone morphology and length. Portions were identified numerically from the extremity closest to the animal's skull to the furthest, as portrayed in Figure 3.6. The humerus portrays the portion division applied to all long bones (ulna, radius, femur, tibia, metacarpals, and metatarsals). Irregular and articular bones were not divided by portion but were documented according to the preserved surface.

Each complete element has four preserved surfaces: anterior, cranial, or dorsal; posterior, caudal, or palmar/plantar; lateral or exterior; and medial or interior (Rufà, 2017; Schmidt, 1972).

- **Minimum Number of Individuals (MNI)**

The MNI was calculated by considering each species' most abundant anatomical element and laterality, which differed from taxon to taxon. Additionally, the age of individuals was considered when applicable, along with the preserved portion (Lyman, 1994). The simplest method of MNI calculation, which involves dividing the total number of elements by the number of times the most abundant element is present in an animal's skeleton, was not used so that any predominance in laterality or age ranges was more easily identifiable (Detry, 2007; Pereira, 2014).

- **Relative Abundance (RA)**

Identifying the **frequency of anatomical elements** by taxon was considered an essential part of this analysis to understand dispersion patterns and potential biases on the representation of elements by taxa. It may also provide insights into the preservation of these elements through post-depositional processes and the role of the Mesolithic community or other predators as accumulating agents (Rufà, 2017). The proportion of anatomical elements preserved might provide some key elements to diagnose if there was any intentional selection of body parts or if the lack of specific elements is related to other post-depositional processes.

To estimate the biases on skeletal representation, it is important to know which the proportion of elements preserved is in relation to those elements expected. This is called the Relative Abundance (RA). It is calculated considering the total of MNE recovered in the assemblage and the number of elements expected (MNEe) to be found in the assemblage (that is, the MNI of the site in relation to the number of remains expected in a complete individual) and expressed as a percentage (*100). This calculation is made by each identified taxon individually following this formula:

$$RA = \frac{NME * 100}{NMEe}$$

3.3. Taphonomic Analysis

The term “taphonomy,” from the Greek *taphos* (burial) and *nomos* (law), was coined in 1940 by Russian paleontologist I.A. Efremov, who defined the discipline as the *“study of laws governing the transition of organic remains from the biosphere to the lithosphere”* (Cadée, 1991, p. 3; Lyman, 2010). The concepts encompassing this field of study were not new. However, they had yet to be applied synchronously in this research area. This field of study grew from paleontology and paleobiology and was initially only applied to animals. Nonetheless, it has since become an integral part of archaeological studies due to the invaluable insight that taphonomic alterations may give regarding a site’s formation processes, use, and subsequent abandonment (Cadée, 1991; Lyman, 2010).

The initial study of taphonomy had two focuses. Biostratinomy refers to the pre-burial biological process (regardless of whether the carcass was buried, exposed, or with multiple burials). The second focus was diagenesis, the geological and chemical processes that the remains go through post-burial and before recovery from the paleontologists (Lyman, 2010).

After the boost in major publications regarding the analysis of taphonomic alterations of animal bones that started in the ’70s (Cadée, 1991), Anna Behrensmeyer and Susan Kidwell (1985) highlighted the importance of taphonomy outside of the fossilization process. They proposed that taphonomic alterations are not always equivalent to the loss of information caused by biostratinomy and diagenesis but also can provide information such as predatory activity. Since the mid to late 80s, taphonomy has refocused on a better understanding of palaeoecological contexts (Lyman, 2010).

Currently, taphonomy “*seeks to understand processes [that have influenced organic remains] so that data from the fossil record can be evaluated correctly and applied to palaeobiological and palaeoecological questions*.” (Behrensmeyer, et al., 2000, p. 103 *quoted in* Lyman, 2010). Taphonomy is no longer the study of processes that destroy and bias faunal assemblages but that of any process an organism goes through, from death to retrieval from an archaeological site, that is informative and pertinent to site formation and post-depositional history (Lyman, 2010).

The processes accompanying an animal's death in archaeological contexts will usually be intermeshed with human behaviors. However, non-human agents, such as scavenging or necrophagous animals, and naturally occurring physical and chemical agents, can also provide insights into a site’s occupation. These are the reasons why taphonomic analysis of zooarchaeological remains is considered so important - the taphonomic analysis is usually determined by the documentation and interpretation of the phenomenon that affects the anatomical elements of an animal from the moment of its death until its retrieval in an archaeological excavation.

The interpretation of faunal assemblages in archaeology can be affected by various processes. These processes can be categorized into two types - biotic and abiotic factors. The former includes all living components of a given ecosystem, such as humans and the animals they exploit or share the environment with. They are the primary agents contributing to the accumulation of faunal remains in archaeological sites and can be identified by physical changes in bones and the pattern of disarticulation. When combined with the analysis of abiotic processes, such as erosion, wind, water, and temperature, an assemblage may provide a complete picture of the agents responsible for bone modifications, providing essential data on a site's depositional and post-depositional history.

3.3.1. Preservation Factors and Conditions

Despite the various types of shell middens found all over the world, for the most part, they are open-air sites named after the accumulation of shells distributed horizontally and vertically. The shell layers are, unsurprisingly, comprised mostly of bivalves but also fish, mammals, and terrestrial gastropods, amongst other animals. These sites are found worldwide and represent complex resource exploitations in different environments, from coastal areas to estuaries and continental lakes (Detry, 2007).

Erosion is one of the biggest dangers for the preservation of open-air sites, excluding those with high sedimentation rates, such as the Muge shell middens. In this case, the fast-paced deposition of layers of anthropic origin favored the excellent preservation of zooarchaeological remains. However, due to the nearby riverine and estuary environments, this area frequently undergoes flooding, an erosive agent of Muge sites at a lower altitude (Detry, 2007). Additionally, anthropic actions such as farming and dams have negatively affected the preservation of other shell middens, as evidenced by the destruction of Fonte do Padre Pedro and Arneiro do Roquete in Muge (Bicho, et al., 2013b) and Magos de Baixo e Magos de Cima in the Magos River[6] (Cardoso & Rolão, 1999/2000). Cabeço da Amoreira has survived such attacks due to the protection and patronage of Casa Cadaval, who retains ownership of the land.

Other anthropic actions that have influenced the preservation of the site are the fall and

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[6] Information available online in the Salvaterra de Magos Municipality [Consulted on 31st of January of 2024]: https://www.cm-salvaterrademagos.pt/apav/item/64-historia

destruction of archaeological profiles of the XIX and XX-century excavations. However, since 2000, there have been attempts to minimize this issue, such as sandbags to protect the profiles from collapsing and geotextile to protect from animals, vegetation, and water damage (Rolão & Roksandic, 2007).

Another active agent in the destruction of the site is burrowing animals, such as rabbits, martens, foxes, mongoose, and badgers (Pelletier, et al., 2016). Other animals, such as snakes, have been documented nesting inside the most recent excavations. During the past few decades, excavators at Cabeço da Amoreira covered the site in geotextile (Figure 3.7) to avoid profile erosion and animal burrowing; however, despite significantly minimizing these issues, this is not always effective, as seen in (Figure 3.8). It is, then, paramount for this research to account for these agents in the dispersal of faunal remains.

Figure 3.7 – Photograph taken at the end of the 2023 field season demonstrating the measures of protection via geotextile of the site. Photo: Célia Gonçalves.

The shell-rich layers of middens create ideal environments for preserving archaeological materials. The diagenesis of hydroxyapatite, the inorganic component of bone, relies on levels of calcium and phosphorus in the sediment. In the case of the Muge shell mounds, the calcium carbonate from bone and shells gets dissolved by rainwater, which then creates hardened layers in the deeper levels of the midden, creating a geochemical environment ideal for bone conservation. This geochemical process is responsible for the tubular hardened structures in archaeological layers, which are caused by the underground water movement accompanied by the carbonate from shell and bone linked to the growth and decay of plant roots (Detry, 2007).

Figure 3.8 – Photograph of the East Profile of Area S1 of excavation in 2023. Smaller orifices were made by reptilians and insects and the larger one to the left was possibly a fox burrow. Photo: Célia Gonçalves.

These calcium carbonate concretions can form around the specimens, sometimes covering them completely, which may impact the quantitative results regarding surface-level taphonomic alterations or the identification of remains taphonomically or anatomically.

3.3.2. Taphonomic Agents and Alterations

Any taphonomic alterations, whether of natural, carnivorous, or anthropogenic origin, were characterized and counted following the literature, namely Lyman (1994), Valente (2000), Shipman and colleagues (1984), and Fernández-Jalvo & Andrews (2016).

All taphonomic modifications observed on bones were analyzed macroscopically using a Euromex stereomicroscope under 6-35x. All taphonomic modifications whose documentation reported measurements, such as cut marks, pits, punctures, and notches, were measured using a digital caliper ruler (Fixpoint 77001).

3.3.2.1. Bone Fragmentation

> "*It cannot be assumed that all split and fractured bone on an archaeological site has been broken by man.*"
>
> (Clark 1972, p.149 *quoted in* Lyman, 2010)

Despite not being the only agent responsible for fragmentation, in the framework of this research, anthropic actions are amongst the most relevant and are therefore included in this section. Bone fragmentation patterns and conditions can offer important insights into the preparation or use of a carcass, such as the consumption practices related to bone marrow. Identifying the taphonomic agents responsible for bone fracturing can also reveal the formation processes of an archaeological site. Another agent of bone fragmentation includes bone-gnawing carnivores. which typically accompany fractures derived from the weakened structural strength of long bones after the chewing and gnawing of the epiphysis, or by directly chewing on the diaphysis. This creates a specific fracture pattern and may be accompanied by other markings such as pits and punctures (Lyman, 1994; Detry, 2007).

Previous works tend to follow Shipman et al. (1981) fracture typologies, later modified by Marshall (1989), to characterize faunal assemblages. These two publications amounted to 8 types of breakage patterns; however, if these patterns are unambiguously identified, the agent responsible has been denied since the first publication mentioned. Additionally, spiral fractures are divided by type, with Type I being attributed to the breakage of dry bone and Type II of fresh bone (Lyman, 1994).

Since then, multiple other researchers have established their own morphological typologies (see Johnson, 1985; Gifford-Gonzalez, 1989). Despite the similarities between these, differences *"underscores the subjective and intuitive nature of the typologies and indirectly illustrates how difficult they may be to use"* (Lyman, 1994, p. 320). These terms and descriptions are more difficult to apply to highly fractured assemblages where a fragment or surface may show different breakage types. Regardless, these studies were critical in determining the state of bone during breakage; for example, Johnson was able to ascertain that coloration, texture, and shape of the angles produced by the breakage were good indicators to determine if the bone was dry or fresh/green when the fracture took place (Lyman, 1994).

As previously mentioned, the assemblage described here was heavily fragmented, which made the identification and quantification of skeletal elements and taxonomic approximations difficult, as well as the application of these typologies. Therefore, we decided not to determine fractures by typology but rather by their state at the time of breakage - if the bone was dry, fresh/green, or if the break was modern. Only the fragmentation of long bones was characterized.

3.3.2.2. Anthropic Modifications

Humans are one of the main accumulating agents in archaeological sites, as is the case of the Cabeço da Amoreira shell midden. Meat, fat, marrow, skin, teeth, tendons, organs, and bone may all have a place in the lives of pre-historic communities. The preparation, skinning, dismembering, de-fleshing, and consumption of faunal remains can attest to bone fragmentation patterns, cut marks, thermal alterations, and anatomic element distribution, amongst other factors within an archaeological assemblage. Understanding these elements allows researchers to gather important information regarding food consumption, preparation, hunting technologies or methods, as well as palaeoecological and sociological contexts – or, in other words, it helps understand human behaviors in the past.

This segment details and explains the alterations attributed to anthropic agents, such as bone breakage, cut marks, or thermal alterations. It also explores the potential use of bones as tools.

Intentional Breakage

Ethnographically, intentional bone breakage has been shown to be related to bone marrow extraction and bone toolmaking. Breakage patterns showed the recurrent morphologies and location of these marks for marrow extraction; however, these modifications may differ depending on the methods employed in the breaking of the bone. Signs of intentional breakage include deformed cortical surfaces, flakes, adhering flakes, pits and grooves, partial or total collapse of bone surfaces, notches (negative of flake detachment), fracture lines, striations, etc.

The terminology used to document intentional breakage was established by Vettese, et al. (2020) in reference to “percussion marks *sensu stricto*” and “Traces consecutive to bone breakage”:

- **Parasitic Flake** (adhering flake): The flake is still attached to the bone due to an incomplete fracture line.
- **Crushing** mark: A roundish lesion in the cortical surface caused by repeated impacts, which lacked enough force to create fracture lines but formed multiple

adhering flakes. This lesion is often, but not exclusively, located near articular portions of long bones.

- **Flake**: Bone flakes, similar to lithic flakes, may exhibit certain characteristics such as a platform at the point of impact; a percussion bulb below this platform; some ripple marks close to the bulb; greater proportions of breadth to length; and the absence or reduction of the cortical surface.
- Percussion **notch**, used synonymously to **impact point**, are the negatives of flakes left on fracture edges. Notches may display a variety of characteristics but are usually identified through an internal conchoidal scar, occasionally possessing an exterior or outer scar as well.
- **Percussion pit and groove**: These are described as superficial pits of various shapes; occasionally accompanied by other taphonomical modifications. Grooves tend to be more elongated than pits, with an oval morphology with a V-shaped cross section. They form due to impact on the bone, groves may be caused for rebound effect.
- **Peeling**: Peeling happens when fresh bone is forcefully separated when a fracture is not complete, through a torsion loading such as twisting or flexing. These marks display a roughened surface and are often found on ribs.
- **Ripple marks**: Ripple marks or hackle marks are a wave-like relief located at or near the bulb or platform of a flake or a notch. These marks are more common on green bone.

Cut marks

Lyman (1994) highlighted the role of Shipman in the study of cut marks in which microscopic analysis allowed the differentiation of marks done by stone tools from those done by carnivore or rodent activity, which were deemed morphologically distinct. Despite some criticism of the validity of the experimentation process, Shipman's conclusions offered the base for the identification of cut marks, defining them with the following characteristics: a cut mark’s cross-section was usually V-shaped (U-shaped, sporadically), possessed micro-striations on the “wall” of the mark, and, occasionally, paralleled to the cut (known as shoulder effect) (Lyman, 1994; Shipman, 1981; Shipman & Rose, 1983). Later studies arrived at similar conclusions, attributing V-shaped cross-sections to flint tools and U-shaped cross-sections to carnivore and rodent activity or organic acids produced by roots, fungi, and algae (see references in

Fernández-Jalvo and Andrews, 2016).

It may be difficult to distinguish between cut marks and trampling with these criteria alone. Domínguez and colleagues (2017) have developed an experimental approach to account for the variables that must considered when distinguishing trampling marks from butchery marks, such as the trajectory, orientation, shape, presence and trajectory of micro-striation, and location of the marks. The specific location and orientation of marks may be indicative of actions derived from the handling of a carcass, typically falling within traditional proposals of either skinning, disarticulation or dismemberment, and filleting. These actions are found recurrently within a species or throughout many species (Domínguez-Rodrigo, et al., 2009; Lyman, 1994).

> "*Extraction of viscera, blood, brains, marrow, grease, bone, and sinew, and periosteum removal are other activities that might be considered subsidiary to, in particular, dismembering and filleting or food extraction.*"
>
> (Lyman, 1994, p. 300)

Dismemberment or disarticulation marks tend to be found in the joints and articulations of the skeleton. Marks associated with skinning are often found in the mandible and lower limbs where bones are closer to the skin (*e.g.*, metapodials, phalanges, radius, tibia), whereas marks associated with meat extraction are often found longitudinal to the long bones (Detry, 2007).

Identifying these activities within the assemblage could help understand the subsistence strategies employed by this Mesolithic community. However, the degree of fragmentation affected the analysis of cut marks in the assemblage since many bones were of an unidentifiable anatomical element or species. Regardless, all cut marks were documented since they may provide information regarding butchery practices or patterns.

Marks were characterized as:

- **Incisions**: thin striations caused by contact with the cutting tool. These may be isolated, grouped, or dispersed along the surface of the bone, with varying orientations and shapes.
- **Sawing** marks: deep incisions caused by sawing motion from the cutting tool.
- **Chopping** marks: deep, wide, and short marks left by the strong impact of the cutting implement on bone. They are more commonly found in areas where tendons and muscle insertions might be more common and might require more strength to cut.

- **Scraping** marks: shallow but wide striations, caused by the longitudinal movement of the cutting implement on the surface of bone to, for example, remove the periosteum.

Concretions covering bone surfaces are an additional challenge when analyzing cut marks, hindering the identification of potential anthropogenic activities. These concretions cover the assemblage substantially, and in most cases, they can be too attached to the bone for removal since it might damage the cortical surface. Additionally, assemblage fragmentation may also significantly affect the quantification of cut-marked remains.

In addition, it is important to compare cut-mark distribution amongst the different taxa, as these data might show the different uses a carcass might have had, depending on the species. In previous studies, cut marks were not commonly found in smaller taxa, such as lagomorphs. Detry proposes that these animals were cooked whole or with minimal butchering and, therefore, would not preserve many cut marks. She also found very few cut marks in roe deer (*Capreolus capreolus*). The taxa with the most significant presence of cut marks were the Auroch (*Bus primigenius*), the wild boar (*Sus scrofa*), and the red deer (*Cervus elaphus*). Cut marks were associated with disarticulation/dismemberment since they were primarily found in areas of muscle insertion or tendons (Detry, 2007).

In Detry's research, she did not find cut marks on lagomorphs. She concluded that this phenomenon could be correlated with the preparation of carcasses for transport and cooking, as small animals could be transported and cooked whole. In contrast, larger species had to be prepared and butchered for these same purposes (Detry, 2007).

The categorization is carried out based on the type, utilizing the classical descriptions of Fernández-Jalvo & Andrews (2016), considering the affected area, arrangement (isolated, grouped, scattered), orientation, and through length measurements (mm).

Thermal alterations

> *"(...), there seem to be minimally two steps to interpreting burned bone: identifying bone as burned, and identifying when the bone was burned relative to its depositional and burial history."*
>
> (Lyman, 1994, p. 383)

Fire has been an invaluable element of food preparation since the start of its use by human ancestors. Thermally altered bone and charcoals prove Muge's hunter-gatherers' use of fire for food preparation. The charcoals identified are mostly, but not exclusively, of the genus *Pinus* (Monteiro, et al., 2017). This information could be helpful in future experimental studies, as they might provide more accurate results regarding the methods employed in food preparation.

Thermal alterations on bones can be detected and analyzed through various methods. Microscopic methods include Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). Other methods, such as X-ray diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIS), are effective in measuring crystallinity and may help understand changes to the mineral bone matrix (Ellingham, et al., 2015). Despite this, macroscopic identification of thermal alteration on bones is possible by discerning differences on bone surface coloration (*e.g.*, Nicholson, 1993; Shipman, et al., 1984; Stiner, et al., 1995). Following this method, a visual approach was preferred since it did not involve specific technologies that might not be accessible, but also due to the experience, knowledge, and costs required to apply these methodologies.

Thermal alterations affect bone surfaces on different levels. For example, on a microscopic level, they change the crystalline structure of the bone. On a macroscopic level, heat causes fractures, fissures, distortion, or shrinkage of the bone, and, most importantly for this study, color alterations (Lyman, 1994). It is also accepted that manganese or other mineral agents can cause chromatic changes on bone surfaces that can be sometimes interpreted as burning damage. However, these agents are not commonly found in Muge nor identified in this faunal assemblage or previous faunal studies. Thermal alterations differ from mineral staining through their more uniform borders and surface alterations. Aside from the previously mentioned characteristics, heat may also cause bones to develop a more polished appearance due to the changes in their crystalline structure (Detry, 2007; Fernández-Jalvo & Andrews, 2016).

This study used a macroscopic analysis of thermal alterations, maintaining a level of continuity with previous faunal analysis in the Muge shell middens; this approach was considered sufficient to establish interpretations of burnt bone, such as for food consumption or its use as fuel (Detry, 2007). Bone has been associated with the longevity of a fire (Théry-Parisot, 2002) and could be helpful in areas where wood is scarce. However, that is not the case in Muge, as forests were thriving and providing extensive resources in the region (Detry, 2007).

> "*As collagen is carbonized, the bone turns black. With continued heating, the black carbon is oxidized and the bones become white and has a chalky consistency.*"
>
> (Lyman, 1994, p. 385)

With the main element of the thermal alteration analysis being coloration, Shipman, et al.'s (1984) proposal of chromatic levels was adopted. The five levels are as follows: (1) minor changes in the coloration of the faunal remains; (2) reddish tone; (3) black tone; (4) gray tone; (5) white. The Munsell chart was not used, as rigorous color matching would not have yielded more valuable insights.

The coloring observed on bones after exposure to fire can vary based on factors such as the temperature intensity, duration of exposure, soil chemical composition, bone density of the remains, the degree of contact with the flame (whether direct with or without attached flesh or indirect), the individual's age and size, the state of bone at time of burning, among others. This complexity can lead to multiple layers of coloration on the bone surface, sometimes manifesting as double or triple colorations (Lemmers, et al., 2020; Lyman, 1994; Nicholson, 1993; Shipman et al., 1984).

Bone Industries

After the obtention of animal nutrients, it is possible that some bones were worked and used for many purposes. When it happens, their surfaces look polished, with scraping marks all along its surface and polished surfaces. Thus, any faunal remains that appeared to have been anthropically altered for any specific utilitarian or aesthetic purpose, such as hammers, scrapers, and needles, were considered bone tools (Lyman, 1994).

Despite being uncommon in the Mesolithic levels of the midden, examples have been found in the uppermost levels of the site. In Detry (2007), no bone tools were identified, but their presence was considered likely, and their absence was a matter of preservation and fragmentation of the sample. Therefore, the database was assembled with this in mind, and if identified, the tools would be characterized by their apparent use or of undetermined use.

3.3.2.3. Carnivorous Modifications

Apart from humans, other agents can prey on animals and accumulate them in archaeological sites. This is the case of mammalian carnivores and birds of prey, whose activities are commonly documented in the archaeological record. Bone assemblages can be directly accumulated by carnivores or be result of more complex dynamics, where carnivores scavenge on human leftovers. Thus, evidence of predatory activities serve as an indicator of a site's depositional processes. It may indicate that remains were left exposed to the elements, easily accessible to opportunistic animals, or as a representation of species that, although absent from the faunal assemblage, share a space with the human occupation of the site (Costa, 2013).

The taphonomic alterations attributed to carnivorous agents may be physical or chemical. Physical alterations are those that take place during mechanical actions such as chewing and gnawing of the bone. The force of the jaw or beak creates pits, punctures, notches, scores, and bone fractures. Chemical alterations are those made by interactions of bone with chemical agents such as saliva and gastric acids, leading to marks of digestion on the remains.

Pits, Punctures, and Notches

The documentation of these elements is done by type (as described below), by frequency within the bone fragment (isolated, grouped, dispersed), by the portion and surface affected, and by measurements of length and width (when applicable). Mechanical modifications are widely described in the scientific literature (Binford 1981; Lyman, 1994; Fernández-Jalvo & Andrews, 2016). Their definition follows:

Pits are small circular or oval-shaped depressions on the surface of specimens caused by the pressure of teeth on the remains, producing partial collapse of the cortical surface. When it causes the complete collapse of the cortical surface, it is called a **puncture**. Gnawing of the epiphysis is common and may lead to **pitting**, which is the accumulation and high frequency of pits in a single area (Binford, 1981).

When the force of the teeth causes the fracturing of the bone, leaving behind a negative of the tooth along the fracture line, it is called a **notch**. These can often be mirrored on opposing bone surfaces in a semi-circular shape. **Crenulated edges** are fractures that, due to multiple concave edges, make it difficult to distinguish the point of impact where the tooth broke the bone (Binford, 1981; Fernández-Jalvo & Andrews, 2016; Lyman, 1994).

Several studies have proposed identifying predators based on pit/puncture morphology and dimensions (Andrés, et al., 2012). However, they have primarily focused on large carnivores such as large felids and hyenas, as well as baboons, wolves, and the smallest being domestic dogs and foxes. Small carnivores and small prey are vastly underrepresented in these studies since experimentation has been done predominantly on larger taxa (Lyman, 1994; Rufà, 2017).

The taphonomic alterations left by birds of prey differ from those of carnivorous mammals due to their lack of teeth. Despite similarities between the marks left by their sharp beaks and claws and mammal-made pits or punctures, their morphologies differ. Birds’ beaks often make triangular or irregular-shaped punctures, whereas mammals' punctures tend to be rounder and more regular (Rufà, 2017).

Scores

Scores are described as transversal striations of varied size, width, and depth produced by the dragging of teeth or beaks along the cortical surface of a bone and causing a U-shape section. Birds' beaks often make more superficial and broader scores, whereas mammals' teeth tend to create more pronounced marks.

Digestion

When an animal ingests elements such as bones and teeth, these corrode when in contact with gastric acids. The digestive process can cause different degrees of both surface and internal modifications of faunal remains (Andrews, 1990). For this study, signs of digestion were analyzed microscopically, considering the alteration caused by the high acidity of predators' stomachs, which produce acid etching in the surface of the remains, and digestive enzymes that deteriorate the organic constituents of bone and teeth. These agents cause the rounding of fractures and porosity on bone or loss of cortical tissue (Fernández-Jalvo & Andrews, 2016).

Digestion marks were documented based on the degree of degradation of the cortical surface of the bone, with characterization ranging from mild to moderate, severe, or extreme degradation (Fernández-Jalvo & Andrews, 2016). Multiple studies have been made to identify predators based on the degree of bone surface corrosion. Succinctly explained, it has been concluded that diurnal birds of prey and carnivorous mammals leave more aggressive digestion marks (more pronounced loss of cortical tissue) than nocturnal birds of prey (Andrews, 1990; Fernández-Jalvo & Andrews, 2016; Rufà, 2017). However, identifying carnivorous agents responsible for digestion marks within an assemblage is not as linear as hoped. Fernández-Jalvo & Andrews point out that "*Vertebrate digestion varies among predators, with some species having higher acidity levels in their digestive tracts than others*" and that "*Both acidity and digestive enzymes require time to operate, and so the degrees of modification are related to the time bones are exposed to the digestive processes*" (Fernández-Jalvo & Andrews, 2016, pp. 238, 239).

Other differences arise in terms of ingestion. There is a significant discrepancy in the proportion of the digestion of smaller animals in comparison with larger species. Larger animals are not as often found with digestion marks since their bones are too large to be easily ingested. However, smaller bone fragments can be ingested if broken beforehand. Bone breakage increases the surface area exposed to corrosive agents, leaving behind higher degrees of digestion marks since gastric acids can easily penetrate the medullary cavity of long bones (Fernández-Jalvo & Andrews, 2016).

The proportions of bone fragmentation, as well as degree of damage observed on bones, could identify carnivorous agents responsible for accumulating assemblages. Nocturnal raptors usually ingest prey whole, therefore not causing significant bone breakage. In contrast, mammals and diurnal birds of prey tend to chew or tear apart faunal remains, often resulting in bone breakage (Andrews, 1990; Fernández-Jalvo & Andrews, 2016).

Time is a significant factor in the degree of bone alteration by digestion – the longer the exposure to gastric acids, the more pronounced the taphonomic alterations. The type of predator ingesting bones may also influence the degree of alteration. Avian predators often regurgitate parts of their prey that are not as easily digested (*e.g.*, hair, feathers, bones). Therefore, the remains won't pass through the entire digestive process, leaving less severe alterations to the bone surface. Meanwhile, Mammalian carnivores, reptiles, and some birds rarely or never regurgitate their meals, which allows bones and teeth to have more prolonged exposure to gastric acids. Additionally, hungry predators tend to retain their meal in their stomachs longer, causing more significant degrees of bone digestion, resulting in substantial inter-species and even inter-individual variation. This could also explain why some micromammal remains are never recovered from the pellets or scats of predators, as they may be completely digested (Fernández-Jalvo & Andrews, 2016).

Since birds often regurgitate bones, this also influences the dispersion of the alterations along the bone surface. In this case, bones have a shorter exposure to the digestive juices, producing more localized modifications, specifically on areas of the bone that are more porous, such as the epiphyses and articular surfaces. General digestion, in which modifications are found homogeneously on the specimens, is more common in large mammalian carnivores and large reptiles (Fernández-Jalvo & Andrews, 2016). However, neither agent is expected to be present in Mesolithic Muge.

3.3.2.4. Post-Depositional Processes

> "*Whether or not a bone survives to become fossilized depends on the intensity and rate of various destructive processes and the chance for permanent burial prior to total destruction*."
>
> (Behrensmeyer, 1978, p. 150)

Post-depositional taphonomic alterations were considered those that affect the surface of archaeological faunal remains after their abandonment by the accumulator agents. Post-depositional processes can be a physical or chemical phenomena, such as those described below.

Physical Phenomena

Weathering

> "*Weathering is defined* (…) *as the process by which the original microscopic organic and inorganic components of bone are separated from each other and destroyed by physical and chemical agents operating on the bone* in situ*, either on the surface within the soil zone.*"
>
> (Behrensmeyer, 1978, p. 153)

Weathering is the result of unburied faunal remains exposed to atmospheric agents through time. As they decompose and their nutrients are recycled into the soil, bones are more exposed to environmental changes (*e.g.*, sun exposition, contrast of temperatures, desiccation/humidification) that degrades bone. This process of degradation starts with the development of fissures and flaking, penetrating depth in the bone until its complete destruction (Behrensmeyer, 1978).

In 1978, Anna Behrensmeyer proposed the first categorization of weathered stages of bone based on the assemblage of the Amboseli Basin (Kenya), mainly comprised of larger mammals such as bovids. She employed (as cited above) a definition that included physical and chemical agents.

Early studies in this field, like the ones conducted by Behrensmeyer, primarily focused on medium to large-sized animals. Some experts have noted that Behrensmeyer's definitions may not apply to smaller taxa. The unburied remains of these animals are more vulnerable to damage, and fragments are more easily blown away by the wind or buried, which could account for the underrepresentation of weathered faunal remains within an assemblage (Andrews, 1990). Additionally, recent research has revealed that bird bones tend to display weathering characteristics at a faster rate than mammals. Although they may initially show more resilience to microorganisms, they become substantially more fragile at a significantly earlier stage than mammal bones (Behrensmeyer stage 2 in birds, stage 4 in mammals). This justifies the absence of bird bones in archeological assemblages where the subaerial exposition of remains is present (Behrensmeyer, et al., 2003).

The weathering stages of Behrensmeyer (1978) are still the most commonly used categorizations of this taphonomic alteration in zooarchaeological literature. However, it may be complemented by Andrews' (1990) (Table 3.2) and Behrensmeyer and colleagues' (2003) findings regarding smaller mammals and birds.

TABLE 3.2
Weathering stages of large and small mammals summarizing the data of Behrensmeyer (1978) and Andrews (1990). Authorship: Fernández-Jalvo & Andrews (2016, p203)

Stage	Behrensmeyer large mammal categories	Years	Andrews small mammal categories	Years
0	No modification, bone still greasy, marrow present, skin or other tissue may still be present	0-1	No modification, bones may still be connected	0-2
1	Cracking parallel to fiber structure, articular surfaces may have mosaic cracking	0-3	Slight cracking parallel to the fiber structure, chipping of enamel and cracking of dentine	0-5
2	Concentric flaking associated with cracks and loss of most of outer bone, crack edges angular	2-6	More extensive cracking but little flaking; of enamel and deep dentine cracks extending into the enamel leading to loss of parts of the crown	3-5
3	Bone surface with patches of rough compact bone resulting in fibrous structure extending to cover the entire surface, penetration up to 1.5 mm, crack edges rounded	4-15	Deepening cracks in both bone and dentine of teeth; cracks deep in enamel	4-5
4	Bone surface is coarsely fibrous and rough, splinters falling away, cracks open and have rounded edges	6-15	Deep cracks and some loss of segments of bone; sections of enamel broken away	4-6
5	Bone falling apart in situ with splinters of bone around the remaining bone core which is fragile and easily broken	6-16	Bone splits apart and disintegrating, teeth fragmented	5-7

Multiple factors can be active in the weathering of bone, including environmental and sedimentary factors and interspecies differences. However, intraspecies characteristics, at an individual level, can also affect the weathering of bone – such as the anatomical element, the age of the individual, the sex of the animal, etc. (Costa, 2013). Such variation in the elements that influence the weathering of bone makes proposals such as Behrensmeyer's hypothesis on calculating site formation processes difficult to test accurately. These proposals were challenged by authors such as Costa (2013), who claim that, due to the aforementioned reasons, weathering stages cannot portray the passage of time or the processes of accumulation of faunal assemblages. However, this author highlights that analyzing these taphonomic changes is not without merit and proposes that weathering should be analyzed individually, as the study of weathering on a single bone could portray this element's individual post-depositional history.

Therefore, the presence of several stages of weathering cannot be an indicator of the history of the assemblage but of different histories of several individual remains, which could portray the strategies of accumulation by human communities (Costa, 2013).

Root etching

Root-etching is the term applied to the shallow groves that roots of vegetation may make on faunal remains. The presence of these marks on bones and teeth is due to the humic acid plants excrete as they grow around the remains, feeding on the nutrients they still possess. These display an irregular dendritic pattern and U-shaped cross-sections, which helps distinguish them from other taphonomic changes (Costa, 2013; Lyman, 1994).

While in possession of organic matter, faunal remains will promptly be covered in vegetation seeking to absorb their nutrients; therefore, some authors propose that root-etching is a process that starts soon after the deposition or burial of the specimens (Andrews, 1990). There is, however, still much unknown information regarding this phenomenon. Little is known regarding which plants can develop grooves and at which rate they develop; it is also relatively unknown the part that fungi, lichen, and moss have, which raises questions about the necessity of bone being buried for the development of root-etching (Lyman, 1994).

Root etching serves as an indicator of sedimentary environments with plant-supporting properties, and *"the presence of root marks on fracture surfaces or the internal surface of limb-bones can be essential clues about the relative timing of bone fracture"* (White, 1992 quoted in Lyman, 1994).

Other studies have concluded that the difference in the proportions of root-etched bones amongst different strata could be paleoenvironmental indicators (Lyman, 1994). However, the focus of this research is not to tackle paleoenvironmental problems through root-etching analysis. Therefore, root-etching documentation provides recorded data that could be used for comparative analysis later on. Thus, the only parameter documented was their arrangement patterns along the bone's cortical surface (isolated marks, grouped or scattered).

Trampling

Trampling is the term applied to alterations on remains caused by pressure applied on sediment through surface movements of land animals, whether human or otherwise. Studies have shown that the effects of trampling on faunal assemblages are threefold: it creates marks on the specimens that can sometimes fracture the remains, and it may be an agent in the spatial displacement (vertical and horizontal) of elements within the assemblage. Often, trampling fractures occur when the bone is dry, creating a layered fracture of both transversal and longitudinal planes (Olsen & Shipman, 1988). Additionally, the type of sediment that surrounds the buried remains may influence trampling marks. Domínguez-Rodrigo and colleagues (2017) found that fine-grained sediments developed lesser marks than coarse sediment and gravel.

It would not be uncommon for scratch marks created by trampling to show some similarities with cut marks (Domínguez-Rodrigo, et al., 2017; Lyman, 1994). However, these tend to be more randomly oriented and distributed (usually alongside the diaphysis of long bones). In contrast, cut marks (as previously mentioned in this chapter) tend to be more consistent in their anatomical distribution and orientation. The former typically creates shallower marks than the latter (Olsen & Shipman, 1988).

In this research, trampling was separated from bone fragmentation and abrasion, which may be concurrent but are not inherently so. Trampling was defined exclusively as the superficial markings or fractures that were undoubtedly caused by applied friction of the soils. Spatial information is not expected to provide extensive data regarding the vertical and horizontal dispersion of bone by trampling. The only elements documented regarding trampling were the presence/absence in the specimens and the surface affected.

Gastropod-etching

Gastropod-etching are small irregular marks with U-shaped cross sections, sometimes similar to root etching, but without a dendritic or continuous shape to them, caused by terrestrial gastropods that feed off of fungus growing on bone surface or the calcium present in the faunal remains (Costa, 2013).

Gastropod etching was considered in this analysis; however, since no elements in this assemblage portrayed signs of this taphonomic alteration, it was not included in the results chart.

Abrasion

Abrasion is the term applied to the taphonomic phenomena that cause the polishing or rounding of remains. Various organic and inorganic agents may cause abrasion, such as the transport of specimens through water in sedimentary environments, eolic transport of sediment impacting the specimens, trampling, and transportation of sediment, bioturbation, water bioerosion, corrosion, etc. Polishing and rounding of bone can also occur due to intentional or unintentional actions of hominins while they are used as tools (Fernández-Jalvo & Andrews, 2016). While eolic action and high-energy water movement create polished looks on bone, with rounded fractures, low-energy water movement seems to cause striations on the bone surface (Costa, 2013).

Research shows there are many other variables to consider in the abrasion of bone, such as type of sediment (Rozada, et al., 2018) and state of the specimen, as they react differently to abrasion whether they are dry or fresh/green – research shows that weathered and dry bone is more susceptible to abrasion (Fernández-Jalvo & Andrews, 2016)

Analyzing the abrasion on the faunal remains could provide data regarding the post-depositional history of the specimens and the site. The documentation of abrasion was done regarding its presence/absence and affected surface.

Chemical Phenomena

Chemical agents affect the bone due to its' apatite absorption of trace elements in the sedimentary composition of the layers and deposits, usually affected mainly by the geological matrix of the site and interstitial waters.

Chemical corrosion

Chemical corrosions are "*surface modifications arising out of chemical attack due to either biological or geochemical action*" (Fernández-Jalvo & Andrews, 2016, p. 235). Corrosion may happen due to organic and inorganic processes that portray environments that, although not subaerial, are moist and chemically reactive, such as soil corrosion, fungi, algae, moss, lichen, bacteria, long-term immersion in still or stagnant water, cave corrosion, urine, etc. Another process that may lead to chemical corrosion is gastric juices; however, due to the importance of carnivore activity in the present assemblage, they are separated from other chemically corrosive agents (Fernández-Jalvo & Andrews, 2016).

The corrosion characteristics, such as location/distribution, depth, and degree, indicate the chemically corrosive agent responsible (*see* Fernández-Jalvo & Andrews, 2016). In the study presented here, chemical corrosion was documented when there was an apparent loss of bone tissue through chemical action, recording the presence/absence and affected surfaces.

Oxidation

Oxidation was applied to the precipitation of manganese (MnO^2) and iron (Fe^2O^3) dioxides on faunal remains. These elements are active in the discoloration of the bones and may be mistaken for thermal alteration due to their coloring. Macroscopically, manganese dioxide appears as dark-colored stains on the bone surface, whereas iron dioxide takes a reddish-brown tone. In both cases, the staining is irregular in morphology and distribution. However, it can uniformly cover the bone in its most severe forms (Costa, 2013).

Both manganese and iron play essential roles in sediment composition. Manganese oxidation commonly occurs in humid, pH-neutral environments rich in water and organic matter to support the growth of bacteria and fungi that cause manganese staining. Iron dioxide also develops in oxygenated and biologically rich environments with high water content (Costa, 2013; Fernández-Jalvo & Andrews, 2016).

The high concentration of calcium carbonate on the site attests to soil alkalinity, therefore suggesting this site is unlikely to develop the dioxides described above since they require pH-neutral sedimentary contexts (Costa, 2013; Fernández-Jalvo & Andrews, 2016). Regardless, these elements provide environmental data regarding the site's post-depositional history; therefore, their documentation accounted for the presence/absence of these elements on the analyzed specimens and the affected surfaces.

Calcium carbonate

As stated in the section Preservation Factors and Conditions the shell-rich layers of middens – although an essential factor of the preservation of archaeological bones – pose challenges to the analysis of the faunal assemblage. As the calcium in bone and shell interact with rainwater, they form calcium carbonate concretions that grow around faunal remains, potentially over taphonomic alterations (such as cut marks, pits, punctures, notches, root etching, thermal alterations, etc.) or the anatomical characteristics that would make possible taxonomical determinations. To minimize the effects of these challenges on the qualitative and quantitative aspects of the presented research, the concretions were removed (when possible) manually with softwood implements, uncovering cortical surfaces in good conservation and condition.

Softwood implements were selected since metal scalpels could easily create marks that could otherwise mistakenly pass as cutmarks, which could affect quantitative studies of this element in the assemblage. Detry (2007) submerged two specimens of her assemblage (distal humeri of birds) in diluted acetic acid (5%); after an undisclosed number of minutes, the bones were placed in distilled water and later washed with running water until the elimination of the acid. This approach successfully cleared the bone surface of any concretions; however, she observed that the bone seemed to have lost some of its rigidity. This method was not routinely used since it is relatively time-consuming and can impact DNA preservation, which could be relevant for future studies.

Concretions were documented based on the proportion of bone affected, following the categories stated below:

- Absent or Residual: >15% of the bone surface with concretion (did not cover the bone surface substantially to justify the loss of information).
- Partial: 20-50% of the bone surface is covered in concretions.
- General: 50-85% of the bone surface is covered with concretions.
- Total: 85-100% is covered with concretions, having only a residual amount of bone tissue visible.

3.4. Spatial Analysis

The employed methodology integrates three-dimensional spatial information and contextual attributes of each collected archaeological artifact within a unified Geographic Information System (GIS) environment (Gonçalves, et al., 2018a).

> *"The recording system allows not only to review the already excavated contexts, but also to perform rigorous spatial analyses to identify the existence or absence of areas with higher density of materials and to evaluate, interpret and explain spatial relationships"*
>
> (Gonçalves, et al., 2018a)

The isolation of Feature C during the excavation of Layer 9 in the A1 and B1 squares was possible due to the remarkable spatial preservation and concentration of fire- cracked and larger bones. Observation of the feature proved its continuation into the already excavated A2 and B2 squares where other deposits had been found— Feature B in the A2 square in 2016, and Bone Cluster in B2 excavated in 2018. Their relationship was clear and, as previously stated, their nomenclature was promptly corrected and are now referred to as Feature C and were included in the spatial analysis as such.

Since the excavations took place in different years, and acknowledging the measures taken to minimize the degradation of the archaeological profiles, spatial analysis was considered paramount. Refits and modern breaks were accounted for to ascertain the degree of profile decay and understand contemporary dispersion of materials. Materials are individualized from sieved sediment buckets were not accounted for in spatial analysis since they would create artificial clusters of faunal remains.

This analysis will use the Spatial Analyst extension in ESRI's ArcGIS Pro 3.2. Kernel Density Estimate (KDE) is also employed as it is a widely accepted method for exploring spatial variation and identifying areas with the highest archaeological material densities. The Ripley K function addresses potential errors in determining the KDE radius (Gonçalves, et al., 2018a). This approach was used to create density maps to understand the dispersion of taxa and anatomical elements within the structure, as well as identify any accumulations of specific taphonomical modifications throughout the feature.

The goal of this methodological approach is not only to further investigate the post-depositional history of Feature C through its taphonomical history but also to create a solid database that future studies could use as a starter point for their own research regarding the aforementioned taphonomical changes of this assemblage.

4. Results

4.1. Radiocarbon Dating

The radiocarbon dating was done at Curt- Engelhorn-Zentrum Archäometrie gGmbH in Manheim (Germany) laboratory and at the University of Waikato's Radiocarbon Dating Laboratory (Hamilton, New Zealand). All samples selected possessed were considered viable. Collagen-to-carbon ratios all fell into the appropriate interval of 2.9 to 3.6 – samples falling outside these limits probably contain degraded collagen and would not provide accurate dating. Samples with a relative collagen content of 1% are preferred for this type of analysis; however, all samples above 0,5% of collagen content are analyzed. The only sample that contained a collagen content below 1% was from the middle of Feature C (5.2023; B1-1153); however, no indication from the lab was sent that would suggest the dating of the sample had been compromised in any way.

Radiocarbon results for the samples originating from the Feature are presented in Table 4.1.

TABLE 4.1
^{14}C results from the submitted samples. Dates, Collagen, and Carbon-Nitrogen proportions are displayed as submitted by the laboratories.

Lab Code	**Context**	**^{14}C Age (yr BP)**	**±**	**Probability 95%**	**$\delta^{13}C:\delta^{15}N$**	**Collagen [%]**
Wk-50404	Southeast	6935	23	cal BP 7830-7690	-	-
MAMS-6692	Southwest	6992	23	cal BC 5979-5795	3.3	5.8
MAMS-6693	Top of Feature	6945	23	cal BC 5888-5741	3.3	5.1
MAMS-6694	Base of Feature	7010	23	cal BC 5984-5833	3.3	6.4
MAMS-6695	Middle of Feature	6919	23	cal BC 5878-5731	3.3	0.6
MAMS-6696	Layer 9	7019	24	cal BC 5985-5839	3.2	5.7

4.2. Anatomic and Taxonomic Analysis

4.2.1. Taxonomic List

Specimens were identified to the species level whenever possible; when this proved unviable, an approximation to the genus or family level was performed. The bibliography referred to in the text and the Virtual Museum of Biodiversity[7] (Museu Virtual de Biodiversidade- MVBio) of the Évora University were used to develop the taxonomic listing.

Class **Mammalia**, Linneaus, 1758
Order **Lagomorpha**, Brandt, 1855
Family **Leporidae**, Gray, 1821
Lepus granatensis, Linnaeus, 1758

The genus *Lepus* is represented in Europe through the presence of three species: *Lepus granatensis*, the predominant species in the Iberian Peninsula, especially in mountainous or forested areas; *Lepus europaeus*, which extends over a large geographical area covering Central and Mediterranean Europe almost in its entirety, and whose presence in the Iberian Peninsula is mainly confined to the northern region; and *Lepus capensis*, which is currently limited to North Africa and some islands in the Mediterranean (Callou, 1997).

Despite the relatively unknown distribution of these species in prehistoric Iberia, the current dispersion of the species throughout the territory suggests that it is most likely that the taxon present in the analyzed collection is *Lepus granatensis* (Detry, 2007).

Oryctolagus cuniculus, Linnaeus, 1758

The wild rabbit (*Oryctolagus cuniculus*) is a highly adaptable species abundant in Europe and, without exception, in the Iberian Peninsula. It occupies various environments and creates burrows (MVBio) that may often disrupt archaeological sites (see section 3.3.1. Preservation Factors and Conditions).

Its recurrence in the collection under study may symbolize **a)** an important element in the subsistence strategy of the last communities of hunter-gatherers, **b)** the use of shell mounds for burrows, with this being an intrusive species (differing from the hare),

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[7] Available online: https://www.museubiodiversidade.uevora.pt/ [Consulted on the 06h of March of 2024]

c) an accumulation by carnivores or **d)** a combination of the previous three making taphonomic analysis essential part of this research. Its taxonomic and anatomical identification is facilitated by similarities to the hare, albeit in smaller size (Callou, 1997, 2003).

Order **Artiodactyla,** Owen, 1848

Family **Cervidae** Gray, 1821

In Portuguese territory, there are three species of cervids, none of which inhabit the area surrounding the Muge River: *Capreolus capreolus* and *Cervus elaphus* identified in archaeological contexts, and *Dama dama*, which was not identified in the archaeological record of the Muge shell mounds and seems to have been extinct in Iberian territory during the Mesolithic period (Detry, 2007).

Cervus elaphus, Linnaeus, 1758

The species is adapted to various habitats of temperate climates and is found throughout almost all of Europe – in Portuguese territory; it seems to prefer habitats of open forests, Mediterranean scrublands, and pastoral landscapes (MVBio). Although not currently found on the outskirts of the shell mound, its abundance in the archaeological record justifies its presence in the area during the Mesolithic period. The collection analyzed here continues previous studies insofar as this species remains the most recurrent medium-sized animal in the archaeological record of the shell mound (Detry, 2007).

This species is important for hunter-gatherer communities, as reflected by the archaeological record – in addition to providing a large food portion, it would also supply other secondary products such as skins, antlers, and even teeth (as adornments).

Capreolus capreolus, Linnaeus, 1758

This is the smallest deer species in Europe, currently uncontrolled in Portuguese territory only in mountainous areas in the north of the country (Detry, 2007). They are adapted to habitats with dense shrubbery, such as woodlands, forests, Mediterranean scrublands, meadows, and agricultural fields (MVBio; Kurtén, 1968).

Due to its size, it is relatively easy to distinguish from the Red Deer; however, compared to larger deer species, it appears less frequently in the archaeological record. Detry (2007) proposes that the discrepancy in the number of roe deer remains compared to red deer – also identified in previous studies — is due to an ecological issue, as the former prefer habitats with dense shrubbery and, therefore, would be less abundant in this region, but also because, due to their size, agility, and speed, they are less desirable and more difficult to hunt.

Family **Suidae**, Gray, 1821

Sus scrofa, Linnaeus, 1758

It is a species adapted to a wide variety of habitats, with its European distribution encompassing woodland areas throughout the continent, which makes its presence in the Muge shell mounds unsurprising (MVBio; Kurtén, 1968). Despite the difficulty distinguishing between wild species and domestic pigs, the absence of evidence of pig domestication in Mesolithic Iberia allowed confidence in identifying all remains of *Sus* as wild boar (Detry, 2007). Detry (2007) comments that these animals are considered challenging to capture, and therefore, hunting wild boar reveals sophisticated hunting techniques.

Family **Bovidae**, Gray, 1821

The two large prehistoric bovids of the Iberian Peninsula were the aurochs, which inhabited areas with a more temperate climate, and the bison, which inhabited colder climates. Therefore, all large bovids were classified as aurochs (Kurtén, 1968).

Bos primigenius, Bojanus, 1827

According to Detry (2007), the aurochs were considered the third most numerous artiodactyl in the archaeological record, but their numbers seemed to decrease in more recent occupation periods. However, in the analyzed collection, only one auroch remains was identified, which was an atlas.

Order **Carnivora,** Bowdich, 1821

Family **Mustelidae,** Fischer de Waldheim, 1817

Many of these species can be found in Portuguese territory. Amongst them are the *Mustela erminea, Mustela nivalis, Mustela putorius, Martes foina, Martes martes, Meles meles,* and *Lutra lutra* (MVBio). Due to taphonomic factors, Detry (2007) highlights that small mustelids are likely abundant but not well preserved in the archaeological record. In her research, she identified *Meles meles, Lutra lutra,* and *Martes* sp.; Lentaker (1986) identified in Cabeço da Arruda *Meles meles, Lutra lutra*, and possibly *Mustela nivalis*; these first two were also identified in Cabeço da Amoreira as well as *Mustela putorius*, *Martes foina*, and a specimen that was either *Martes foina* or *Martes martes*.

Due to the size of the humerus found, it is unlikely to be an otter; however, no further approximations were able to be made regarding the individual found.

Class **Aves,** Linneaus, 1758

Order **Columbiformes**, Latham, 1790

Family **Columbidae**, Leach, 1820

Columba oenas Linnaeus, 1758*/* ***Columba livia*, **Gmelin, 1789

Previous research found other individuals of the genus *Columba*, namely *Columba palumbus* and *Columba livia*, in Cabeço da Amoreira (Detry, 2007; Lentaker, 1986). Compared to the specimens found, the reference collection of the LARQ allowed the exclusion of *C. palumbus*; however, as both *C. oenas and C. livia* were quite common in the region and had similar morphologies, they are difficult to differentiate in the archaeological record. The low number of remains made further taxonomic approximations unviable.

Class **Reptilia**, Laurenti, 1768

Order **Testudines**, Batsch, 1788

Family **Emydidae/Geoemydidae**, Rafinesque, 1815/Theobald, 1868

Emys orbicularis, Linnaeus, 1758/***Mauremys Leprosa***, Schweigger, 1812

Lentacker first mentioned testudines in 1986 by highlighting the presence of 3 specimens that could be *Emys orbicularis* or *Mauremys caspica*. Detry (2007) identified remains of what could be *Emys orbicularis* or *Mauremys leprosa* instead but did not distinguish between the two. Later, Boneta (2022) analyzed 30 remains of Testudines from Cabeço da Amoreira and found *Mauremys leprosa*. Comparative analysis with the faunal collection of LARQ permitted narrowing down the remains found in the current study between *Emys orbicularis* and *Mauremys leprosa*. However, the absence of more conclusive anatomical elements made it impossible to distinguish between the two species as both share some similarities.

4.2.2. Quantification

Number of Remains (NR)

The *in situ* documentation of artifacts and subsequent lab work found that bones comprised 14.57% of the Feature C recovered remains. The total sum of all analyzed faunal remains, determined and undetermined, was 322 specimens.

Number of Determined Remains (NDR)

Number of Anatomically Determined Remains

Remains were considered anatomically determined regardless of whether the identification of laterality was possible. Vertebra were considered determined remains should they be identifiable as cervical, dorsal, lumbar, or caudal. Phalanges were considered determined remains regardless of identification of laterality or number (I, II, or III). Around 66% of the faunal assemblage was considered Anatomically Determined Remains, consisting of 214 specimens. The specimens that were considered anatomically undetermined can be found in the Table 4.2.

TABLE 4.2
List and count of anatomically undetermined remains from Feature C, including those of whose laterality was able to be identified.

Elements	Undetermined	L	R	Total
Unknown Metapodials	7	-	-	7
Carpal	3	-	-	3
Rib	3	-	-	3
Vertebra	7	-	-	7
Articular Bone	2	-	-	2
Cranial Bone	16	1	2	19
Flat Bone	17	-	-	17
Flat or Cranial Bone	3	-	-	3
Long Bone	34	-	-	34
Long or Articular Bone	3	-	-	3
Long or Cranial Bone	1	-	-	1
Long or Flat Bone	4	-	-	4
Undetermined	5	-	-	5
Total	**105**	**1**	**2**	**108**

Limb bones were the most recurrent anatomical elements identified, the tibia being the most frequent (NDR=28). Teeth were the second most recurrent anatomical element and were documented based on the sum of attached and detached teeth; mandibles were the next most frequent element. The complete list of skeletal elements considered anatomically determined remains can be found in Table 4.3.

TABLE 4.3

List and count of anatomically determined remains from Feature C, including laterality

Elements	Undetermined	L	R	Total
Maxilla	1	-	2	3
Mandible	1	3	10	14
Teeth- Individual + Attached	15	12	19	46
Zygomatic Process of The Temporal Bone	-	1	-	1
Tympanic Bulb	1	-	-	1
Stylohyoid	2	-	-	2
Vertebra-Atlas	2	-	-	2
Vertebra-Axis	1	-	-	1
Vertebra-Caudal	2	-	-	2
Vertebra-Dorsal	2	-	-	2
Vertebra-Lumbar	1	-	-	1
Sacrum	1	-	-	1
Scapula	3	6	3	12
Humerus	4	5	2	11
Radius	1	6	4	11
Ulna	-	1	5	6
Coxal	-	3	2	5
Femur	-	5	7	12
Tibia	6	10	12	28
Fibula	1	-	-	1
Metacarpus	-	-	2	2
Metacarpus II	-	-	1	1
Metacarpus IV	-	1	1	2
Metacarpus V	1	-	-	1
Metatarsus	2	-	2	4
Metatarsus II	-	2	-	2
Metatarsus III	-	1	-	1
Metatarsus V	-	1	1	2
Phalange	7	-	-	7
Phalange I	6	-	-	6
Phalange II	5	-	-	5
Phalange III	7	-	-	7
Astragalus	-	2	1	3
Navicular	-	1	2	3
Nuchal	1	-	-	1
Sesamoid	2	-	-	2
Cuboid	-	-	1	1
Carapace	1	-	-	1
Carapace- Peripheral Plate	1	-	-	1
Total	**77**	**60**	**77**	**214**

Number of Taxonomically Determined Remains (NDRt)

The analysis showed that, though highly fragmented, over 53.4% of the assemblage could be identified at least to the degree of Order and *c.* 49.7% to the species level. It was considered taxonomically determined remains all elements of which the species was identifiable, as well as the Mustelidae, as only a single specimen was identified; this meant that the NDRt is 169 remains (50% of the assemblage). Undetermined mammals were documented based on size, accounting for 140 specimens of the assemblage (Table 4.4). The most recurrent (definitive) size was Medium (=32); however, 37 specimens were of unclear size, ranging between small and medium.

TABLE 4.4
Count of taxonomically determined and undertemined remains of Feature C, with the corresponding percentage within the assemblage.

Taxon		**NDR**	**%**
Lagomorph			
	Oryctolagus cuniculus	90	28.0
	Lepus granatensis	3	0.9
	Leporidae	9	2.8
Artiodactyla			
	Bos primigenius	1	0.3
	Cervus elaphus	40	12.4
	Capreolus capreolus	7	2.2
	Sus scrofa	24	7.5
	Undetermined	2	0.6
Carnivora			
	Mustelidae	1	0.3
Aves			
	Colomba livia/oenas	1	0.3
	Undetermined	2	0.6
Testudines			
	Emys orbicularis/Mauremys leprosa	2	0.6
Undetermined Mammal		140	43.5
	Undetermined	9	2.8
	VS	28	8.7
	VS-S	11	3.4
	S	23	7.1
	S-M	37	11.5
	M	32	9.9
Total		**322**	**100.00**

Minimum Number of Elements (MNE)

The minimum number of elements was calculated using the laterality and preserved portions of their remains for all determined taxa. For this count, the teeth (isolated and attached to mandibles) were counted without differentiation among incisors, canines, premolars, and molars. Metapodials were not differentiated between metacarpus and metatarsus unless a single element was preserved per taxon. Phalanges were counted without differentiating the first, second, or third phalanges.

The wild rabbit has the highest MNE (Table 4.5), followed by the red deer (Table 4.6), roe deer (Table 4.7), and wild boar (Table 4.8). All other species were placed in a single table, as they possessed a low enough number of remains to not detriment the readability of the data portrayed (Table 4.9).

TABLE 4.5
List and count of anatomical elements attributed to *Oryctolagus cuniculus* with calculated MNE by laterality, and with total MNE count.

Anatomical Elements	**Undetermined**	**L**	**MNE L**	**R**	**MNE R**	**Total**	**MNE Total**
Cranial Bone	1	-	-	-	-	1	-
Mandible	-	3	3	1	1	4	4
Teeth	5	7	7	1	1	13	13
Vertebra-Dorsal	1	-	-	-	-	1	1
Scapula	-	1	1	-	-	1	1
Coxal	-	1	1	1	1	2	2
Humerus	3	3	2	1	1	7	3
Radius	-	4	4	-	-	4	4
Ulna	1	1	1	3	2	5	3
Femur	-	3	2	2	1	5	3
Tibia	-	6	4	7	3	13	7
Metapodials	2	5	5	3	3	10	8
Phalange	16	-	-	-	-	16	14
Carpal	2	-	-	-	-	2	2
Astragalus	-	2	2	1	1	3	3
Navicular	-	1	1	1	1	2	2
Sesamoid	1	-	-	-	-	1	1
Total	**32**	**37**	**33**	**21**	**15**	**90**	**71**

TABLE 4.6
List and count of anatomical elements attributed to *Cervus elaphus* with calculated MNE by laterality, and with total MNE count.

Anatomical Elements	**Undetermined**	**L**	**MNE L**	**R**	**MNE R**	**Total**	**MNE Total**
Mandible	-	-	-	4	3	4	3
Teeth	1	2	2	7	7	10	10
Vertebra-Axis	1	-	-	-	-	1	1
Coxal	-	2	2	-	-	2	2
Scapula	-	1	1	1	1	2	2
Radius	-	2	1	3	2	5	3
Femur	-	-	-	4	2	4	2
Tibia	-	-	-	1	1	1	1
Metapodials	4	-	-	4	4	8	4
Phalange	2	-	-	-	-	2	2
Sesamoid	1	-	-	-	-	1	-
Total	**9**	**7**	**6**	**24**	**20**	**40**	**30**

TABLE 4.7
List and count of anatomical elements attributed to *Capreolus capreolus* with calculated MNE by laterality, and with total MNE count.

Anatomical Elements	**Undetermined**	**L**	**MNE L**	**R**	**MNE R**	**Total**	**MNE Total**
Mandible	-	-	-	1	1	1	1
Teeth	-	-	-	2	2	2	2
Scapula	-	-	-	1	1	1	1
Radius	-	-	-	1	1	1	3
ulna	-	-	-	1	1	1	1
Tibia	-	-	-	1	1	1	1
Total	**0**	**0**	**0**	**7**	**7**	**7**	**9**

TABLE 4.8
List and count of anatomical elements attributed to *Sus scrofa* with calculated MNE by laterality and with total MNE count.

Anatomical Elements	**Undetermined**	**L**	**MNE L**	**R**	**MNE R**	**Total**	**MNE Total**
Cranial bone	-	-	-	2	-	2	-
Mandible	-	-	-	3	3	3	3
Maxilla	-	-	-	1	1	1	1
Teeth	3	3	3	8	8	14	14
Humerus	-	1	1	-	-	1	1
Metacarpus V	1	-	-	-	-	1	1
Phalange	1	-	-	-	-	1	1
Cuboid	-	-	-	1	1	1	1
Total	**5**	**4**	**4**	**15**	**13**	**24**	**22**

TABLE 4.9
List and count anatomical elements attributed to *Lepus grantensis*, *Bos primigenius*, *Mustelidae*, *Columba livia/oenas*, *Emys orbicularis/Mauremys leprosa* with calculated MNE by laterality, and with total MNE count.

Anatomical Elements by Taxon	**Undetermined**	**L**	**MNE L**	**R**	**MNE R**	**Total**	**MNE Total**
Lepus granatensis							
Teeth	2	-	-	-	-	2	2
Femur	-	1	1	-	-	1	1
Bos primigenius							
Vertebra-Atlas	1	-	-	-	-	1	1
Mustelidae							
Humerus	-	1	1	-	-	1	1
Columba livia/oenas							
Scapula	-	1	1	-	-	1	1
Emys orbicularis/Mauremys leprosa							
Carapace- Peripheral	1	-	-	-	-	1	1
Carapace	1	-	-	-	-	1	1
Total	**5**	**3**	**3**	**-**	**-**	**8**	**8**

Minimum Number of Individuals (MNI)

The wild rabbit (*O. cuniculus*) possessed the highest MNI. The MNI was calculated based on the left tibia (NDRt=6, 4 MNE) and right radius (NDRt=4, 4 MNE). Despite the most recurrent element being the right-side tibia (NRDt=7). Portion preservation of the right-side tibias could only conservatively account for three individuals, whereas the left side and the right radius could account for four individuals. At least one infant was identified, based on a mandible and unfused humerus.

The *Cervus elaphus* MNI was calculated using the right-side mandible, which comprised of four fragments belonging to three elements. The portions of the specimens were not always the same; however, only two fragments could be refitted, and the remaining two were considered distinct individuals. The same number of fragments were found for the femur. Nevertheless, three of the four fragments could be refitted to each other, accounting for only two elements. At least two individuals were considered young adults – one based on the porosity of the cortical surface of a mandible, and the other was calculated as under three years of age due to the presence of a decidual premolar 4 (Marín et al., 2024).

The wild boar is the third most frequent species in the assemblage. The most recurrent anatomical element was the right side of the mandible (NDRt=3), all of which still preserved some teeth. Since all specimens preserved the same portion, it was concluded that the number of specimens accurately portrayed the number of individuals. No adult individuals were recorded; two were considered sub-adult because of bone surface porosity, and one infant (< 2 years) due to the absence of m3 tooth eruption (Schmidt, 1972).

Only one individual was identified for all other species (*Lepus granatensis, Bos primigenius, Capreolus capreolus, Colomba livia/oenas, Emys orbicularis/Mauremys leprosa*, and the unknown Mustelidae). The count for all taxa can be found in Table 4.10.

Relative Abundance

Relative abundance or Survival Index was counted per taxon, as is succinctly represented in the tables below. Individual tables were made for the four taxa with the largest NDRt; data from the remaining taxa was collected and represented in a single table, as it didn't seem to affect the reading and comprehension of the information. Considering individual variation within species, the elements per individual and the MNEe were calculated using the largest number of elements an individual may have to not overrepresent the elements within the assemblage.

TABLE 4.10
MNI for all taxa and their percentage within the assemblage

Taxon		**MNI**	**%**
Lagomorphs			
	Oryctolagus cuniculus	4	25.0
	Lepus granatensis	1	6.3
Artiodactyl			
	Bos primigenius	1	6.3
	Cervus elaphus	3	18.8
	Capreolus capreolus	1	6.3
	Sus scrofa	3	18.8
Carnivora			
	Mustelidae	1	6.3
Aves			
	Columba livia/oenas	1	6.3
Testudines			
	Emys orbicularis/Mauremys leprosa	1	6.3
Total		**16**	**100**

For the wild rabbit, the preservation of remains ranged between 3.6% (dorsal vertebrae) and 87.5% (tibia), averaging a survival rate of 30.1% (Table 4.11). The red deer's preservation rate ranges between 1.39% (phalanges) and 50% (mandibles and radius). Element preservation is only slightly lower than rabbit's, averaging 29.5% (Table 4.12). The roe deer had the highest survival of skeletal element average, preserving 42.7% of its sole individual. Relative abundance showed equal preservation to all identified elements (50%) except for teeth, of which only two specimens were identified (Table 4.13).

Although the wild boar preserved 50% of the expected number of elements for the three individuals identified, only one phalanx was identified, which would comprise less than 1% of the expected number of elements per individual. The average preservation for the identified anatomical elements was 19.8% (Table 4.14).

For the remaining taxa, an average of element preservation was not deemed necessary as few elements were identified (Table 4.15).

TABLE 4.11
Expected MNE for *Oryctolagus cuniculus*. This table includes the MNE calculated and the expected number of elements per individual in order to calculate the MNEe and survival of each element in the assemblage.

Anatomical Elements	**MNE**	**Elements per individual**	**MNEe**	**%**
Mandible	4	2	8	50.0
Teeth	13	14	56	23.2
Vertebra-Dorsal	1	7	28	3.6
Scapula	1	2	8	12.5
Coxal	2	2	8	25.0
Humerus	3	2	8	37.5
Radius	4	2	8	50.0
Ulna	3	2	8	37.5
Femur	3	2	8	37.5
Tibia	7	2	8	87.5
Metapodials	8	16	64	12.5
Phalange	14	44	176	8.0
Carpal	2	10	40	5.0
Astragalus	3	2	8	37.5
Navicular	2	2	8	25.0
Total	**70**	**-**	**-**	**-**

TABLE 4.12
Expected MNE for *Cervus elaphus*. This table includes the MNE calculated and the expected number of elements per individual in order to calculate the MNEe and survival of each element in the assemblage.

Anatomical Elements	MNE	Elements per individual	MNEe	%
Mandible	3	2	6	50.0
Teeth	10	34	102	9.8
Vertebra-Axis	1	1	3	33.3
Coxal	2	2	6	33.3
Scapula	2	2	6	33.3
Radius	3	2	6	50.0
Femur	2	2	6	33.3
Tibia	1	2	6	16.7
Metapodials	4	4	12	33.3
Phalange	2	48	144	1.4
Total	**30**	**-**	**-**	**-**

TABLE 4.13
Expected MNE for *Capreolus capreolus*. This table includes the MNE calculated and the expected number of elements per individual in order to calculate the MNEe and survival of each element in the assemblage.

Anatomical Elements	MNE	Elements per individual	MNEe	%
Mandible	1	2	2	50.0
Teeth	2	34	34	5.9
Scapula	1	2	2	50.0
Radius	1	2	2	50.0
Ulna	1	2	2	50.0
Tibia	1	2	2	50.0
Total	**7**	**-**	**-**	**-**

TABLE 4.14
Expected MNE for *Sus scrofa*. This table includes the MNE calculated and the expected number of elements per individual in order to calculate the MNEe and survival of each element in the assemblage.

Anatomical Elements	MNE	Elements per individual	MNEe	%
Mandible	3	2	6	50.0
Maxilla	1	2	6	16.7
Teeth	14	22	66	21.2
Humerus	1	2	6	16.7
Metacarpus V	1	2	6	16.7
Phalanges	1	48	144	0.7
Cuboid	1	2	6	16.7
Total	**22**	**-**	**-**	**-**

TABLE 4.15
Expected MNE for *Lepus granatensis*, *Bos primigenius*, *Mustelidae*, and *Columba livia/oenas*. This table includes the MNE calculated and the expected number of elements per individual in order to calculate the MNEe and survival of each element in the assemblage. MNEe and RA for *E. orbicularis/M. leprosa* was not calculated.

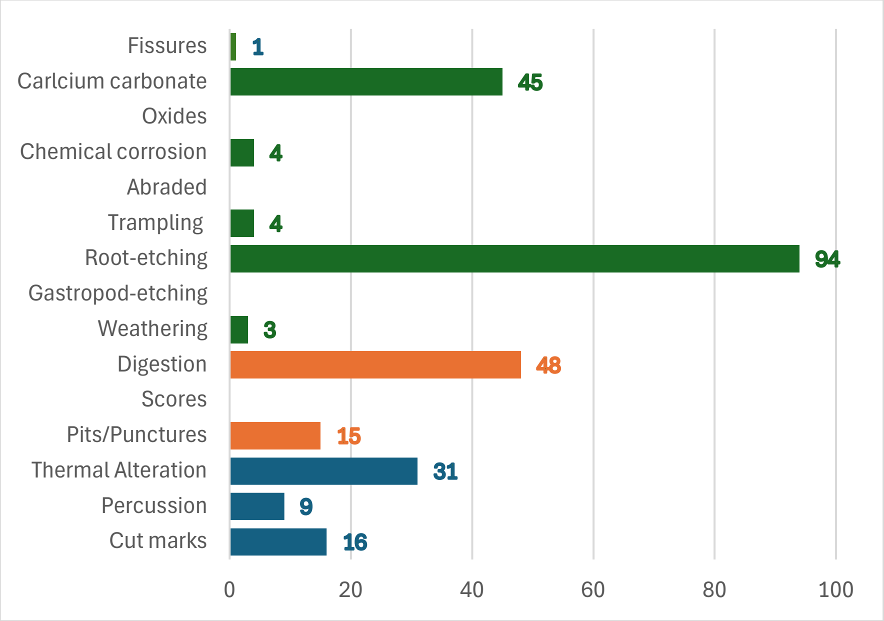
Anatomical Elements per Taxon	MNE	Elements per individual	MNEe	%
Lepus granatensis				
Teeth	2	14	14	4.8
Femur	1	2	2	16.7
Bos primigenius				
Vertebra-Atlas	1	1	1	33.3
Mustelidae				
Humerus	1	2	2	16.7
Columba livia/oenas				
Scapula	1	2	2	16.7
Emys orbicularis/Mauremys leprosa				
Carapace- Peripheral	1	-	-	-
Carapace	1	-	-	-
Total	**8**	**-**	**-**	**-**

4.3. Taphonomic Analysis

Many taphonomic modifications were documented in the assemblage, anthropic, and carnivore modifications, as well as other post-depositional bone alterations (Graph 4.1). In addition, it is important to highlight the high level of fragmentation of the assemblage, which is the main factor in the inability to determine the remains at a taxonomic and anatomical level. Patterns of fragmentation and types of fractures can originate from anthropogenic, carnivore, and other natural actions. It is important to mention that 80% of the long bones had fresh fractures, which might sometimes be associated with anthropogenic activities.

4.3.1. Anthropic modifications

Anthropic modifications were the least representative modification within the assemblage. No bone tools were identified and, therefore, not included in the data presented. Most anthropic action identified was caused by thermal alterations (NR=31 specimens). Only five of the 31 fragments identified in the assemblage were identified *in situ*. Heat often makes bones more susceptible to breakage, which is likely why most of the fragments with burn marks were found while sieving or during lab work. The species that displayed more thermal alterations was the wild rabbit. Of undetermined taxa, small animals displayed the highest amount of burn marks (Table 4.16).

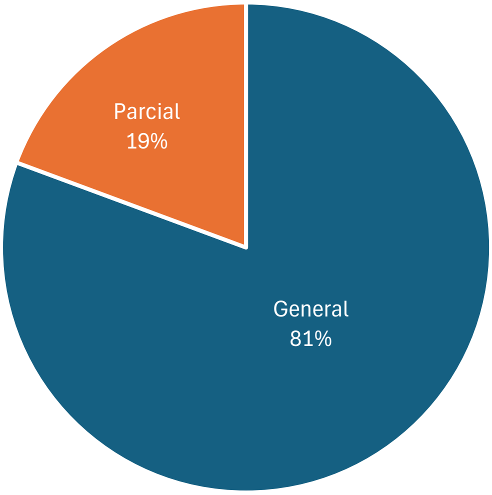


Graph 4.1 – Count of bone surface modification by type of modification and differentiating by agent responsible: green (post-depositional modifications); orange (carnivorous modifications); blue (anthropic modifications).

TABLE 4.16
Count of cut marks, percussion marks and thermal alterations (burning) per taxon. NR1 refers to the sum of remains displaying anthropic modification; NR2 refers to the total number of remains per taxon; these serve to calculate the percentage of modified bone per taxon.

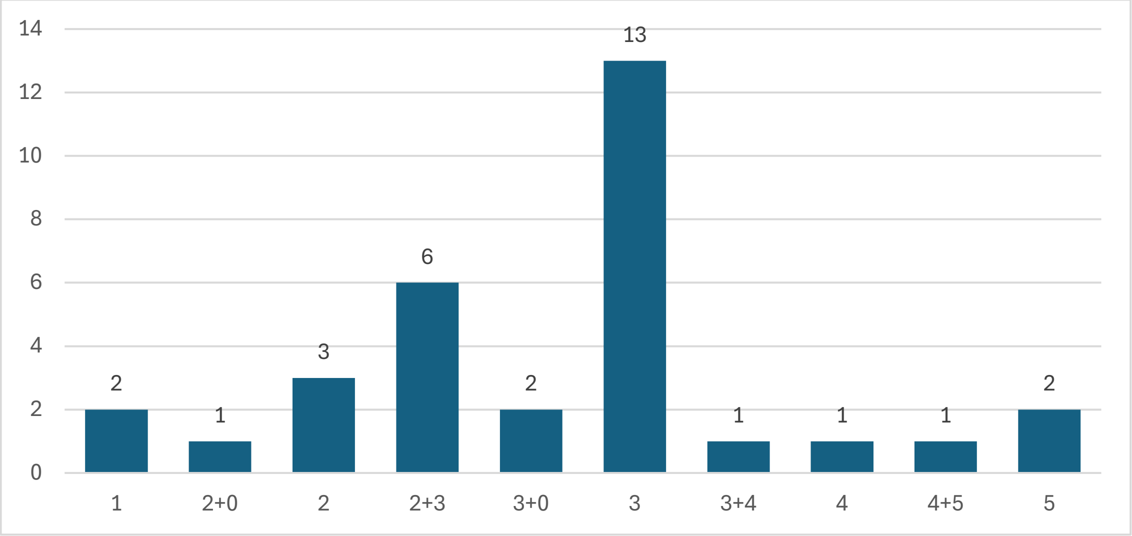
Taxon	**Cut marks**	**Percussion**	**Burning**	**NR1**	**NR2**	**%**
Oryctolagus cuniculus	-	-	6	6	90	*7*
Bos primigenius	-	-	1	1	1	*100*
Cervus elaphus	5	1	1	7	40	*18*
Capreolus capreolus	-	1	-	1	7	*14*
Sus scrofa	1	-	-	1	24	*4*
Emys orbicularis/Mauremys leprosa	-	-	1	1	2	*50*
Undetermined Taxon						
VS	-	1	4	5	28	*18*
VS-S	-	-	2	2	11	*18*
S	-	-	8	8	23	*35*
S-M	6	3	4	13	37	*35*
M	3	3	3	9	32	*28*
Undetermined Size	1	-	1	2	9	*22*
Total	**16**	**9**	**31**	**56**	**304**	**18**

Most thermally altered bones displayed a general disposition of burn marks, whereas a significantly smaller amount displayed partial burn marks (Graph 4.2). Partial burn marks are represented in Graph 4.3 by degree 1, which is intrinsically partial. The most common degree of thermal alteration is the third, corresponding to the bone's carbonization or blackening of the cortical surface. Generally, most burnt bones display mid-levels of thermal alteration ranging between 2 and 3, with low numbers in the remaining degrees (Graph 4.3, Figure 4.1).



Graph 4.2 – Count and percentage of partially burnt bone and of bone with general affectation of burning.

Figure 4.1 – Radius of Oryctolagus cuniculus displaying general coverage of thermal alteration degree 3.



Graph 4.3 – Count of remains per degree of thermal alteration. Degree 0 is used to illustrate partially burnt bones.

Cut marks were the second most common anthropic modification. There were 16 specimens that preserved some kind of cut mark, the overwhelming majority of which were incisions (NR=14 specimens) (Table 4.17). Of these cut marks, around 75% were grouped (more than one mark), and less than 13% were isolated. Only one specimen displayed grouped and dispersed simultaneously. The figures shown (Figure 4.2, Figure 4.3, Figure 4.4) All display grouped cut marks of various appearances and orientations.

TABLE 4.17
Count by type of cut mark

Type of Cut mark	**NR**
Incision	14
Scraping	1
Scraping + Incision	1
Total	**16**

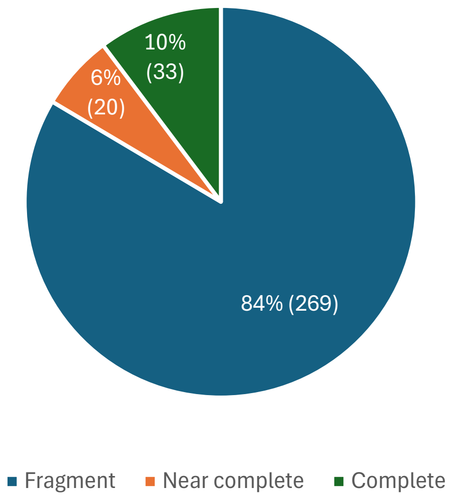
The red deer and the wild boar were the only species displaying cut marks; no individuals of very small or small size were identified bearing cut marks –this could be related to the unnecessity of using tools to process very small animals, as they can be manipulated with the use of hands and mouth. However, in larger animals, the use of tools is required to be able to separate the flesh attached to the bones. Similarly, the use of tools will be necessary if the bone is subsequently cleaned in order to break the bones and access the internal marrow, or if the material is to be used for purposes other than food consumption.

Figure 4.2 – Grouped transversal incisions on the border of a scapula of a small/medium sized animal.

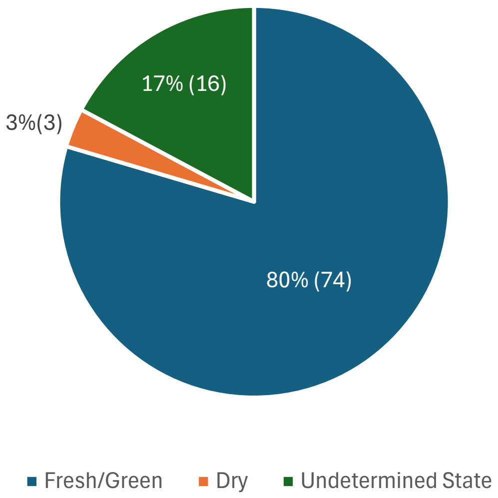
Figure 4.3 – Grouped scraping marks and incisions of various orientations on a stylohyoid of an undetermined medium sized animal.

Figure 4.4 – Grouped scraping and incisions of various orientations on a *Cervus elaphus* left side scapula.

As stated, the assemblage was heavily fragmented, with only 10% of complete elements and 6% of almost complete elements (Graph 4.4). The state of bone when broken was accounted for only on long bones, 80% of which were broken when fresh or green; this could be sometimes representative of bone marrow consumption (Graph 4.5). Modern fractures were encountered on six specimens that displayed fresh brakes, one that displayed dry breaks, and one on a specimen of an undetermined state at the time of breakage.



Graph 4.4 – Count and proportion of fragmentation states in the assemblage.



Graph 4.5 – Count and proportion of the state of bone when broken. No specimens displayed dry and fresh/green states simultaneously. Modern breaks were not accounted for in this graph.

Intentional breakage of faunal remains was preserved in the form of percussion marks. These taphonomic modifications were the least documented anthropic modifications in the assemblage, with only nine specimens identified. The most recurrent signs of percussion were the impact points — these were found either isolated (NR=5) or dispersed/grouped through a single bone fragment (NR=2). In one case, the point of impact created a parasitic flake (Figure 4.5). Only one isolated flake was identified (Table 4.18).

TABLE 4.18
Count by type of percussion mark documented

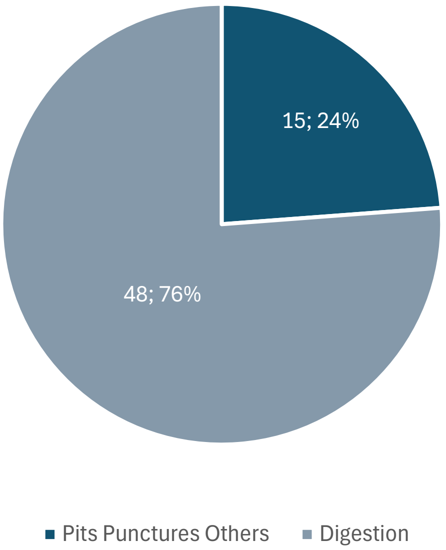
Type of Percussion Mark	**NR**
Flake	1
Impact point + Parasitic Flake	1
Impact Point	7
Total	**9**

Figure 4.5 – Three specimens displaying percussion marks. From left to right: Impact Points on long bone of undetermined small or medium sized mammal; Impact points on a radius of a *Capreolus capreolus*; impact point with parasitic flake on undetermined long bone of a small/medium size mammal.

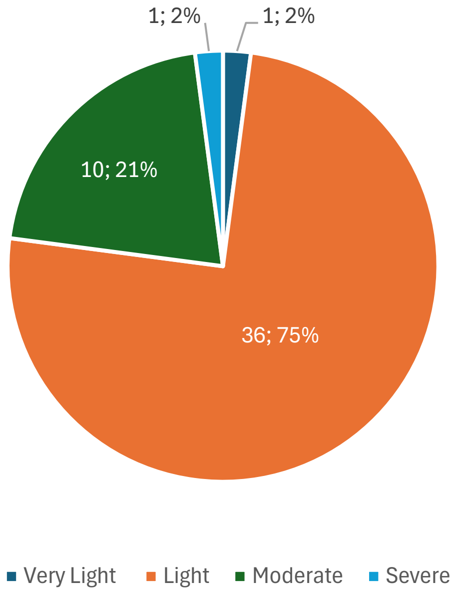
4.3.2. Carnivorous Modifications

Carnivore modifications were relatively common in assemblage, as they were present in 23% of specimens. Digestion marks were the most common, accounting for 76% of carnivorous activity (Graph 4.6) – of the 48 specimens identified with this kind of modification, 75% displayed a light degree of alteration (NR=36 specimens) (Graph 4.7; Figure 4.6).

Of the modifications attributed to carnivores, scores were not identified in the feature. The assemblage also contained a variety of pits, punctures, notches, pitting, and crenulated edges (Table 4.19). The most common among these were isolated pits and notches (Figure 4.7; Figure 4.8). None of the specimens preserved pits, punctures, or others, and digestion marks simultaneously. The only specimen that displayed signs of carnivorous and anthropic behaviors was a humerus of unidentified taxa that preserved grouped incisions and an isolated puncture.



Graph 4.6 – Count and proportion of pits and puncture and digested remains. No specimens displayed pits/punctures and digestion simultaneously.



Graph 4.7 – Count and proportion od degrees of digestion.

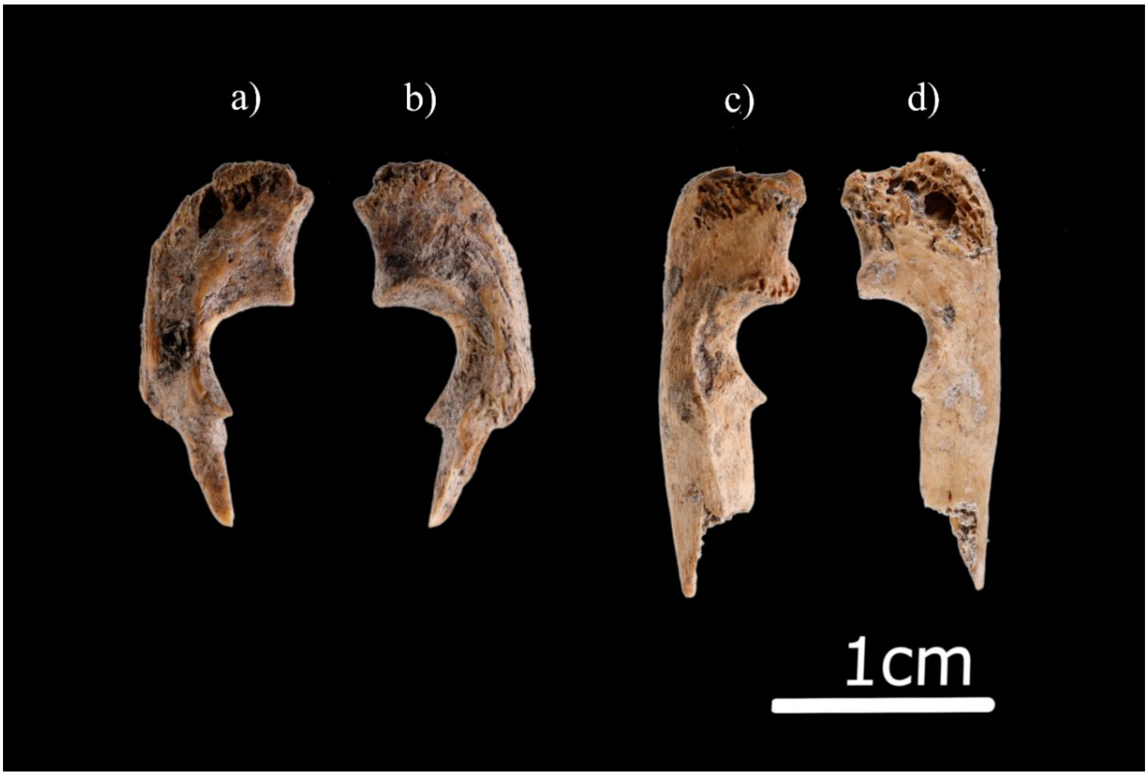


Figure 4.6 – Two lightly digested ulnas of *Oryctolagus cuniculus*: medial (a) view and lateral (b) of a left side ulna; laterial (c) and medial (d) view of a right side ulna.

TABLE 4.19
Count of pits/punctures and digestion per taxon. NR1 refers to the sum of remains with carnivorous modification; NR2 refers to the total number of remains per taxon; these serve to calculate the percentage of modified bone in the assemblage.

Taxon		Pits/Punctures No.	Digestion	NR1	NR2	%
Lagomorph						
	Oryctolagus cuniculus	1	23	24	90	26.7
	Leporidae	1	3	4	9	44.4
Artiodactyla						
	Cervus elaphus	5	3	8	40	20.0
	Capreolus capreolus	1	-	1	7	14.3
	Undetermined	-	1	1	2	50.0
Undetermined Mammal						
	Undetermined	-	2	2	9	22.2
	VS	1	7	8	28	28.6
	VS-S	1	1	2	11	18.2
	S	-	2	2	23	8.7
	S-M	3	5	8	37	21.6
	M	2	1	3	32	9.4
Grand Total		**15**	**48**	**63**	**288**	**21.9**

Figure 4.7 – Fragment of a vertebra with a pit. General picture with the location (right side) and its magnification (left side).

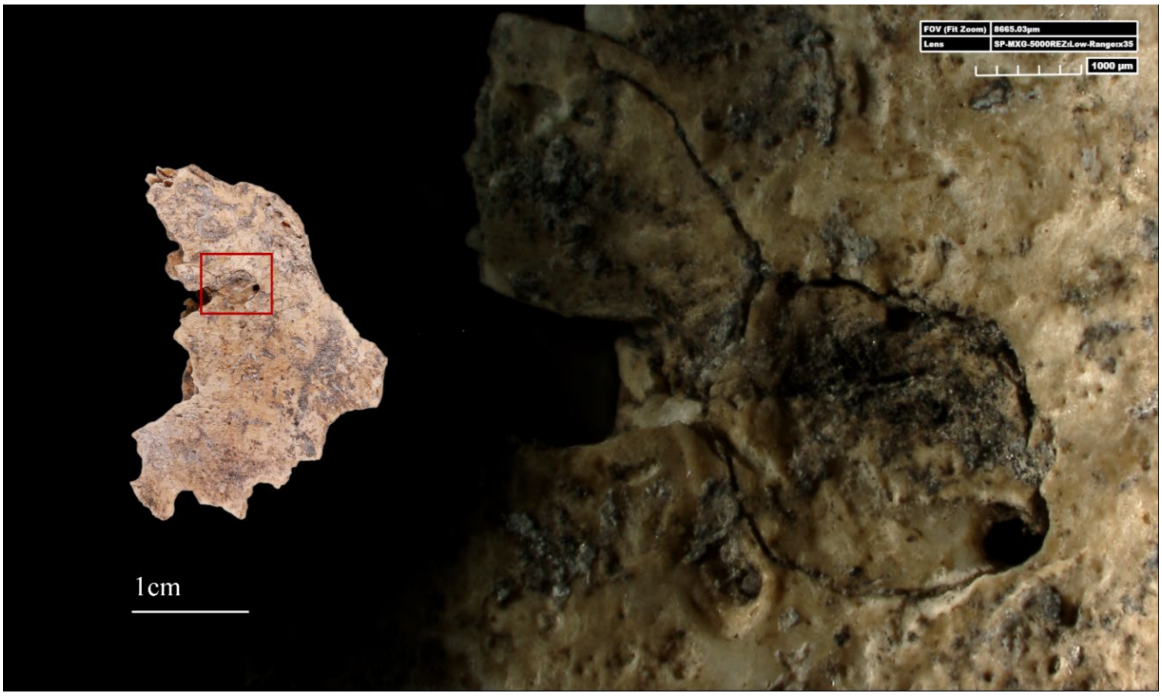


Figure 4.8 – Fragmented of an undetermined cranial bone with a pit. General picture with the location (left side) and its magnification (right side).

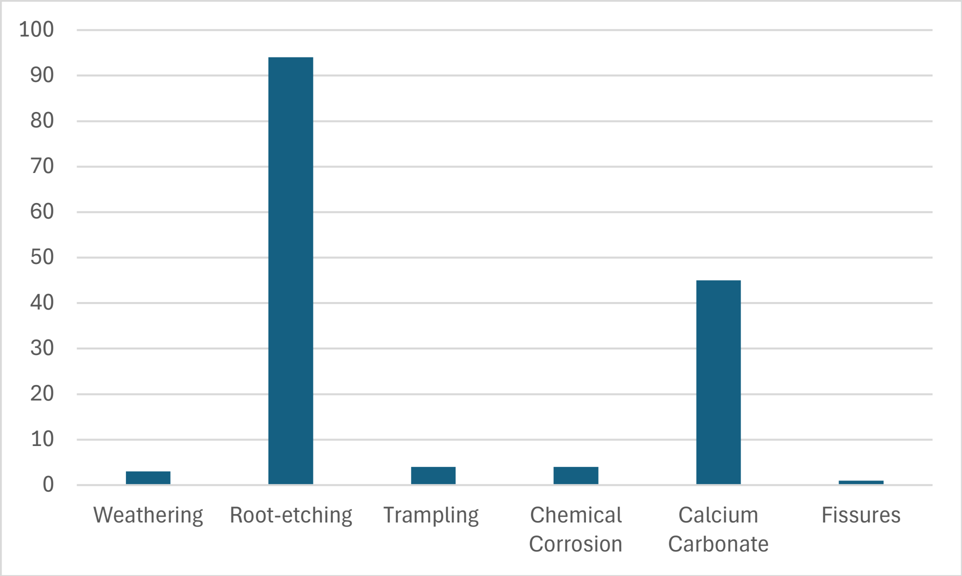
4.3.3. Post-Depositional Modifications

Over half of the analyzed assemblage contained some form of post-depositional modifications. No abrasions, oxides, or gastropod etching were identified in the current assemblage. It is possible that the high concentration of calcium carbonate protected the faunal remains from the development of oxides, and the fast deposition of shell layers influenced the low levels of abrasion.

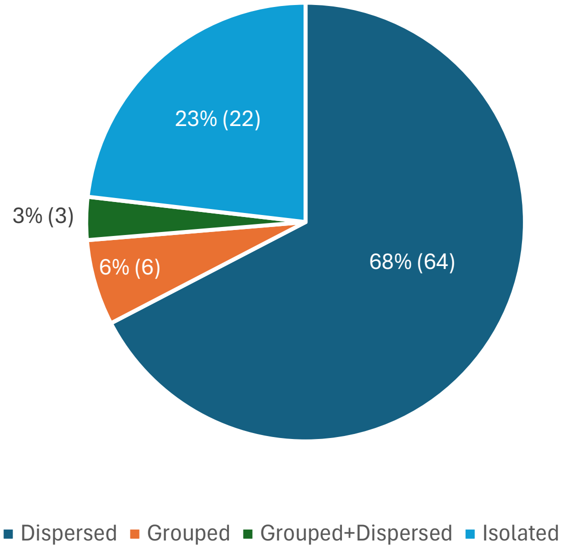
The most recurrent modification found was root etching, followed by calcium carbonate. Other types of bone surface alterations, such as chemical corrosion, trampling, weathering, and fissures, were not recurrent enough to provide relevant data to the current research, as its percentage never surpasses de 1.2% of the total assemblage for each alteration (Graph 4.8). Only weathering stage 1 was identified, which suggests fast deposition of sediments and shell layers.

Root-etching is the most common bone alteration documented (NR=95), comprising a 29.5% of the total assemblage. was commonly found dispersed across the surface of the faunal remains. Only around 3% of specimens displayed isolated root etching, as the roots often created multiple dispersed or grouped marks (Graph 4.9)

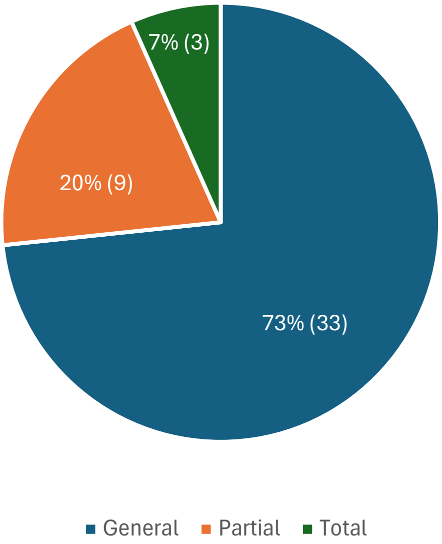
Calcium carbonate concretions were found on 45 of 322 specimens analyzed (*c.* 14% of the total assemblage). In cases where they occurred, they rarely partially covered the surface of the remains. Often, these concretions covered over half of the bone surface; however, complete coverage of the surface of the bone was rare and occurred only in 3 specimens (Graph 4.10).



Graph 4.7 – Count of post-depositional modifications in the assemblage.



Graph 4.8 – Proportion and count of the dispersion of root etching on affected bone.



Graph 4.9 – Proportion and count of the dispersion of Calcium carbonate on affected bone.

4.4. Spatial Analysis

4.4.1. Distribution of Taxon

As stated in the methodology (section 4.4), the spatial analysis approach was only conducted on specimens found *in situ* to not create artificial density clouds where sieved materials originated. Sieved materials were separated from *in situ* materials in the database, which resulted in the number of remains displayed in Table 4.20. The species most significantly affected by this approach is the *Oryctolagus cuniculus*, which, due to its size, is more commonly found while sieving.

Kernel density maps were used to display the accumulation of materials, first to understand the general bone distribution and second to the most representative taxa within the assemblage (*Oryctolagus cuniculus, Cervus elaphus, Capreolus capreolus*, and *Sus scrofa*); the remaining taxa did not have enough specimens to deem this approach helpful.

With this data, a Kernel density map showed that the general distribution of faunal remains displayed a significant accumulation in the southeast area of the structure, followed by less severe accumulations to the south-west and, to a lesser extent, the northwest portions of the structure (Figure 4.9). It is important to note that this map is more representative of the larger taxa, as seen by the significant difference in wild rabbit remains accounted for.

TABLE 4.20
Number of remains from each taxon accounted for in spatial analysis

Taxon	**NR**
Lagomorph	
Oryctolagus cuniculus	11
Lepus granatensis	2
Leporidae	1
Artiodactyla	
Bos primigenius	1
Cervus elaphus	31
Capreolus capreolus	5
Sus scrofa	16
Undetermined	1
Carnivora	
Mustelidae	1
Testudines	
Emys orbicularis/Mauremys leprosa	1
Undetermined Mammal	69
Total	**139**

The distribution of faunal remains seen in the figure above is not represented equally in all species (Figure 4.10 and Figure 4.11). The specimens of *Oryctolagus cuniculus* excavated *in situ* were found mainly in the southwest and northwest accumulation, but no specimens were documented to the southeast. The southeast accumulation seen above seems to be comprised mostly of roe deer, wild boar, and some red deer. The species that displays a broader dispersion rate is red deer, which, although displaying a larger accumulation to the southeast, seems more evenly distributed within the assemblage. The wild boar was amongst the species least dispersed through the analyzed area, with only six of 16 specimens outside the A2 square. The roe deer offered little spatial information as only five elements were found in situ, three in the southeast accumulation and two outside this quadrant.

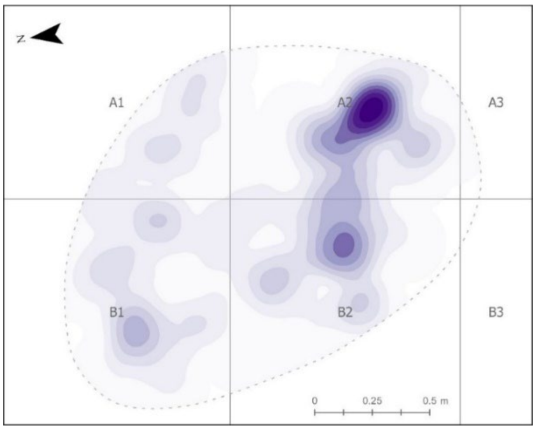


Figure 4.9 – Density map of the faunal remains retrieved within the limits of Feature C.

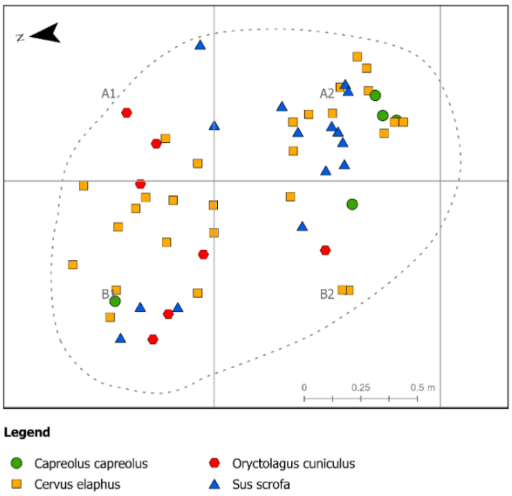


Figure 4.10 – Distribution of faunal remains of the most statistically significant taxa.

4.4.2. Distribution of Taphonomic Modifications

The heavily fragmented state of the assemblage also greatly influenced the amount of taphonomically altered bones found *in situ*. Bones with modifications produced by anthropogenic and carnivore action, as well as post-depositional modification were found in all quadrants of Feature C. The count specimens with these modifications can be found in Table 4.22 and Table 4.21.

The location of all bones with depositional modifications can be seen in Figure 4.12. Specimens that displayed signs of percussion, such as impact points and flakes, were found mainly in the southern quadrants of the feature, particularly in the southeast

(A2). Fragments of bone and teeth that had been thermally altered were mostly found while sieving due to their highly fragmented state, so spatial information gathered was minimal. However, all five specimens with burn marks found *in situ* were located in the northern portion of the feature. Cut marks were found spread over the feature; though, with two main points of focus to the north and to the south-east (Figure 4.13).

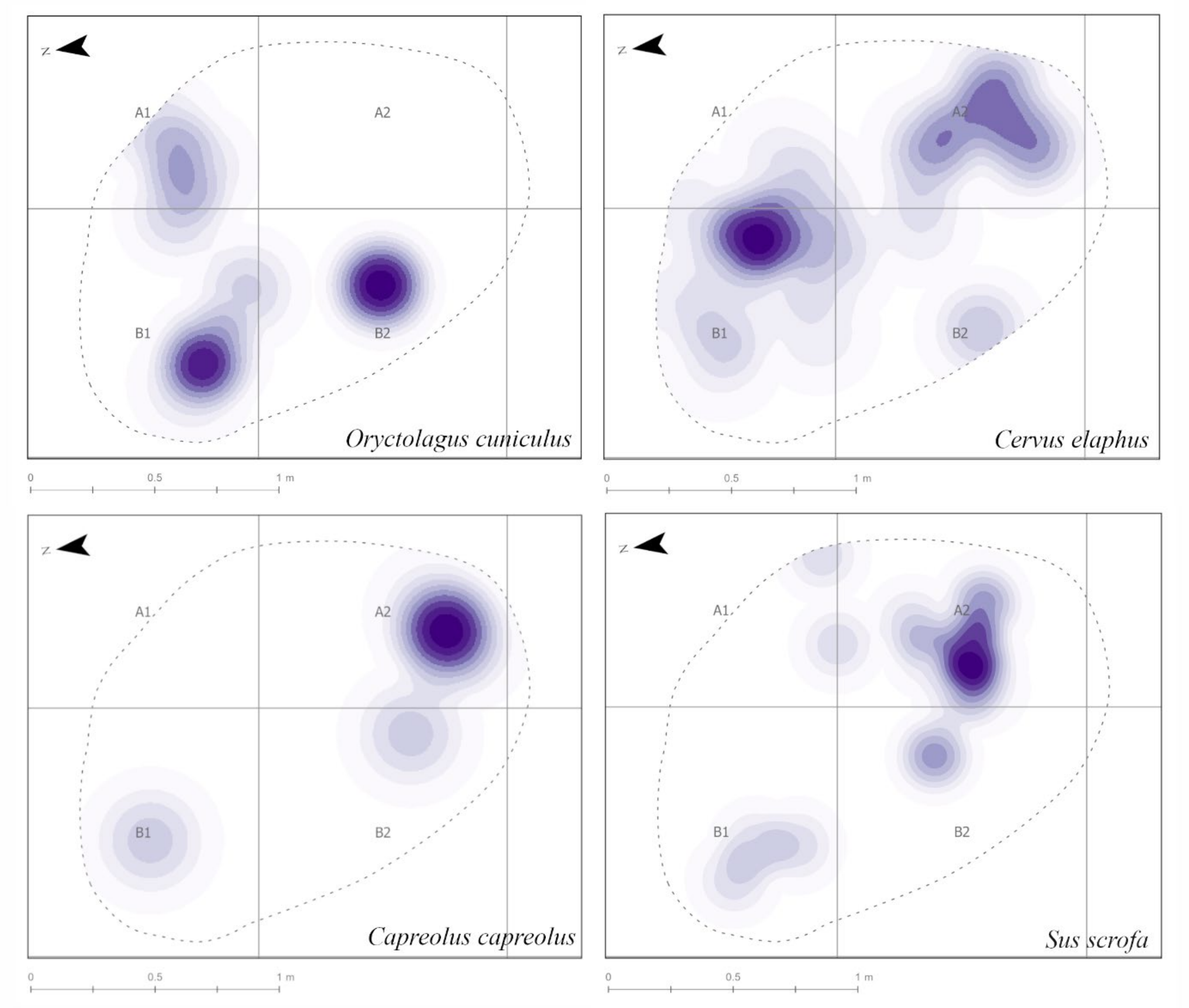


Figure 4.11 – Density maps of the most recurrent taxa from within the limits of Feature C.

TABLE 4.21
Number of remains displaying Human and Carnivore modifications found *in situ*

Human and Carnivore Modifications	**NR**
Cut marks	14
Percussion	8
Burning	5
Pits and Punctures	12
Digestion	9
Total	**48**

TABLE 4.22
Number or remains displaying Post-Depositional Modifications found *in situ*.

Post-Depositional Modifications	**NR**
Weathering	2
Root-etching	61
Trampling	1
Chemical Corrosion	4
Calcium Carbonate	37
Fissures	1
Total	**106**

The dispersion of carnivore-made marks appears to be more localized. Bones displaying pits and punctures were primarily found (but not exclusively) to the southeast of the feature. Nine of the twelve marks caused by the carnivore's teeth were found in the A2 square (Figure 4.14), which somewhat diverges from the marks caused by digestion, which are mainly accumulated to the southwest, with only a single specimen found in the A2 square (Figure 4.15). Most of the specimens accounted for spatial analysis displayed some form of post-depositional, spread over most of the feature. The effect of natural agents influencing the entire feature evenly was not more pronounced in any sections of the structure (Figure 4.16).

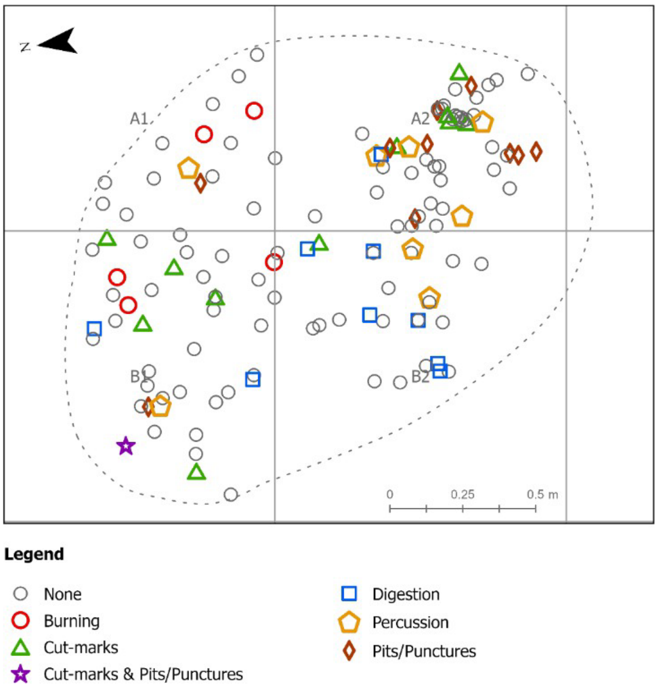


Figure 4.12 – Map of the dispersion of remains modified by Human and Carnivorous action from Feature C.

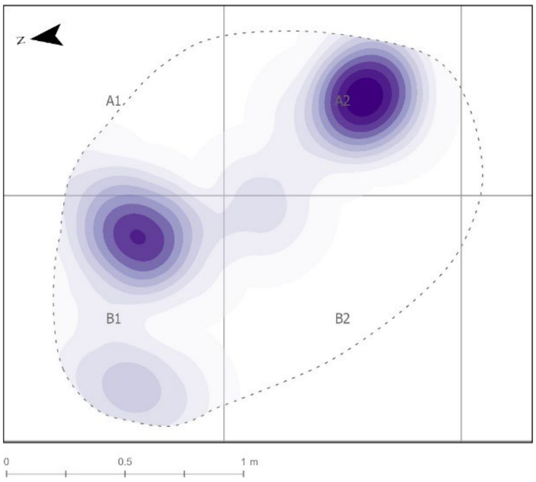


Figure 4.13 – Density map of faunal remains displaying cut marks.

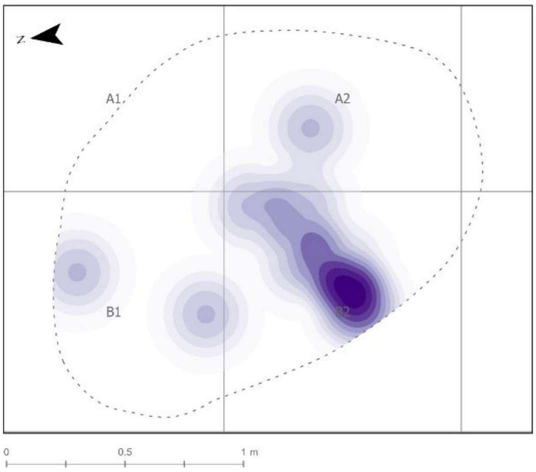


Figure 4.14 – Density map of faunal remains displaying pits and punctures.

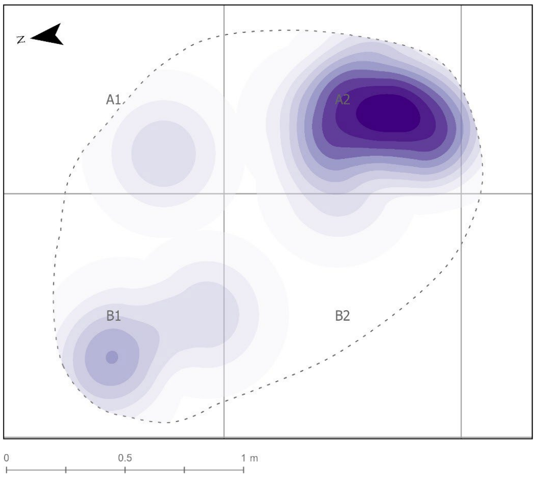


Figure 4.15 – Density map displaying digested remains.

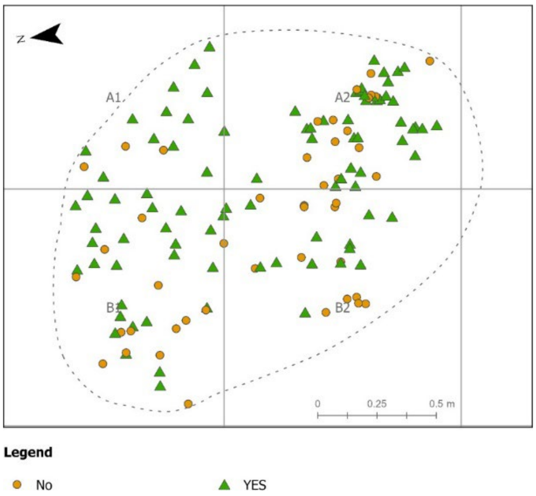


Figure 4.16 – Map of the dispersion of remains with and without post-depositional modifications.

5. Discussion

The results of radiocarbon dating Feature C between 7010 and 6919 ± 23. The dates allocated to the base and top of the feature were coherent. The middle of the feature dated earlier than the top; however, that might be due to poor collagen preservation of the sample compared with the remaining ones. It appears that the Feature was likely a structure of short-term use.

This study did not add to the extensive taxonomic list already associated with the site. It did, however- reinforce some aspects of the paleoenvironmental conclusions of previous studies. Despite the assemblage's size, multiple species were identified, some of which may provide information about the environment surrounding the site. The most common taxa are *Oryctolagus cuniculus* and *Cervus elaphus*, two highly adaptable species that do not provide much environmental data. Other species, such as Mustelids, though documented in multiple studies, also do not provide extensive ecological information, as Detry evidenced in her 2007 study. However, other species found in the assemblage may portray a more extensive picture of the encompassing landscape.

Small and medium-sized taxa were common and represent the different biomes found around the site. Both the wild boar and the roe deer strive in forested areas, woods, and bushy meadows, which offer protection and a food source (Detry, 2007). These species are no longer found around the site.

Detry claims there is a higher proportion of auroch in Cabeço da Amoreira than Cabeço da Arruda, which could mean that the Muge River could have served as an environmental barrier. This species was present in the current assemblage in a single specimen; however, it does suggest the proximity to open landscapes nearby. Aurochs often preferred open landscapes by bodies of water and forests. It was highly adapted to temperate and humid environments. Another taxon that favors open landscapes is the hare (Detry, 2007).

Both *Emys* and *Mauremys* thrive in fresh or low-salinity waters, which coincides with the aquatic environment already known for the site (Detry, 2007; MVBio).

As stated, both the rabbit and the red deer may inhabit various environments. The rabbit, however, favors landscapes with dense vegetation, which offers protection from predators and provides roots that protect burrows from erosion. The sandy substrate is preferred, which makes this area ideal for rabbit populations.

It is evident that agricultural practices in this region have seriously affected the landscape. The surrounding area is now mostly comprised of farmland however, in the Mesolithic, there likely were nearby forests and open landscapes, possibly rich in bushes.

The analysis of taphonomic modifications in the Feature C helped to identify at least two moments of activity of the structure:

- The first phase of occupation was of **anthropogenic** origin, as indicated by the presence of multiple remains with heat alterations, cut marks, percussion impacts, and flakes, among other things. The disposition of these elements on bone surfaces seems to correlate with the primary access of humans to animal carcasses, probably in relation to the creation and use of the structure as a hearth for food preparation by the Mesolithic community. The assemblage displayed preferential transport of larger animals, such as the deer and wild boar, but not of smaller taxa, like the wild rabbit. The location of cut marks can be associated with different human activities, such as the disarticulation and skinning of the carcass, as well as the removal of the tongue. Also, the presence of multiple coloration patterns in thermally altered remains may indicate the roasting of meat, which may generate differential burning of bones. Finally, the presence of percussion marks, flakes, and other elements related to intentional bone breakage shows that humans also access the internal contents of the bones, such as the bone marrow.
- A period of anthropogenic abandonment follows, and subsequent **activity of carnivores**. This observation is based on the remarkably high number of remains affected by gastric acids (digestion marks), pits, and punctures. The modifications found correlate with marks left by carnivorous mammals, a presence that has been previously found in the site, including in the surrounding layers such as *Canis lupus* and wild *Felis* teeth (unpublished data from layer 9, in which a single specimen of each was found). However, this does not rule out the possibility that some remains were accumulated by diurnal or nocturnal birds of prey (Andrews, 1990).

Mesolithic Occupation

Results show a higher presence of small and very small taxa, predominantly wild rabbits. In this assemblage, the rabbit composes 28% of the total assemblage. Like Detry and Pereira, the red deer is the most prevalent species of larger taxa, followed by the wild boar and roe deer. The auroch abundantly identified in the previous studies was present in this assemblage in almost vestigial quantities.

The proportions of species within the assemblage could be related to their availability in the environment surrounding the midden or the effort/reward coefficient of hunting each species. Pereira says auroch and roe deer both require a greater effort in hunting, one due to their size and the other due to their habits and agility. She reinforces that though the effort is great in the case of the auroch, so is the return.

The large percentage of rabbit remains in the assemblage undoubtedly reflects their abundance in the surrounding landscape. Due to their burrowing habits, they may often be intrusive archaeological sites, which may influence the species' NR and proportions within the assemblage. Lentaker concluded that many of the identified rabbit bones were recent in the lower layers of Cabeço do Amoreira. Detry refuted this hypothesis and claimed that rabbits' intrusive nature would have been non-determinant. The remains of the current study must be interpreted in light of taphonomic evaluation.

Experimental research done by Lloveras and colleagues (2009) found that butchery, skinning, eviscerating, disarticulation, and defleshing marks could be found recurrently on rabbit remains and distinguished by frequency, location, orientation, and intensity of the marks; the modifications were easily identified under light microscope (x10-x40) (Lloveras, et al., 2009). It is then expected that these surface modifications would also be identified in the presented analysis using a stereomicroscope (x45); however, the same was not observed. No cut marks were recorded on rabbit bones, although that might be expected as small taxa would not require extensive butchery or carcass preparation and might be cooked whole. If the specimens in the current assemblage had been roasted before any butchering other than skinning, it would justify the absence of disarticulation or butchery marks. Additionally, high temperatures were also found to make the bone more fragile and susceptible to breakage, creating highly fragmented assemblages and potentially affecting the identification of cut marks (Lloveras, et al., 2009). Further tests would have to be done to determine a more precise history of the environment that produced the thermal alterations, such as Scanning Electron Microscopy, Transmission Electron Microscopy, X-ray diffraction, or Fourier Transform Infrared Spectroscopy.

The study of Lloveras and colleagues also concluded that roasted carcasses would show thermal alteration of the bones only on areas of the skeleton that were not significantly protected by meat or flesh, such as the paws, the snout, or distal ends of long bones. Their experiment concluded that an ash temperature of around 320ºC was enough to carbonize bone (black surface, 3rd degree on the standards of the current analysis) (Lloveras, et al., 2009). Other researchers have used rabbit bones for archaeological experiments concerning hearths, namely Pérez and colleagues (2017), and found that the bones did not have to be in the ashes to suffer chromatic alterations due to heat. These researchers concluded that if a bone is thrown into flames or placed at the base of the hearth, it will often be wholly calcinated (degree 5), partially calcinated (degree 4), or carbonized (degree 3). However, bones buried underneath the hearth were more often carbonized (degree 3) or with less significant thermal alterations (degree 1 or 2). Bones thrown into the embers of the experimental hearths varied between degrees 1 and 4 of thermal alterations (Pérez, et al., 2017). These findings suggest that the rabbit bones in the analyzed assemblage were not in direct contact with the flames as there were few remains displaying the 4th and 5th degrees of thermal alteration. Instead, they were likely located underneath the base of the hearth or placed in the embers after the extinction of the fire (Figure 5.1; Figure 5.2.).

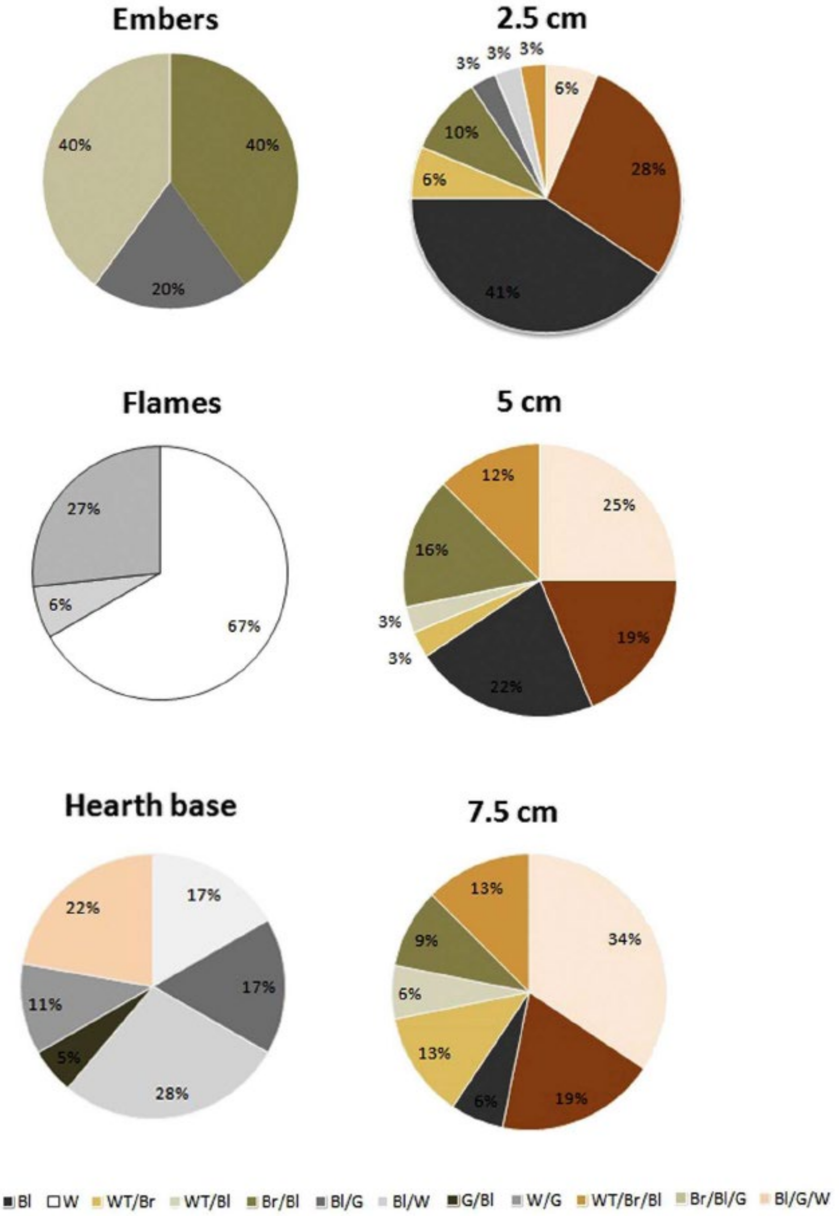


Figure 5.1 – Chromatic distribution of thermal alterations in relation to the heat source in the experiment carried out by Pérez, et al., 2017 Abbreviations used are WT (without thermal alterations- grade 0); Br (Brown- degree 2); Bl (Black- degree 3); G (Grey- degree 4); and W (White- degree 5). Source: Pérez et al, 2017, p.297.

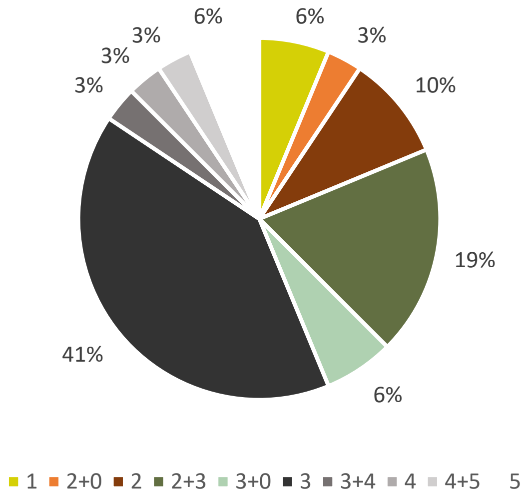


Figure 5.2 – Degrees of thermal alteration in the analyzed assemblage. The percentage per no thermal alterations was not included as it pertains to 90% of the assemblage.

The presence of all body parts for rabbits is unsurprising since, due to its size, it is easily transported to the site. In Pereira's study, the relative abundance of body parts showed that deer and wild boars were transported whole to the site. This was not seen in the present assemblage nor the study of Feature A. This feature was excavated in 2014, where they found, amongst other artifacts, the faunal remains of a single taxon – a minimum of two red deer. This study identified a higher representation of the appendicular skeleton (*c.* 76%) than the axial skeleton (*c.* 14%) (Gonçalves, et al., 2018a). A similar pattern can be seen in the red deer of the Feature C. The appendicular skeleton comprises 62.5% of deer remains, primarily due to long bones but also accounting for the fragments of pelvis bones and a cut-marked scapula, which attest to limb dismemberment. The remaining 37.5% of the axial skeleton in the assemblage is mainly comprised of mandibles, suggesting the heads were taken as well; however, the absence of ribs and dorsal and lumbar vertebrae suggests the body was not carried to the site. Only one element of the non-cranial axial skeleton was found: the axis, which could have been transported to the site if the severing of the head included the cervical vertebra.

Considering that in the upper levels of the midden, there appears to be no preferential transport of red deer, Feature A and the feature in the study may represent a significant change in strategies employed by the occupant population throughout time.

A similar analysis had to be conducted for wild boar, which Pereira also said possessed no preferential transport. In the present study, only elements from the skull and limbs were identified, which could portray a similar preferential transport of body parts as the deer or be affected by the sample size.

Although the most recurrent taxon in the assemblage, wild rabbits were not the most significant food source. The meat provided by the four individuals accounted for is substantially less than that of the three deer identified. Lentacker (1986), who calculated the usable meat proportion, achieved a similar conclusion.

Pereira (2014) highlights the preference for red deer and wild boar consumption and states that taphonomic analysis also makes this evident. Previous studies showed anthropic modifications on bone surfaces were observed in multiple species, mostly artiodactyls (Detry, 2007; Pereira, 2014). Cut marks, thermal alterations, and purposeful fracturing of specimens all served as indicators of hunted species. Although not found in very small individuals, these marks may portray the difficulty of butchering larger animals and not necessarily a dietary preference. Additionally, the proportions of cut marks and thermal alterations within an assemblage may be challenged when considering smaller individuals since Pereira did not analyze rabbit bones or smaller taxa, which in the present study are the most predominant thermally altered species.

The location of cut marks and percussion marks indicates many carcass uses. The documented modifications are congruent research regarding bone marrow consumption, meat removal, and skinning. Following the reference collection proposed by Costamagno and colleagues (2019), cut marks found on red deer were congruent with those caused by actions of defleshing (scapula) and disarticulation (metapodials). The same can be said for Undetermined Medium and small-sized taxa, in which most marks found on anatomically determined remains were associated with defleshing (scapula and tibia). Ethnographic and experimental studies, as well as other zooarchaeological analyses regarding various taxa, have agreed that cut marks on the hyoid are usually caused by the removal of the tongue by severing its muscular attachments or by the cutting of the throat (Bunn, et al., 1986; Piper, 1991; Tagliacozzo, et al., 2013). Similar cut marks on the hyoid were found in Detrys' and Pereira's research, in which they concluded the marks were issued by the removal of the tongue - Detry described the specimen as an unknown artiodactyl (likely red deer or wild) (Figure 5.3), whereas Pereira's were of unknown artiodactyl with multiple marks with similar orientations (Detry, 2007; Pereira, 2014).

The only specimen that displayed signs of carnivorous and anthropic behavior was a humerus of unidentified taxa that preserved grouped incisions and an isolated puncture. This element could suggest that carnivores were not accumulating agents but either cohabitated with humans on the site or exploited domestic waste left behind.

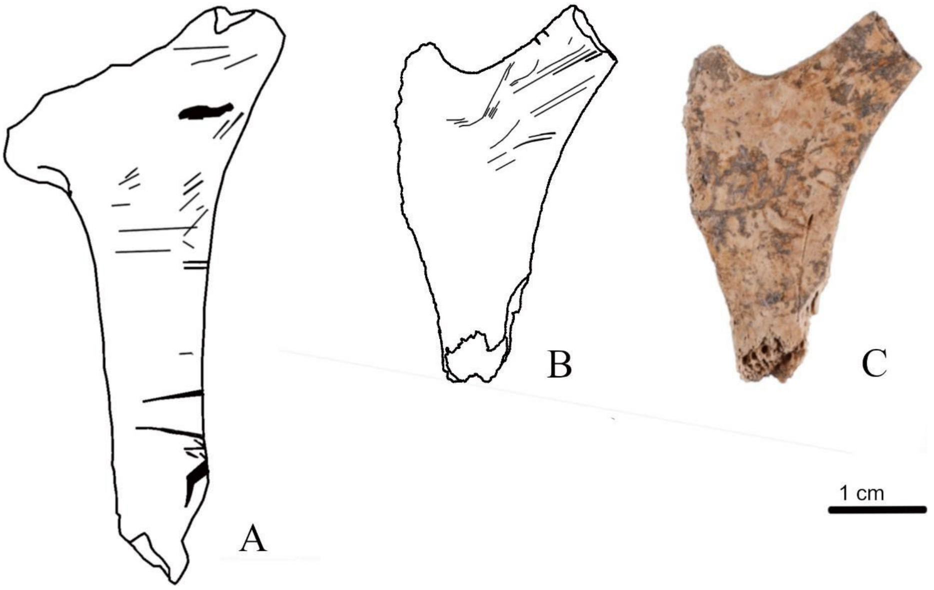


Figure 5.3 – Cut marks on hyoid bones. Left: Unknown Arctyodactyl. Authorchip of C.Detry (2007, p277). Center and Right: specimen of an unknown medium sized mammal. Authorship of Leonor Filipe.

No significant conclusions were achieved through the remains of auroch as its presence was documented with only one atlas. Moreover, no fragments of unidentified large taxa were documented.

Very few remains of roe deer were found, amounting to a single individual. However, impact points in a radius suggest this species' consumption of bone marrow. The same can be said about red deer. Most identified impact points were found on long bones, except one outlier on a rib of a medium sized animal - this mark could have been left during the carcass preparation to remove the organs.

Lentaker (1986), Detry (2007), and Boneta (2022) had already documented the presence of *Emys orbicularis* or *Mauremys lepros*a. This assemblage identified some elements of the carapace, which aligns with Detrys’ claims that aquatic reptiles were surely a part of the Mesolithic diet.

Very few bird remains were identified, most of which were of undetermined taxa. Only one specimen of *Columba livia/oenas* was detected. Other researchers have claimed that birds could have been an important resource. However, they can be quite fragile and are highly susceptible to taphonomic modifications, making their proportions in archaeological assemblages differ from their consumption and role in the Mesolithic diet (Detry, 2007).

In Detry’s research (2007), she did not identify a greater preference for the hunting of young or senile individuals. She states that adult animals of medium and large taxa appear to be a preference, which suggests sophisticated hunting techniques. The hunting of young wild boars was a pattern identified by Pereira (2014). In the assemblage presented, there was an apparent preference for sub-adult wild boars, as two of the individuals still displayed notable surface porosity in the mandible and were classified as sub-adult, and another one still showed signs of tooth eruption and was calculated to be under the age of two (Schmid, 1972). Multiple deer remains were also found to belong to at least two young or young adult individuals— one under three years of age, estimated due to teeth eruption (Marín, et al., 2024).

Abandonment of the Structure

In previous studies, carnivore activity is usually credited to small predators that inhabited this area, such as felids (Iberian lynx and wild cat), canids (fox and dog), and some mustelids and birds of prey (Detry, 2007). The first two groups likely were the agents responsible for the taphonomic modifications found in the assemblage. The type of marks left on the bone was considered to distinguish between alterations made by each group. Moran and O’Connor (1991) claim that dogs chew and gnaw at bones more regularly than felids. In that case, grouped pits or pitting could be attributed to canids.

Both felids and canids are highly represented in all previous studies. However, it remains unclear if, in Cabeço da Amoreira, the dog is a companion or commensal to the Mesolithic occupation. Regardless, they leave a significant mark in the faunal assemblage, which could be underrepresented considering the degree of destruction canids may impact on faunal remains. The gnawing and chewing of bone make the specimen more fragile and susceptible to erosion, fracturing, or complete destruction over its taphonomic history (Detry, 2007). Munson and Garniewiez (2003) found that dogs seriously affect bone preservation, particularly in young individuals. This study fed 35 demi-mandibles (24 white-tailed deer and 11 sheep) to two medium-sized dogs. Results showed reasonable survival rates amongst individuals over 30 months old (90 to 100%). In contrast, the youngest specimens (3 to 4 months old) had a survival rate of 0% if the bone had been subject to cooking and 17% if they were raw. This could be relevant considering the presence of young individuals in the assemblage.

In Detry’s research, some chew marks were attributed to humans and some to carnivorous animals on bones previously consumed by humans. A mark found on a wild cat humerus was attributed to a small carnivore, likely a sign of opportunistic necrophagy. Some marks were located in areas that would be impossible to access without the removal of meat and organs, therefore suggesting the carnivore pits found were made after humans' preparation of the carcass. Detry adds that birds of prey probably had little impact on the assemblage, as there was no clear indication of their activity on the site. However, they remain a possible agent responsible for taphonomic alterations.

Pereira (2014) arrived at conclusions similar to those of Detry (2007) regarding the agents responsible for pits and punctures within the assemblage. Additionally, she mentions a considerable number of digested remains (66% of the representation of carnivorous activity), including multiple wild boar phalanges, an Iberian lynx phalange, and a roe deer astragalus. The size of these elements suggests it was not a particularly small carnivore that ingested them. However, since this study focused on large mammalian taxa, it is possible that the digestion of smaller animals, and therefore, smaller carnivores, could still have been present.

Fernández-Jalvo and Andrews (2016) state that carnivorous mammals, such as mustelids, canids, and felids, often display extreme levels of digestion. However, despite the multiple pieces of evidence of carnivorous mammals, no specimen displayed such a heavy display of digestion in the assemblage. In fact, 77% of specimens had light digestion or less, which is more commonly associated with nocturnal birds of prey (Andrews, 1990; Fernández-Jalvo & Andrews, 2016). Some moderate digestion was identified, suggesting the presence of perhaps mammals or diurnal birds of prey. Regardless, it is impossible to deny the presence of canids and felids as agents responsible for pits and punctures, whereas there is no direct evidence linking birds of prey to the assemblage.

In her work, Pereira identified multiple carnivore-made alterations, some of which possessed both digestion and teeth marks (a total of 3), a phenomenon not found in the current assemblage. It is possible that since no bones displayed pits or punctures and digestion simultaneously in the assemblage presented here, the two were performed by different agents. Although not exclusively, pits and punctures were more common in medium-sized taxa, whereas digestion was more commonly found in very small taxa. This does come with some exceptions, as some digested remains would have been difficult for nocturnal birds to consume, such as a *Cervus* scapula.

Unfortunately, due to the assemblage size, little information could be retrieved from spatial analysis. There was, in fact, a concentration of faunal remains to the southeast of the feature, where a concentration of digested remains was also found. Pits and punctures were not found within that concentration, and cut marks appeared to be relatively distributed throughout the feature. North of the feature has relatively few signs of carnivorous activity. The dispersion of post-depositional modification suggests that the feature was covered/buried underneath a sedentary matrix relatively quickly due to the absence of weathered remains. Disposition of post-depositional modifications was found homogeneously within the feature, suggesting that the feature was covered in its entirety simultaneously. Photographic documentation shows a shell-rich layer covering the top of the feature.

It is possible that these apparent nuclei of accumulated materials were areas of disposal of the hearth ash; however, further analysis of the rest of the archaeological collection would have to be made to determine that. If this is the case, it may explain the diverse distribution of remains per taxon within the feature.

6. Conclusion

This study aimed to analyze the faunal assemblage of Feature C, focusing on the main fundamental goals of this research, such as interpreting the archaeological record, discussing issues related to the diachronic history of the site, and examining human behavior over time. It also analyzed the post-depositional processes to understand the history of the feature, its functionality, accumulating agents, and post-depositional influence.

The faunal analysis reinforced the knowledge already acquired regarding the ecosystem around the site as a paleo-estuary of low salinity surrounded by various landscapes, such as open bushy landscapes and forests rich in resources.

The fragmented state of the assemblage heavily influenced anatomic, taxonomic, and taphonomic identification. This phenomenon influenced the number of determined remains and, possibly, could have been caused by intentional bone breakage, as proved by the presence of percussion marks, and potential bone breakage due to carnivorous activity, as evidenced by multiple pits, punctures, pitting, and other marks left on the remains.

As with previous studies, artiodactyls remain the most significant food source. There is a trend of continuity with the higher levels of the midden in terms of the most consumed species, namely with layers 1 and 2 studied by Pereira (2014). Red deer was the most significant food source, followed by the wild boar. Despite the number of remains found, the auroch would've provided an abundant food source. The roe deer was considered the least significant food source as only one individual would not be offered much sustenance. In this case, the abundance of rabbit bones in the assemblage would not significantly influence the diet, as four individuals would have still provided less meat than other taxa, such as the red deer or the wild boar.

Extensive butchery marks attest to the preparation of the carcass for food consumption. In line with previous studies, the consumption of bone marrow, as proved by the multiple impact points and flakes, and of the tongue, as demonstrated by cut marks in the hyoid, perdured.

There is a break in continuity from the utmost levels studied by Pereira to Feature C. No preferential transport of species was identified in layers 1 and 2. However, Feature C and Feature A suggest preferential transport of limbs and heads of larger Mammalia taxa. It is possible that these animals were prepared elsewhere around or away from the site and not deposited with the remaining skeleton, which was used for consumption.

The presence of juvenile or young adult individuals was evident in the most representative taxa (*Oryctolagus cuniculus*, *Cervus elaphus*, and *Sus scrofa*). In the case of the red deer and the wild boar, it is possible that these individuals were targeted because they were easier to capture. This trend had already been documented in Pereira's study. However, Detry did not document preferential ages in the consumption of these species. In future studies, the analysis of juvenile red deer may provide data on seasonality in the site's occupation.

There is clear evidence of carnivore tooth marks in the assemblage, which might be related to the presence of canids at the site. Multiple bones displayed pits and punctures, but also pitting. Gnawing on the extremity of the bones is a typical characteristic of canid accumulations, and it has already been found on the site in previous studies, including evidence of faunal remains. It is possible that birds of prey were responsible for light digestion marks. However, no direct evidence linked these predators to the osteological remains, so it remains possible that canids digested the bones. It remains unclear if the canines that modified the assemblage were commensal or domesticated; However, there has been evidence of domestication in the Muge shell middens in the past, so it is possible that the individuals that caused the pitting were not wild.

After both human and non-human accumulating agents abandoned the feature, post-depositional processes ensued. The sedimentation process was relatively fast and homogenous throughout the feature. This fast process protected bones from being severely weathered, and the high calcium concentration in the matrix might have safeguarded the bones from corrosive agents and oxides.

After observing the spatial distribution of the post-depositional modifications on bone and observing photographic documentation of the profile of the feature whose highest point was delimited by a shell layer, a hypothesis surfaces. It's possible that after the feature had served its purpose, it was covered purposely by a shell-rich layer. However, further stratigraphic studies must be completed to confirm that accurately.

Further analysis will be necessary to understand this structure better. All archaeological materials from the feature and surrounding layer (layer 9) should be analyzed collectively. Fire-cracked rocks, charcoals, and lithics may provide abundant information regarding the structure's use and are, therefore, integral to understanding Feature C. From the faunal analysis alone; it remains unclear if the structure is composed of solely a hearth or other deposits as well, possibly from food waste or cleaning of the hearth.

7. Bibliography

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