Finding Moby: Novel approaches to identifying human-cetacean relationships in Atlantic Scotland from *c.* 2500 BC to *c.* AD 1400

Sally Jane Evans

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Cardiff University

Department of Archaeology and Conservation

School of History, Archaeology and Religion

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ABSTRACT

This thesis examines cetacean bone zooarchaeological assemblages and investigates human-cetacean relationships on the Scottish Islands. Cetaceans provide a wide variety of resources including flesh, baleen, bone and oil and although cetacean bone is found on archaeological sites spanning millennia this material is often overlooked due to methodological and interpretive hurdles. By identification and examination of cetacean remains through time and space this thesis explores human-cetacean relationships in Atlantic Scotland over a four-thousand-year period.

A key part of this work is the development of a method and toolkit for morphometric identification of cetacean vertebrae. This is achieved through study of a large novel dataset combined with data from existing studies and drawing on research into functional morphology and evolutionary biology. Species-level identifications using this method are possible, and the data covers all species which inhabit north-eastern Atlantic today, and one third of all species globally.

Cetacean bone assemblages from two multiperiod sites, Cladh Hallan and Bornais, are recorded, analysed and identified using morphometric data and biomolecular analyses (Zooarchaeology by Mass Spectrometry). Investigation reveals complex patterns of utility. The Hebridean islanders used cetacean meat, oil, bone and likely blubber, but use also went beyond functional utility, and cetacean remains represent social processes. There are hints that active whaling may have occurred in prehistory, and comparison of historical evidence with zooarchaeological data revels complex patterns from the Norse period suggesting interplay between cetacean exploitation and that of other marine species. While many cetacean species were exploited, the sperm whale held a special place in the Hebridean past and the relationship with this animal may have been the focal point of human-cetacean relationships on the islands.

The methodological advances and analysis of two large cetacean bone assemblages shed new light on human-cetacean relationships in the past and pave the way for future investigations.

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Chapter 1: Introduction

1 INTRODUCTION

This thesis explores zooarchaeological evidence for past human-cetacean relationships on the Western Isles of Scotland. The current chapter gives an overview of where the work can contribute to original knowledge, and why cetaceans (whales, dolphins and porpoises) and the Western Isles have been chosen for study. It then provides a further introduction to the key areas of research undertaken within this thesis.

1.1 ORIGINAL CONTRIBUTION AND AIMS

This thesis takes steps to overcome methodological hurdles facing researchers of cetacean zooarchaeological assemblages and goes on to explore human-cetacean relationships over a four-thousand-year period in Atlantic Scotland. Its primary goals are to develop a new method and toolkit for taxonomic identification and apply this alongside existing investigatory methods to bone recovered from archaeological sites in the Outer Hebrides of Atlantic Scotland. This approach will investigate human-cetacean relationships through patterns of cetacean use and procurement from the prehistoric to the Norse periods. It is in these areas that the thesis aims to make a contribution to original knowledge.

1.2 WHY WHALES AND THE WESTERN ISLES?

Human-cetacean relationships in the modern world are varied. Cetaceans evoke strong emotions among human communities today and the ways in which we interact cover a wide spectrum of different scenarios. Some go whale-watching, others go whale-hunting, others run to the aid of those unfortunate animals who find themselves stranded on the shore. Cetaceans may be mundane resources, foci of scientific enquiry, or imbued with symbolic meaning. The varied and often high-profile roles cetaceans hold today contrasts starkly with how little we know of human-cetacean relationships in the past. While their bones and teeth are present on archaeological sites from the Palaeolithic period onwards many of their products such as blubber, oil and meat are not well represented in faunal assemblages. Additionally, cetaceans have been neglected by zooarchaeological study owing to problems with analysis and interpretation which confound attempts to understand the nature of past human-cetacean relationships.

The Western Isles, or Outer Hebrides, have a complex history of biocultural interactions and present an ideal area in which to investigate human-cetacean relationships. Zooarchaeological evidence from this area shows complex patterns of subsistence both on land and at sea. Studies of terrestrial fauna extend to in-depth discussions of diet, animal management practices, seasonal cycles and human-animal relationships, with marine species including fish, seals and birds woven into these discussions. However, cetacean research trails far behind owing to the methodological difficulties in analysing the large and often highly fragmented cetacean bone assemblages. The paucity of current knowledge on cetacean use and procurement is reflected within the Scottish Archaeological Research Framework (ScARF) which set out a series of aims which demonstrate the need for research into cetacean remains in Scottish contexts. This research will contribute towards these aims.

1.3 AREAS OF STUDY

This research therefore focuses on a number of key areas: methodological development in identification; and archaeological evidence for human-cetacean relationships as evidenced through cetacean bone use and deposition, and procurement.

Methodological advances in taxonomic identification are the first step and this study develops a methodology and toolkit for morphometric identification. Functional morphology and evolutionary biology are drawn on to provide insights into which osteological traits can be used for taxonomic identification, and a large morphometric dataset is presented to demonstrate differences between taxa.

This method is then employed alongside existing biomolecular techniques to investigate cetacean taxa present in the zooarchaeological assemblages of Cladh Hallan and Bornais. By conducting work to enable the identification of cetacean bone this thesis facilitates more detailed investigations of cetacean zooarchaeological assemblages, enabling a more precise examination of specific human-cetacean relationships.

Using these new and existing methodologies for identification, and targeting analysis, the research then examines spatial and temporal patterns in cetacean use, deposition and procurement to develop an understanding of human-cetacean relationships. Examination of cetacean utility considers evidence for the use of meat, of bones and marine ivory for artefact production, and of blubber and oil. It also recognises that utility can go far beyond the functional and can illuminate social practices and wider human-animal-landscape interactions. These different areas of utility are explored by reviewing data on taxa, elements, bone modifications and patterns of deposition through space and time.

Procurement patterns are also a key area of study within this work and again taxonomic identification is investigated to provide insights. The habitats and characteristics of taxa identified are explored in reference to wider patterns of contemporary marine exploitation, contributing to our understanding of potential modes of procurement. The temporal span of the work also allows parallels in the rich historical literature on cetacean use and procurement in the North Atlantic to be drawn upon.

1.4 WIDER CONTEXT AND RELEVANCE

Methodological advancements have wider relevance and improvements in methods for taxonomic identification have the potential to provide other researchers with tools to analyse other assemblages. The method and toolkit for identification were designed with potential for wider use in mind.

The research allows the role of cetaceans in prehistoric and Norse economies to be understood, allowing these taxa to be integrated into the wider understanding of diet, resources, economy and society on the Atlantic margins.

This research also holds wider relevance which reaches beyond the discipline of archaeology. Analysis of archaeological cetacean remains has the potential to shed light on past cetacean populations, ecology and distribution, and taxonomic identification can unlock the wider research potential of assemblages (e.g. Kitchener et al. 2021).

2 CHAPTER OUTLINE

Chapter 2 gives an overview of the key areas of research relating to archaeological cetacean bone, elaborating on the areas outlined above. The chapter presents the main methodological and interpretive issues to the analysis of this bone and approaches to overcoming these issues. A discussion of previous approaches to cetacean utility and procurement provides the necessarily contextual information required for understanding the methodological developments and interpretations set out in later chapters. Directions in research are also highlighted and research questions addressed within this thesis are established.

Chapter 3 establishes the geographic, environmental and temporal setting of the sites chosen as case studies: Cladh Hallan and Bornais. The reasons for the choice of these sites are outlined. Cetacean biodiversity in Scottish waters is also considered and a review of archaeological work, sites and economies is undertaken with current evidence of cetaceans in Scottish archaeological assemblages and North Atlantic historical documents reviewed.

Chapter 4 sets out the methodology used for the investigation of the assemblages from Cladh Hallan and Bornais, from the basic recording of the cetacean bone assemblages to the assessment, analysis and interpretation of results. Chapter 4 provides an account of the specific methodology employed in the analysis of peptides for taxonomic identification on fragmentary bone using Zooarchaeology by Mass Spectrometry (ZooMS). Specific consideration is also given to the sampling strategies employed on the material from Cladh Hallan and Bornais.

Chapter 5 reports on the development of the method and toolkit for the identification of cetacean bone and focuses specifically on vertebrae. The chapter considers functional morphology and evolutionary biology as a basis for differentiation of taxa based on cetacean vertebral osteology. The primary datasets drawn on in this chapter include measurements and morphological observations collected during the completion of this thesis, as well the work of earlier studies. These datasets are analysed and presented in a manner which allows for their use in cetacean bone identification. Limitations to these methods of identification are discussed, and examples of the toolkit in use are presented, demonstrating the identification of bone from Cladh Hallan and Bornais.

Chapter 6 outlines the results of the assessment and analysis of cetacean bone from the case study sites. The success of the methods of identification is first reviewed, followed by a consideration of the cetacean bone assemblages at each site. Taxa, elements and quantities of bone are reported on after which modifications are reviewed and spatial and temporal patterns are outlined.

Chapter 7 builds on the results outlined in chapter 6 and discusses the utility of cetacean remains from the Bronze Age to the Norse period. Patterns of use and deposition are interpreted in relation to oil, meat and artefactual utility, placing the material from Cladh Hallan and Bornais within the wider discourse on cetacean bone assemblages. The chapter also goes beyond discussions of functional utility and considers evidence for the social utility of cetaceans and human-animal-landscape interactions which aid understanding of the human-cetacean relationships.

Chapter 8 principally addresses the potential modes of procurement in light of wider Hebridean strategies of marine exploitation. This discussion draws on a range of other evidence, including the use of cetacean remains set out in chapter 7, and evidence from contemporary landscapes, economy and society. This chapter also contextualises the debate on procurement with reference to historical documentation of cetacean procurement in the North Atlantic.

Chapter 9 provides the conclusions to the research set out within this thesis. The value of this research in developing a novel integrated methodology of morphometrical and proteomic analysis of cetacean remains is examined. The new insights into the case study sites and our understanding of cetacean use and procurement in the Outer Hebrides and beyond are reviewed and directions for future research outlined.

Chapter 2: Investigating cetaceans in the archaeological record: Research, problems and relevance

1 INTRODUCTION

Human-cetacean interactions can take a variety of forms. Cetaceans may be encountered while engaging in fishing or other maritime activities. They may be pursued deliberately at sea or encountered along the shore, live stranded or as beached carcasses, and their remains can be valued for a variety of reasons. While our interactions with cetaceans in the modern world are highly politicised and an emotive issue, the nature of human-cetacean interactions in the past can be ambiguous. In the prehistoric periods we must rely primarily on archaeological remains to interpret the nature of, and reason for, these interactions. This chapter investigates approaches and obstacles to determining methods of procurement and the utility of cetacean remains to past communities.

2 CETACEANS IN THE ARCHAEOLOGICAL RECORD

Whale bone, oil, meat, baleen, sinew and blubber have formed important resources for human communities for millennia and cetacean remains have been found on archaeological sites dating from the Palaeolithic period onwards (Pétillion 2008). Bone and teeth represent the most frequent type of remains encountered in archaeological contexts (Mulville 2002), though baleen and sinews can also occur when preservation conditions are optimal (e.g., Sinding et al. 2012). Other remains including skin, blubber, meat and oil are much harder to detect. However, whale barnacles can be an indicator of the former presence of flesh (e.g. Álvarez-Fernández et al. 2014; Law 2021), and lipid analysis can identify the presence of marine fats (Regert 2011), which can include cetaceans. This thesis focuses on cetacean bones and teeth, as the most common types of remains found on archaeological sites.

Cetacean bone occurs either as identifiable elements (unworked, broken or with evidence of butchery or other signs of modification); fragments which could represent bone working or oil extraction (e.g. Annandale 1905; Monks 2005); or in worked form, as artefacts. Larger pieces are also frequently used within architecture, in walls, as roofing, or as furniture (Savelle 1997). In a Scottish context cetacean bone occurs frequently on coastal sites and while this bone is not typically a primary component of most individual zooarchaeological assemblages, it is consistently present across a range of sites (Mulville 2002; Szabo 2008). Settlement sites of all periods often include quantities of cetacean bone (Mulville 2002). It is also represented within burial site assemblages, typically included in worked form as grave goods such as the whale bone plaque found in a high-status Viking female grave found at Scar, Sanday, Orkney (Owen and Dalland 1999), reflecting wider practices also seen in

Scandinavia (Petersen 1951; Sjøvold 1971). Shoreline butchery sites are rarer and are more likely to have been lost to erosion and sea level changes (Bernal-Casasola et al. 2016; Betts and Friesen 2013). Few sites of this type have been found in the UK though a series of rorqual skeletons have been found on a former shoreline of the Firth of Forth in association with prehistoric implements thought to have been used for butchery (Clark 1947; Gardiner 1997), and the remains of two right whales with tool marks indicating flesh removal were recorded on the coast at Dengemarsh, Kent (Gardiner et al. 1998).

Despite the ubiquity of cetacean bone on coastal sites (e.g. van den Hurk 2020), analysis and interpretation of these remains is problematic. Although the presence of cetacean bone on sites indicates that the inhabitants of the site must have valued cetaceans in some way and engaged in some form of exploitation, the nature of this value and exploitation, and in particular whether the cetaceans were hunted or exploited as stranded individuals, is often unclear (e.g. Clark 1947; Mulville 2002, 2005; Savelle and Kishigami 2013; van den Hurk 2020). Both the formation of the cetacean zooarchaeological record and analytical hurdles relating to identification and quantification have hampered understanding of past use and exploitation of cetaceans.

2.1 THE NATURE AND FORMATION OF CETACEAN ZOOARCHAEOLOGICAL ASSEMBLAGES

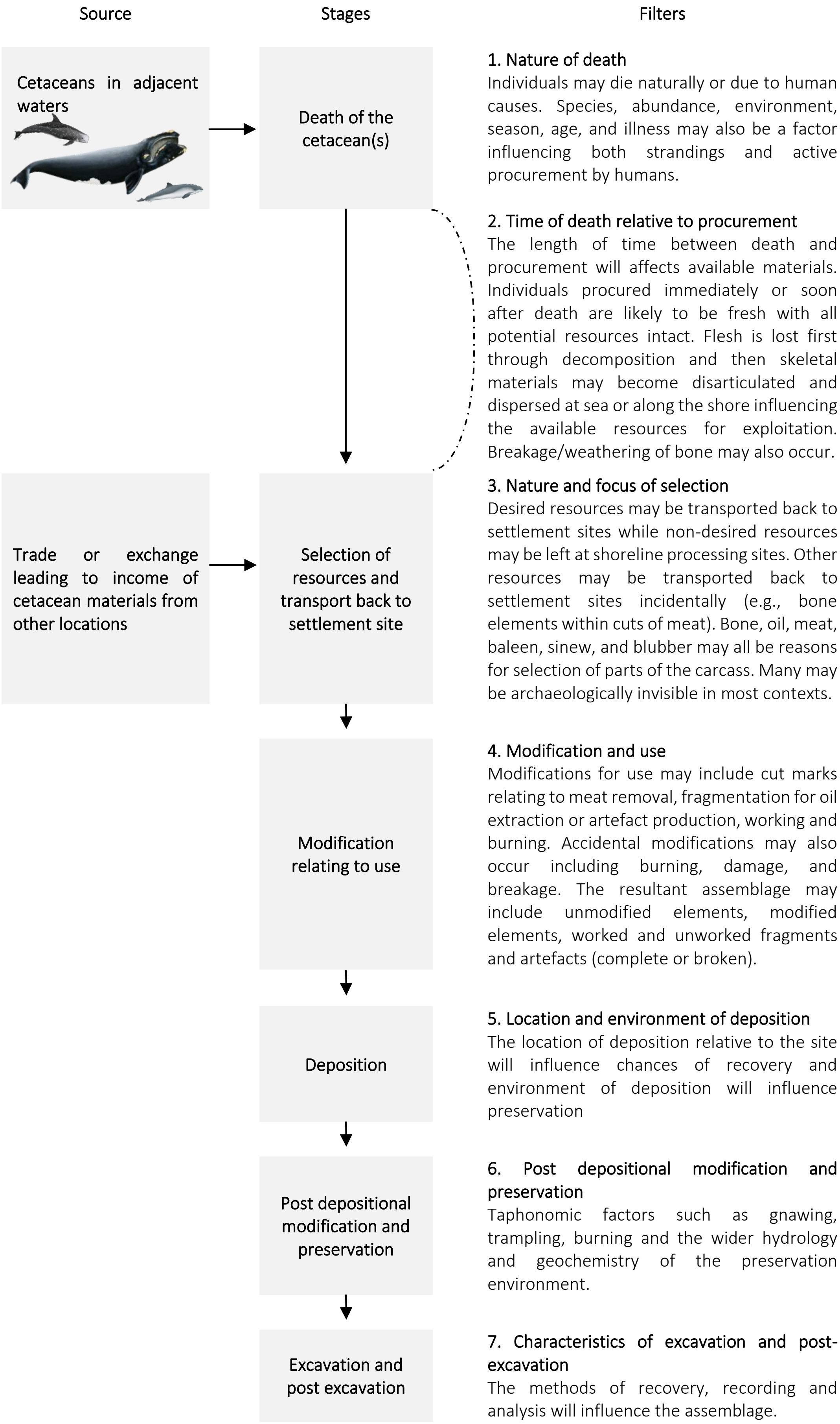
A suite of pre and post-depositional taphonomic factors, i.e. the stages between the death of an organism and its recovery by archaeologists (Efremov 1940; Lyman 2001), affect cetacean bone assemblages and have the potential to influence interpretations. These factors begin with cetacean itself and the nature of its death and reflect a sequence of stages which occur thereafter which act as filters to what remains in the archaeological record. Many of these factors have been reviewed by van den Hurk (2020a: 143). Key stages and filters are summarised in Figure 1.

Firstly, the presence and abundance of different taxa within an area can influence the archaeological record (Yesner 1995). Local species may be the focus of exploitation for a community and different characteristics will influence the modes of procurement. Procurement, i.e. the acquisition of cetaceans, may be through the exploitation of stranded individuals or those sought through hunting, trapping or driving (see Chapter 8). Remains of cetacean species whose habitats may be geographically distant from the site under study may also occur within assemblages through trade. The length of time between death and procurement is also of importance. Individuals exploited soon after death are likely to be fresh with all potential resources intact. However, as time progresses decomposition will occur eventually leading to the loss of flesh and disarticulation of skeletal materials (Schäfer 1972), influencing the available resources for exploitation. The carcass may also be targeted by scavengers and breakage and weathering of bone may also occur.

The focal resources (e.g. meat, blubber, bone, oil) will also influence the assemblage, and assemblages from shoreline butchery sites are likely to have a very different character to those of settlement sites. Meat and blubber may be key resources, however, due to the size of some cetaceans, and the relative ease with which flesh can be stripped from their carcasses, most or all skeletal elements may be left at the shoreline butchery sites (Betts and Friesen 2013; Clark 1947: 95; Savelle and Friesen 1996). Butchery sites can be situated at great distances from settlements, and in these cases soft tissues which were exploited may have little to no physical representation within the zooarchaeological assemblages of settlement sites (Reitz and Wing 2000: 193; Smith and Kinahan 1984). Conversely, bones and other materials may be brought back to settlement sites for their own value rather than within cuts of meat. Value may reflect their utility as a raw material for artefacts, as architectural components, or as a source of fuel (Mulville 2002). Social and cultural practices may also influence the zooarchaeological record and cetacean remains may be transported back to sites and deposited in particular ways due to social and cultural traditions and beliefs (Spencer 1959; Whitridge 2002).

Modifications relating to use also act as a filter. While the removal of meat may result in cut or chop marks, where bones are recovered to settlement sites for their own value they are more likely to have undergone additional modification such as bone working, fragmentation, or burning, associated with the reasons for their recovery from the shoreline. Bones are typically present as unworked or modified elements or fragments and artefacts. Recognition of the origin of the modifications can aid understanding of the value and utility of cetacean remains to past communities.

The location of deposition can also act as a filter, as can post-depositional taphonomic factors including gnawing, trampling, burning and the wider hydrology and geochemistry of the preservation environment. The preservation environment has a large influence on biomolecular preservation, with consequences for the application of analytical techniques such as DNA or ZooMS (Speller et al. 2016). Finally, the characteristics of the excavation and post-excavation process also act as a filter, including location of excavation area, methods of recovery, assessment and analysis (van den Hurk 2020a,b).



1. Nature of death
Individuals may die naturally or due to human causes. Species, abundance, environment, season, age, and illness may also be a factor influencing both strandings and active procurement by humans.

2. Time of death relative to procurement
The length of time between death and procurement will affects available materials. Individuals procured immediately or soon after death are likely to be fresh with all potential resources intact. Flesh is lost first through decomposition and then skeletal materials may become disarticulated and dispersed at sea or along the shore influencing the available resources for exploitation. Breakage/weathering of bone may also occur.

3. Nature and focus of selection
Desired resources may be transported back to settlement sites while non-desired resources may be left at shoreline processing sites. Other resources may be transported back to settlement sites incidentally (e.g., bone elements within cuts of meat). Bone, oil, meat, baleen, sinew, and blubber may all be reasons for selection of parts of the carcass. Many may be archaeologically invisible in most contexts.

4. Modification and use
Modifications for use may include cut marks relating to meat removal, fragmentation for oil extraction or artefact production, working and burning. Accidental modifications may also occur including burning, damage, and breakage. The resultant assemblage may include unmodified elements, modified elements, worked and unworked fragments and artefacts (complete or broken).

5. Location and environment of deposition
The location of deposition relative to the site will influence chances of recovery and environment of deposition will influence preservation

6. Post depositional modification and preservation
Taphonomic factors such as gnawing, trampling, burning and the wider hydrology and geochemistry of the preservation environment.

7. Characteristics of excavation and post-excavation
The methods of recovery, recording and analysis will influence the assemblage.

Figure 1 Formation processes for cetacean zooarchaeological assemblages

There have been different approaches to teasing apart the formation processes of cetacean zooarchaeological assemblages and determining the cultural factors influencing the assemblage primarily with a view to addressing questions in two primary areas: the utility of cetacean remains and the potential modes of procurement in past communities. The key issues and approaches to the analysis and interpretation of cetacean bone assemblages are considered below beginning with identification (skeletal and taxonomic) and quantification and leading on interpretations of cetacean utility and procurement.

2.2 IDENTIFICATION

There are currently 90 recognised species within the Order Cetacea (Carwardine 2020), representing a range of animals with different behaviours, habitats and physical characteristics all of which have the potential to influence procurement and use. In contrast to the remains of terrestrial species, and the recognised importance of the matter for interpretation (Clark 1947), identification of cetacean bone has not generally been carried out. There are several routes to taxonomic identification, from traditional morphological analysis to new biomolecular techniques. The following section considers the different methods.

2.2.1 MORPHOLOGY

Two key issues affect the viability of morphological identification. The first is the high degree of fragmentation of many cetacean bone assemblages, and the second is an absence of adequate morphological guides to assist with identification even where sufficiently complete elements are present. This is compounded by restricted access to reference collections and small numbers of specimens in most museum reference collections (Evans and Mulville 2018).

Although morphological identifications of archaeological cetacean bone have been published by a number of studies (Clark 1947: 96; Cumbaa 1986; Finlay 1984; Hallén 1994; Mulville 2002), recently reviewed on a large-scale by van den Hurk (2020) precise methodologies for identification which include details of which traits were used to identify bones are not typically explicitly stated. In some cases identifications have proved to be inaccurate indicating unreliable methods of identification (e.g. Cumbaa 1986; McLeod 2008; Rastogi et al. 2004). These inaccuracies are coming to light in the face of modern techniques of analysis such as DNA and ZooMS profiling (see below) and demonstrate the need for a reliable method for identifying cetacean bone. Van den Hurk's (2020; 2021) recent study which collated data on known cetacean bone assemblages from across Europe, reported on species wherever identified by the original authors, further investigated some of the material using ZooMS and found a high rate of incorrect identifications in the original morphological identifications (van den Hurk 2020: 232, 246). Van de Hurk (2020; van den Hurk et al. 2020, 2021) also recently reported vertebral centrum dimensions for six individual specimens of species within the Orcininae sub-family, which provide useful comparisons with the current methodology. However, the study did not consider differentiation between and within other taxonomic groupings, nor other features such as process dimensions. Additionally, the restricted number of specimens does not allow for consideration of individual variation, and the effects of age on size were not considered.

Other impediments to morphological identification arise from the large size and endangered status of some cetaceans, factors which are generally prohibitive to the curation, storage and display of comprehensive collections of cetacean skeletons. Institutions also rarely have multiple examples of the largest species, leaving comparisons to be based on the morphological traits few specimens. This causes problems in the identification of osteological traits which are true reflectors of species (Driver 1992) i.e. those which recur consistently throughout the species and thus do not relate to individual conditions. Research has also shown that museum specimens can be incorrectly labelled, causing further problems (Evans et al. 2016). Moreover, the morphology of cetacean bones from different species can be very similar, while males and females of the same species can exhibit extreme sexual dimorphism, making it challenging to accurately identify cetacean bones to species.

Identification issues are compounded by the degree of fragmentation of cetacean bone on many archaeological sites. This can result from butchery or artefact creation, as well as the friability of archaeological cetacean bone, which all lead to the loss of distinctive morphological traits (Speller et al. 2016).

2.2.2 BIOMOLECULAR METHODS

The emergence of DNA and ZooMS analysis have provided solutions to the identification of fragmented bone, and have increasingly been used to analyse cetacean bone assemblages (e.g. Buckley et al. 2014; Evans and Ingrem 2021; Evans et. al. 2016; Pétillon et al. 2019; Speller et al. 2016; van den Hurk 2020). Biomolecular preservation affects both techniques and studies have also shown that ZooMS and DNA can be used together, with the former showing potential for use as a tool for determining overall biomolecular preservation, and providing an indication as to the likely success of the more costly DNA analysis (Evans et al. 2016; von Holstein et al. 2014). The following section gives a short summary of the two techniques.

ZooMS (Zooarchaeology by Mass Spectrometry) relies on the survival of proteins, and in particular collagen peptides, to identify taxa. Taxonomic discrimination is possible due to differences between the amino acid sequences of different peptides, resulting in different peptide mass to charge (m/z) ratios which can be measured by matrix assisted laser desorption/ionisation time of flight mass spectrometry (MALDI TOF MS) (Speller et al. 2016). The technique has been refined over recent years (Buckley et al. 2008, 2009, 2014) and has now proved highly useful in the analysis of zooarchaeological material which has otherwise defied morphological identification. It can, for example, distinguish sheep from goat; a common identification issue (Buckley et al. 2009: 3849; Reitz and Wing 2000: 199). Investigation of the collagen sequences of cetaceans has also demonstrated relatively high diversity in peptide masses, meaning that the technique is well suited to taxonomic identification within this Order, with species-level resolution possible in many, though not all, cases (Buckley et al. 2009). The technique can be used on small bone samples (10-30mg) though studies have also shown successful identifications can be achieved by sampling using an eraser (McGrath et al. 2019). Using the latter sampling method ZooMS has the advantage of allowing non-destructive testing. Additional advantages are that the technique is cheaper and less susceptible to contamination than DNA analysis.

DNA molecules including mitochondrial DNA (mtDNA) and nuclear DNA can also be extracted from faunal remains. Studies have demonstrated that DNA is present within the collagen and mineral components of bone and can be used for a range of analyses, including identification (Campos et al. 2012; Richards 2005). Degradation is a common problem affecting ancient DNA (aDNA) (Campos et al. 2012) and specific methodologies have been developed to account for this. Analysis of degraded aDNA is based on the extraction of surviving DNA sequences which can be amplified using polymerase chain reaction (PCR) techniques (Mullis and Faloona 1987) the resulting sequences can then be compared with reference genetic datasets of known species to allow for identifications (Speller et al. 2016). Analysis of mtDNA has proved highly effective in the identification of cetacean remains from archaeological contexts (Evans et al. 2016; Foote et al. 2012; Losey and Yang 2007; Rastogi et al. 2004; Speller et al. 2016; Yang and Speller, 2006). While this technique is more costly and labour intensive than ZooMS, requires use of appropriate primers for success, and is more susceptible to contamination issues due to the amplification process, it can provide more refined identifications to species and sub-species level, while haplotype analysis can also allow for quantification (Dalebout et al. 2002; Evans et al. 2016).

Both techniques have been used to successfully analyse cetacean remains in zooarchaeological assemblages dating from the early prehistoric period onwards, and from a range of geographical locations worldwide (e.g. Buckley et al. 2009; Evans et al. 2016; Pétillon et al. 2019; van den Hurk 2020). However, these methods are generally more costly than traditional means of analysis, and as such complete analysis of many existing cetacean bone assemblages using these methods is not likely to be possible. Within other zooarchaeological and environmental work assessment and morphological identification typically precede detailed analysis, however, as yet this is not possible with cetacean bone due to the absence of method for morphological identification.

2.2.3 OTHER ANALYSES

A range of other analyses including optical microscopy, measurements of specific gravity and hardness, micro-raman spectroscopy, elemental analysis, isotopic ratio mass spectrometry, scanning electron microscopy, particle induced gamma-ray emission and trace element analysis (Aaris- Sorensen et al. 2010; Schuhmacher et al. 2013) can also be applied to cetacean material and recent studies have shown the success of the methods for differentiating between species in some cases (Schuhmacher et al. 2013).

2.3 QUANTIFICATION

Quantification represents the other key methodological hurdle when assessing cetacean bone in archaeological contexts. Typically, archaeological animal bones are quantified in terms of the Number of Identified Specimens (NISP) and the Minimum Number of Individuals (MNI). These calculations allow an appreciation of changing patterns of faunal exploitation through space and time, and can provide an understanding of the relative importance of different species within an assemblage (Reitz and Wing 2000: 191). However, some specific considerations apply when quantifying cetaceans. As for identification, the large size of some cetaceans and the high degree of fragmentation of cetacean bone is central to this issue. Large amounts of bone can be derived from a single individual (particularly where the larger species are concerned) and deliberate fragmentation, associated with bone working, artefact production or oil extraction, or by other taphonomic processes, all of which are common amongst cetacean bone assemblages, can lead to a very high NISP. Additionally, elements that occur in large numbers within an individual specimen, e.g. ribs and vertebrae (some species of dolphin for example have over 80 vertebrae (Buchholtz et al. 2005)) are common within cetacean zooarchaeological assemblages (Mulville 2002). These issues can obscure understanding of the relative importance of cetaceans, both compared with other taxa, and through space and time. Establishing the MNI is therefore desirable, though problematic when remains are fragmentary.

The overall aim of establishing the MNI is to determine the minimum number of animals represented by the assemblage to allow comparison with other taxa and an appreciation of the contribution made to the site's economy. Understanding the MNI can also aid assessment of utility or procurement methods; where many individuals of the same species are present preferential selection or active procurement may be a factor (e.g. Glassow 2005). While there are different approaches to calculating MNI most tend to focus on analysis of elements. Some choose a distinct element which occurs individually within the body, typically from one side of the body, and establish how many times it occurs within the assemblage (e.g. Huelsbeck 1988). Others identify the Minimum Number of Elements (MNE), considering side, age and size of all elements, and then divide the MNE by the number of times each element occurs within the body, to derive the Minimum Animal Units (MAU). The latter provides both an indication of the number of animals present, and the relative abundance of different elements within the assemblage which can allow for interpretation of factors influencing bone selection or taphonomy (Friesen and Arnold 1995). However, these assessments are only possible where distinct elements can be identified. Many cetacean bone assemblages are dominated by fragmented bone and in these cases establishing the MNI presents a challenge. DNA analysis has been used to investigate MNI of fragmentary cetacean remains in recent years, using a combination of species identity, haplotypes and location to determine the MNI for different species (Arndt 2011: 94; Evans et al. 2016). The approach has led to the identification of different individuals from fragmented bone, identification of large numbers of bone from a single individual (UHI n.d), and at some sites large numbers of individuals of the same species have been identified (Arndt 2011), all of which allow for reflection on potential utility and procurement.

2.4 CETACEAN UTILITY AND INDICES

Bone transport and selection are important factors affecting interpretation of the overall cetacean bone assemblage. Bones may be transported within cuts of meat, and therefore reflect meat utility of that portion of the animal, or they may be gathered for their own oil, architectural, artefactual or other social or cultural utility (Gardiner 1997). Conversely, cetaceans valued for their meat utility may not be represented within the assemblages of settlement sites due to the practice of separating flesh from bone at shoreline butchery areas. Reconstructing and understanding the utility of cetaceans to past populations is therefore can be a complex process but can be aided by use of utility indices.

Following Binford's (1978) work, a range of utility indices, or value indicators, have been developed to explore the different ways in which cetaceans were used and valued. These indices have been developed with recognition that certain elements from certain species may be deposited in particular locales, and with particular modifications owing to their utility (Binford 1978; Monks 2005). Archaeological assemblages can be analysed using these utility indices, with interpretations emerging from the relative frequencies of different elements and their associated meat, oil, architectural, artefactual or social values. Other evidence such as bone modification or fragmentation are also employed in these analyses. The assessment of utility also has the potential to contribute to understanding of procurement, and standardised cetacean bone products for example, have been used to argue for evidence of a reliable supply of bone, indicative of active hunting (MacGregor 1985; Sjøvold 1971). While utility indices provide an important means of analysing cetacean zooarchaeological assemblages, recent years have seen a proliferation in the application of other methods used to identify cetacean utility, such as stable isotope, lipid and residue analyses and are discussed below.

2.4.1 MEAT UTILITY AND DIET

Articulating elements and evidence of cut marks indicative of meat removal can indicate the exploitation of the cetacean resource for meat and meat utility indices, calculated from the weight of edible meat associated with the different skeletal parts, have been developed to generate understanding of the values of different parts of an animal (Savelle and Friesen 1996; Savelle 1997). However, the ease with which meat can be removed from cetaceans means that these calculations may be irrelevant for larger specimens. In these cases weighty bones are left behind at the shore, while meat is removed and taken back to settlement sites. The bones, despite association with significant food resources, would therefore not form part of the zooarchaeological assemblage of settlement sites. Decisions on which bones to move are generally agreed to reflect the threshold at which their transport becomes less energy efficient than shoreline butchery. Savelle and Friesen (1996) indicate that this threshold may mean meat utility indices are only of value for the interpretation of remains of smaller cetaceans.

There are other methods that overcome this transportation bias by considering the zooarchaeological profile of a site to examine the likelihood that large whales were exploited for meat, even in the absence of their bones, based on the principles of optimal foraging theory (Betts and Friesen 2013). However, even when evidence is present to suggest large species may have been exploited as dietary resources, quantification using MNI can obscure the dietary importance of larger cetaceans relative to other taxa, and further rationalisation using comparative meat weights is required to accurately demonstrate the potential contribution of cetacean meat to the diet (Betts and Friesen 2013; Clark 2019: 11-12; Friesen and Arnold 1995; Mulville 2002). Appreciation of the dietary value of marine taxa can also be inferred by consideration of other proxies including stable isotope and lipid analysis (e.g. Cramp et al. 2014; Heron et al. 2013). While in some cases stable isotope analysis has been used to identify general marine proteins (which may derive from fish, cetaceans or other species) (Cramp et al. 2014 Supplementary Information figure S2) other studies have distinguished between the contribution of different marine food sources including seals and cetaceans using this analysis (Coltrain et al. 2004, 2016). Historical evidence has also been used to further appreciation of potential social factors influencing the inclusion of cetaceans within the diet (e.g. van den Hurk 2020).

2.4.2 ARTEFACTUAL AND ARCHITECTURAL UTILITY

Artefactual utility is also considered by researchers involved in the interpretation of cetacean remains (e.g. Betts 2007; MacGregor 1985; Mulville 2002; Savelle 1997; Whitridge 2002). Cetacean bone implements are common on Scottish sites and range from the enigmatic ‘blubber mattocks’ to perforated vertebral epiphyses, hollowed-out vertebrae, plaques, chopping blocks and bone combs, amongst others (Clark 1947; Hallén 1994; Mulville 2002). The large size and density of some of the bones was clearly valued in artefact production (Betts 2007: 133), as was the resilience and strength (Hallén 1994) though a range of bones with different properties were used when they fitted the need. Studies have found differences between bone density, and trabeculae patterning, in large and small cetaceans, which have been interpreted as the cause for preferential use of the bones of larger baleen whales over smaller Odontoceti. Additionally, on some sites preference for certain elements has been identified, due to their density and size, providing artefactual utility (Betts 2007: 133). In a Scottish context for example, evidence for use of balaenopterid mandibles in artefact production has been noted (Mulville 2002).

Architectural utility indices have also been developed for some species (Savelle 1997). Savelle's work on bowhead whales was based on observations of the frequency with which bones of high architectural potential (inherent in their form and mass), as opposed to high meat utility, appear on archaeological sites. Architectural use of cetacean bone is well attested within Scottish contexts and has been briefly examined by Mulville (2002). While Savelle's (1997) architectural utility index covered use of bone as a frame material (e.g. in roof framing) or a bulk material (e.g. for walls) and other uses such as scapulae for roof coverings, it was based on bone properties and an assessment of cetacean bone use on Arctic sites (McCartney 1978, 1979a, b). Most vertebrae are considered by this index to hold lower architectural utility than elements such as mandibles. Architectural use of vertebrae, such as those on Scottish sites interpreted as terminals for roof supports (A' Cheardach Mhor; (Young and Richardson 1960: 142)) and door pivots (e.g. Drimore (MacLaren 1974)) and other smaller pieces possibly used as door snecks (A' Cheardach Mhor (Young and Richardson 1960); Drimore (MacLaren 1974)), are therefore less well represented by the index.

2.4.3 OIL AND BLUBBER UTILITY

Oil utility indices have also been developed for some species of cetacean (Monks 2005). These indices are based on the respective oil content of different bones based on information on the natural history of whales and modern whaling data (Monks 2005). Monk's (2005) study focused on the humpback whale, but later works, focused on the interpretation of whale-fall sites, have also compared the oil content of cetacean bone in a range of large species including blue, fin, sei, humpback, grey and sperm whales, as well as the striped dolphin (Higgs et al. 2011). The studies found that skulls, for example, have a very high oil content and are therefore more likely to be preferentially selected when oil utility is the key consideration, though differences in the oil content of different regions are present between species (Higgs et al. 2011; Monks 2005). Sperm whales, for example, have much higher concentrations of oil in their lumbar and caudal vertebrae than do humpback whales (Higgs et al. 2011). Information on elements present can be assessed together with evidence for modification relating to oil extraction or burning, to support interpretations of the importance of oil procurement in the formation of the cetacean bone assemblage (e.g. Monks 2005). Burnt and fragmented cetacean bone is common on Scottish sites and may relate to fuel or oil extraction (Mulville 2002; Evans 2021).

While oil extraction from bone has the potential to leave traces in the osteological record, use of blubber is typically archaeologically invisible. Residue analyses have, however, enabled the detection of animal fats and studies have demonstrated the possibility of differentiating between marine and terrestrial mammals using lipid biomarkers and single-compound carbon isotope analysis (Heron et al. 2013). Studies have also shown that the presence of flesh can be inferred from certain species of barnacle found on whale skin (e.g. Law 2021).

2.4.4 SOCIAL UTILITY

The social utility of cetacean bones, whereby particular bones or species may hold special value or be used or deposited in particular ways based on social, cultural or traditional rules, has also been recognised in a number of studies (e.g. Betts and Friesen 2013; Clark 1947; Gardiner 1997: 178; Savelle 2002; Whitridge 2002). Historical and ethnographic accounts have been used in these studies to identify the social meanings of cetacean bone, and in some cases specific portions of the whale which may have been significant (Gardiner 1997), a factor which has been used to guide Whitridge's (2002) social utility index. However, socially ascribed value can vary between communities and as such specific social utility indices have limited wider applicability, though social utility can be investigated by consideration of intra-site bone distributions (e.g. Savelle 2002) along with other indicators of social processes within the archaeological record. Historical evidence can also illuminate patterns of social utility and twelfth century English documents for example demonstrate that the king had rights to the tongue of any beached cetacean, but other high-status individuals could claim the right flipper (Clark 1947: 90). Other aspects of social utility can also be represented by evidence for the sharing of cetacean remains, documented in ethnographic literature (e.g. Joensen 2009) and at times evident within the zooarchaeological record (e.g. Evans et al. 2016).

Together these studies demonstrate the importance of considering a wide range of evidence or factors when considering the reasons for cetacean bone procurement, and when interpreting patterns of use and deposition. However, utility varies between species, and therefore as with studies into the nature of procurement, to fully understand the utility of the bone and examine choices which may have been made with regard to this utility, taxonomic identification is necessary.

2.5 ASSESSING THE NATURE OF CETACEAN PROCUREMENT

A key problem, and one which is frequently focused on, is the identification of whaling in the archaeological record. Securely establishing where and when active whaling occurred in the past presents a particular challenge for archaeologists (e.g. Evans et al. 2016; Mulville 2002; 2005; Savelle and Kishigami 2013), one which has been restated recently by van den Hurk (e.g. 2020, 2021; van den Hurk et al. 2021) and overall there is no universally accepted methodology to establish whether the whale remains represent hunted or stranded individuals (Mulville 2005).

2.5.1 RESEARCH AROUND THE WORLD

There are a number of areas worldwide which have formed foci for research into the nature of cetacean exploitation in the past (Ellis 1992). Arctic sites, with their large concentrations of cetacean bone and ethnographic accounts of whaling, have formed the catalyst for numerous areas of research aimed at defining the importance of cetacean exploitation to past communities, and the nature of this exploitation (Betts and Friesen 2013; McCartney 1980; McCartney and Savelle 1985; Savelle and McCartney 1988, 1990, 1991, 1994; Savelle et al. 2000). However, even for sites where whaling is known to be an important part of the culture through other sources, proving this archaeologically is problematic (e.g. Freeman 1979; McCartney 1980; Savelle 1997). Arctic remains and other sites have also formed foci for research in connection with the modern whaling debate, and zooarchaeological evidence has been used as evidence in claims for rights to Aboriginal Subsistence Whaling and in support of the longevity of whale exploitation in other areas including Russia, Japan, the USA, Scandinavia and North Atlantic Islands (Mulville 2005). Other research has focused on Basque whaling, attested to by historical evidence and onshore archaeological features relating to whale hunting and processing (e.g. Aguilar 1986; Clark 1947; Fischer 1881), while a number of sites worldwide have been investigated for evidence of cetacean exploitation primarily based on archaeological evidence (e.g. Glassow 2005 in California; Powell 2020 in northern Peru).

In a Scottish contexts Childe's (1931) excavations at Skara Brae and the recovery of large amounts of whale bone from the site sparked debate about whether the Neolithic inhabitants may have engaged in active whaling. While Childe professed the opinion that the bones were likely from stranded animals, the remains raised the question of how active whaling could be distinguished from the exploitation of stranded animals within the archaeological record (Childe 1931: 97; Clark 1947; Gardiner 1997; Mulville 2002). Many assumed that prehistoric communities would not have had the necessary skills or maritime technology to partake in whaling (e.g. Nordmann 1936), however, those with knowledge of whale hunts in the arctic recognised that even the larger species could be successfully hunted from small boats using hand-held tools (Clark 1947; Murdock, 1892). Reviews of historical evidence have also shown that there are a variety of ways in which cetaceans were procured in the past, many of which do not involve open water exploitation (Lindquist 1994, 1997; Szabo 2008). While this Neolithic site formed the catalyst for this debate, the same question can also be posed to all sites on which cetacean bone has been found, from Mesolithic shell middens (Mellars 1987) to Neolithic and Bronze Age settlements (e.g. Childe 1931; Mulville and Madgwick 2012; Smith and Mulville 2004) and into the Iron Age when the numbers of sites with cetacean bone and cetacean bone use appears to have increased (e.g. Hedges 1987; Szabo 2005, 2008; Mulville 2002). As with other locations, historical evidence is often cited in this debate, and is of particular relevance for the last c. 1300 years, including the later Iron Age and Norse periods in Scotland (Colgrave and Mynors 1969; Lindquist 1994; Mulville 2002; Szabo 2008). However, the question as to how to identify the nature of cetacean procurement in earlier prehistory, and indeed even in the historic period, remains.

2.5.2 UNDERSTANDING PROCUREMENT

Studies into cetacean exploitation have considered a series of pre-requisites, direct and indirect indicators of active procurement. As Clark (1947) recognised, consideration of the species in question is key. Those species which inhabit the waters of north-west Europe range from the blue whale, the largest animal on the planet, to the diminutive harbour porpoise and include a variety of other species from gregarious dolphins to the more reclusive beaked whales. As well as the vast size range, cetacean species exhibit a variety of different behaviours and characteristics, from swimming speed and preferred habitat to the tendencies of different animals to either float, or sink, once dead, all of which have a bearing on methods of procurement (Clark 1947: 84). Taxonomic identification is therefore vital to interpret procurement, but as has been seen, has rarely been attempted until recently.

Environmental and ecological factors are also important in the procurement of cetaceans. Yesner (1995) set out a series of elements which influence whether cetaceans are likely to have been procured through strandings or active procurement. He suggested that areas in which the former is likely include locations in which high densities of strandings occur such as in areas where currents and prevailing winds drive whales ashore, and areas where other scavengers are few. Conversely, Yesner (1995) identified an increased chance of hunting in areas in locations which did not meet the above criteria (i.e. were poor stranding locations or where other predators were present), but in which whales were known to be present within the local area, including regions where whales migrated close to the shoreline (Yesner 1995: 156). Following the latter points, the proximity of archaeological sites with high quantities of cetacean remains in their zooarchaeological assemblages, to areas which are foci for aggregations of cetaceans, has been used in interpretations of active procurement (Glassow 2005).

Beyond environmental factors, other technological, social and economic pre-requisites for active whaling (procurement) have been defined for specific circumstances (e.g. Bockstoce 1976; McCartney 1980; Savelle 2005; Whitridge 2002) but are dependent upon the species targeted and the methods used. Many pre-requisites have been established in reference to harpoon and tow whaling, likely owing to the pre-eminence of this technique within ethnographic accounts of arctic whaling (an area which has been the focus for much of the research into cetacean zooarchaeological assemblages) and modern aboriginal subsistence whaling. However, Lindquist's (1994, 1997) analysis has shown that a wide range of other strategies were also in use in the North Atlantic, many of which revolve around taking an active role in the strandings process, removing the need to tow a whale carcass ashore, and using tools such as lances and spears rather than harpoons. This is discussed in further detail in Chapter 8.

Approaches to the interpretation of cetacean bone from archaeological sites has diversified within recent years, and numerous lines of both direct and indirect evidence have been taken into consideration for identification of active whaling (see Savelle and Kishigami 2013 and van den Hurk 2020, 2021 for recent reviews). These include direct evidence based on analysis of zooarchaeological assemblages, including consideration of:

- Remains of hunting: Evidence at shoreline butchery sites (which may represent hunted or stranded individuals) and the presence of whaling or butchery implements alongside, or in rare cases actually embedded within cetacean bone (e.g. Huelsbeck 1988; Losey and Yang 2007; Reese 2005) have been interpreted as evidence of active whaling at sea or the dispatch and butchery of animals which have stranded (e.g. Clark 1947: 91; Gardiner et al. 1998; Reese 2005; Wellman et al. 2017);

- Selection: Evidence of selection based on species, age or size (Hennius et al. 2018; Krupnik and Kan 1993; McCartney and Savelle 1985; Mulville 2005; Savelle and McCartney 1991, 1994, 2002, 2003) taking into consideration stranding behaviours and frequencies for different species and age groups (Evans et al. 2016; Mulville 2002; van den Hurk 2020) or other archaeofaunal signatures which account for taphonomic processes affecting cetaceans (e.g. Betts and Friesen 2013 who considered what the rest of a zooarchaeological assemblage would be like in the absence of a focal species);
- Comparison with strandings datasets can also be of use (e.g. Evans et al. 2016; Mulville 2002; van den Hurk 2020), however, uncertainties in the size difference between modern and past cetacean population numbers and distributions (and known major changes to population sizes for certain species) generally limits interpretations based solely on this data;
- Frequency: An increase in the relative frequencies of cetacean bone or species on a site (e.g. Glassow 2005; Mulville 2002) or increased numbers of cetacean bones recovered from a phase or stratum (e.g. Hennius et al. 2018; Hiraguchi 1993; Itoh et al. 2011; Loiselle 2020) may in some cases be interpreted as evidence of active whaling, though other studies are more cautious in the interpretation of such remains (Mannino et al. 2015) recognising that large amounts of cetacean bone can be derived from an individual cetacean and that other factors such as mass strandings can occur;
- Large scale spatial and temporal patterns have also been used in conjunction with other evidence to identify periods of greater exploitation of cetaceans, though identifying the mode of procurement on individual sites remained problematic (van den Hurk 2020: 249);
- Use: Standardised use of cetacean bone products and repeated focus on cetacean bone for the manufacture of certain products, with potential trade of these products in some cases, interpreted as reliable access to cetacean bone via active hunting e.g. Hennius et al. (2018), MacGregor (1985) and Sjøvold (1971), critiqued by Hallén (1994). However, until recently few had employed taxonomic identification in these discussions giving little basis for suggesting a regular supply through active procurement as the remains may represent multiple species not likely to be procured

by hunting. Hennius et al. (2018) did demonstrate reliance on an individual species (though with a small dataset); and

- Deposition: Special treatment of cetacean remains e.g. Itoh et al. (2011) and Powell (2020).

Indirect and circumstantial evidence used in the interpretation of means of procurement also includes reference to:

- Historical texts and legislation: Correlation between archaeological remains and historical documentation indicative of cetacean exploitation (Gardiner 1997; Hennius et al. 2018; Szabo 2008) though correlation between archaeological remains and texts is fraught with difficulties and is rarely sufficient to prove the mode of procurement at a particular site;
- Iconography or depictions of whaling have also been used demonstrate methods of procurement in different periods, though often the evidence cited is based on rock art which is notoriously difficult to date (Clark 1947; Gjerde 2013; Helskog 2004; McCartney 1980; Odess et al. 2008);
- Ethnographic parallels are also cited, though even in areas where whaling is known through ethnography, demonstrating this within the archaeological record is difficult (e.g. Losey and Yang, 2007; McCartney 1980; Savelle and Wenzel 2003);
- Isotopic analysis to establish the dietary contribution of marine species including cetaceans (Coltrain et al. 2004, 2016) though in many cases cetacean meat cannot be distinguished from other forms of marine protein (Cramp et al. 2014); and
- Cetacean behaviour and ecology: Archaeofaunal evidence for cetaceans coupled with the presence of marine features which may cause an increase in cetaceans in the local area (e.g. Glassow 2005) and consideration of stranding patterns (Mulville 2005).

Most lines of evidence are fraught with difficulties, and securely identifying the mode of procurement from cetacean zooarchaeological remains is extremely difficult in most cases (van den Hurk 2020). However, cetacean procurement does not occur in isolation and the many different approaches to interpretation demonstrate the importance drawing on multiple lines of evidence (e.g. Clark 1947; Hennius et al. 2018) to root interpretations within what is known about contemporary society, environment, technology, economy and culture in addition to cetacean biology and ecology. This wider perspective is particularly important in the face of some of the issues which beset zooarchaeological assemblages.

3 DIRECTIONS IN RESEARCH

This chapter demonstrates that analysis and interpretation of cetacean remains in the archaeological record is a complex process, numerous filters must be considered, and methodological issues dealt with, in order to arrive at secure conclusions. Two primary foci are apparent within the literature, namely the identification of the nature of cetacean exploitation and procurement; and the utility of cetacean remains to past communities.

The desirability of research into cetacean bone assemblages on Scottish archaeological sites has been highlighted by a number of researchers working in the area (e.g. Clark 1947: 95; Mulville 2002: 45), and other projects focused on the Outer Hebrides have noted the importance of understanding marine resource exploitation in this area (e.g. Benjamin et al. 2014). The Scottish Archaeological Research Framework has also included a series of aims which demonstrate the need for research into cetacean remains in Scottish contexts. The ScARF identifies species identification, research into cetacean procurement and an improved understanding of cetacean bone use in artefact manufacture as key areas for study. These focused on the following points relating to cetaceans and the study of osseous materials.

- ‘Targeted research on sites of all periods in the areas of Scotland where local soil conditions permit the preservation of human and animal skeletal material, in order to address the current gaps in the human and animal bone records’ (Milek and Jones 2012: 38). The paucity of research into cetacean bone demonstrates this is a clear gap in the understanding of the animal bone record, and thus research in this area would contribute toward this aim.
- ‘A clearer knowledge of the range of (cetacean) species represented, and a study of their chronology and quantity on specific sites, would allow a much better-informed discussion of procurement strategies’ (Hunter and Carruthers 2012: 31), demonstrating the need for species identification in order to understand procurement, a need which is echoed in other studies (Clark 1947: 95; Mulville 2002: 45).
- Research into ‘the extent to which wild resources were exploited, the role they played in Iron Age diet and the way they were thought of requires fuller consideration. Specific examples are the nature of the exploitation of resources such as deer (whether for antler or as prey) and cetaceans (hunted or expedient use)’ (Hunter and

Carruthers 2012: 35). This recommendation of the framework specifically relates to the debate on the means of cetacean procurement.

- Existing assemblages contain a great deal of raw material which merits study or re-examination to allow re-thinking and modelling production and procurement systems could be undertaken. Regional case studies for crafts would be a valuable way forward…: c) Bone/antler show evidence of regional or chronological variation in manufacturing techniques, but this has not seen detailed synthesis. There are also hints of varied access to resources e.g. cetacean bone or marine ivory, which merit more work (Hunter and Carruthers 2012: 47).

As noted above approaches to research in each of these areas is generally affected by difficulties identifying the cetacean species present within zooarchaeological assemblages, and subsequent difficulties quantifying the remains. All of which have implications for interpretations relating to procurement and use. While some steps have been taken to address these issues, including use of DNA and biomolecular methods of analysis, the high cost of these techniques is an impediment to reanalysis of the large number of existing cetacean bone assemblages means that most cetacean bone assemblages remain unanalysed. The current work seeks to address these issues, and to take steps towards understanding cetacean procurement and use in Scottish prehistory and early history.

3.1 RESEARCH AIMS AND OBJECTIVES

The overall aims of this research are set out within the introduction. They are reiterated here and objectives are set.

This thesis aims to address the key methodological issues facing researchers working with cetacean bone by creating a toolkit for the morphological identification of cetacean bone, and strategies for the integration of biomolecular methods of identification which also take steps toward addressing challenges with quantification. These approaches will be applied to a suite of cetacean bone faunal zooarchaeological assemblages from two multiperiod Scottish sites to investigate human-cetacean relationships through examination of patterns in cetacean use, deposition and procurement.

Morphometric, proteomic and zooarchaeological analysis will be combined to meet the following objectives:

1. Create a methodology and toolkit for the morphometric identification of cetacean bone;

2. Investigate cetacean remains on multiperiod sites to test the methodology developed under Objective 1, and to use proteomics, to identify cetacean remains from these sites;
3. Draw together the results of taxonomic identification with other evidence from the assemblages including elements, quantities and bone modifications to assess evidence for the utility of cetacean remains through space and time;
4. Investigate cetacean procurement strategies drawing on species identified and their habitats, and wider evidence for use of contemporary seascapes;
5. Draw together the evidence to interpret the nature of human-cetacean relationships on the Outer Hebrides from the Bronze Age to the Norse Periods.

3.2 WIDER RELEVANCE

The study of archaeological remains is of value in marine management. The ScARF Science Panel states that 'one of the main aims for future research should be to provide data that can be of use in the present and future management of fishery resources and which can be incorporated in the history of marine resource exploitation and uses in Scotland' (Milek and Jones 2012: 81). While fisheries are identified as an area of focus, the recommendation could also clearly apply to cetaceans.

Cetacean remains, from museum collections and archaeological sites, are increasingly recognised by researchers as a means by which we can improve our understanding of modern cetacean populations and better guide conservation (Lyman 2006; Speller et al. 2016). Taxonomic identification and analysis of cetaceans can provide researchers with an understanding of their past distribution (Sabin 2005: 4), and facilitate aDNA and isotopic analysis, allowing diversity and populations, ecology and habitat use and a range of other areas to be studied (e.g. Smith et al. 2020; Yolande pers. comm. 2020).

Archaeological investigation and analysis of historic cetacean bone assemblages, and in particular species identification, will unlock the potential of zooarchaeological assemblages within biological sciences and marine conservation research. Thus, the work undertaken as part of this thesis will allow the case study sites to be characterised and through the development of a guide for morphological identification, will provide other researchers with the tools to assess and analyse other cetacean bone assemblages.

Chapter 3: Introduction to the Hebridean islands, their archaeology and cetacean fauna

1 INTRODUCTION

This study is focused on cetacean material recovered from two sites on the Outer Hebrides (Western Isles): Cladh Hallan and Bornais. These settlement sites span the Bronze Age to Norse periods and have been excavated over the past few decades by teams from the University of Sheffield and Cardiff University under the directorships of Mike Parker Pearson and Niall Sharples respectively. The study interprets the cetacean remains from Cladh Hallan and Bornais drawing on wider evidence from zooarchaeology, history and ethnography.

This chapter introduces the islands, their natural environment including the cetacean species present in the surrounding waters, and their cultural history and past economies to frame human: cetacean interactions across time. It will demonstrate why these sites and assemblages provide such a compelling series of case studies for developing methods for identifying and interpreting cetacean zooarchaeological assemblages.

1.1 OVERVIEW OF RATIONALE FOR CASE STUDY SELECTION

Historical and ethnographic evidence for cetacean exploitation in the Hebrides and North Atlantic, changes to wider patterns of marine exploitation and well-preserved cetacean bone assemblages provide the main reasons Cladh Hallan and Bornais were targeted by this study.

The historical record provides evidence for the active procurement of cetaceans in the North Atlantic toward the end of the first millennium AD (Lindquist 1994; Szabo 2008) and ethnographic evidence demonstrates that whaling occurred in recent history in the Hebrides (e.g. Baldwin 2008; Maclennan 2008). Ole Lindquist, in his 1994 thesis, considered *'whales, dolphins and porpoises in the economy and culture of peasant fishermen in Norway, Orkney, Shetland, Faroe Islands and Iceland ca. 900 – 1900 AD and Norse Greenland, ca. 1000-1500 AD'* and Vicki Szabo's (2008) publication *Monstrous fishes in the Mead Dark Sea: Whaling in the Medieval North Atlantic* considered a similar geographic area, though focused specifically on the medieval period. Both draw on archaeological and ethnographic evidence though historical documentation is the primary focus of both studies. The current thesis takes an archaeological approach and therefore compliments these earlier studies. This study also focuses on the Hebrides and thus presents data for a different geographical area than those focused on by Lindquist (1994, 1997) and Szabo (2008), though the islands are geographically close and historically politically connected to the other North Atlantic areas studied by the previous authors. This thesis also extends the time frame under study back into prehistory, to consider the ways in which cetacean exploitation changed through time.

As well as indicating the longevity of whaling in the North Atlantic, historical documents covering the area also provide rich evidence of the inextricable links between cetacean and fish exploitation in the Hebrides, particularly from the post-medieval period onward (e.g. Martin 2010; Monro 1549). The contents of these documents indicate that the consideration of wider patterns of marine exploitation may aid understanding of cetacean exploitation. The period of occupation represented by the study sites spans the Bronze Age to the Norse era and encompasses phases of marked change within the exploitation of marine species in the Hebrides, and across the UK generally. These insular assemblages provide evidence for very low levels of marine exploitation in the Bronze Age, marginally increasing during the Iron Age (Barrett 2016b; Evans and Ingrem 2021) and ending with drastic intensification of marine exploitation in the Norse period, termed the 'Fish Event Horizon' in other North Atlantic areas (Barrett and Richards 2004; Barrett et al. 2004a, b). In the Northern Isles this shift was marked by an increased intensification of cod fishing, whereas on the Western Isles herring bones overwhelmingly dominate the fish bone assemblages (Cerón- Carrasco 2005; Ingrem 2005a, b, 2018, 2021; Serjeantson 2013). The changes in the icthyoarchaeological record may indicate a shift in the ways in which marine resources were used and valued and could therefore be coupled with changes in the exploitation of other marine taxa, including cetaceans.

In a local context, the Hebrides also present a fruitful area for study due to the large and well-preserved cetacean bone assemblages recovered from sites on the machair, the low-lying grassy strip of sandy fertile land which bounds the west coasts of the Outer Hebrides. Excavations which have taken place along the island chain using modern methods and accompanied by extensive sieving campaigns have resulted in the recovery of large cetacean bone assemblages, with those from Cladh Hallan and Bornais being among the largest. The assemblages contain fragments, elements and artefacts and have good biomolecular preservation owing to the calcareous machair soils, making them ideal for both morphological and molecular identification analysis.

Together these factors demonstrate the reasons Hebridean assemblages spanning the Bronze Age to Norse periods represent ideal case studies for addressing issues of identification and interpretation of cetacean remains on archaeological sites.

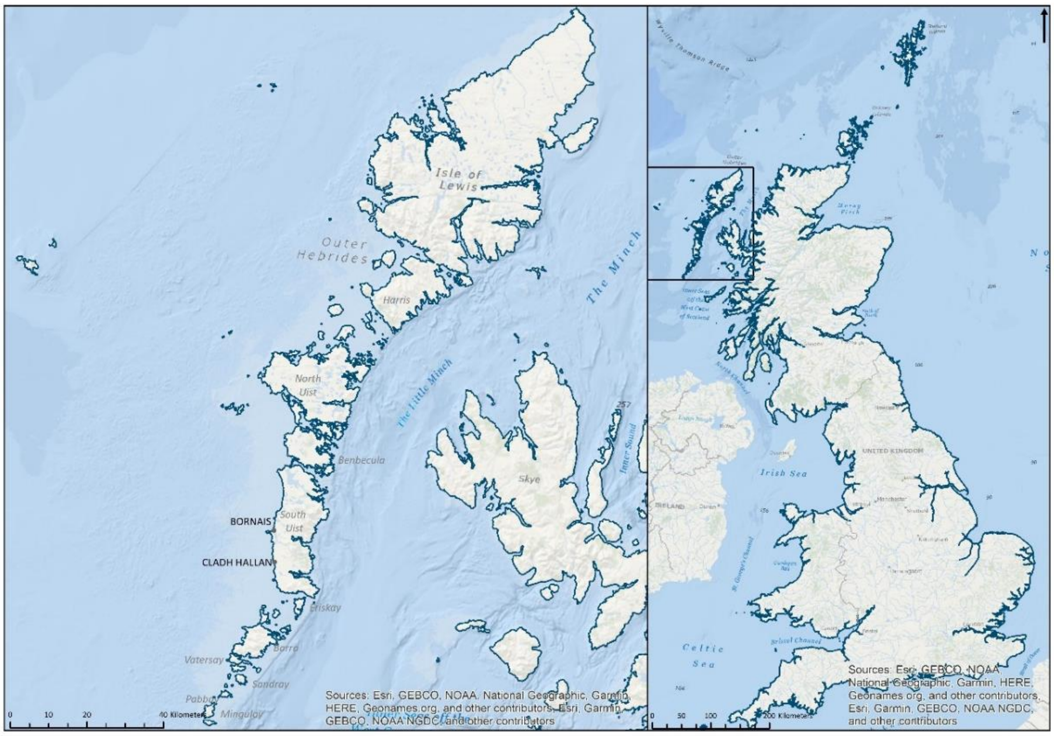


Figure 2 Location of the Outer Hebrides and case study sites

2 THE HEBRIDES

This section sets out key information on the Hebridean environment and cetacean species within nearby waters, in order to frame later discussions of human: cetacean interactions.

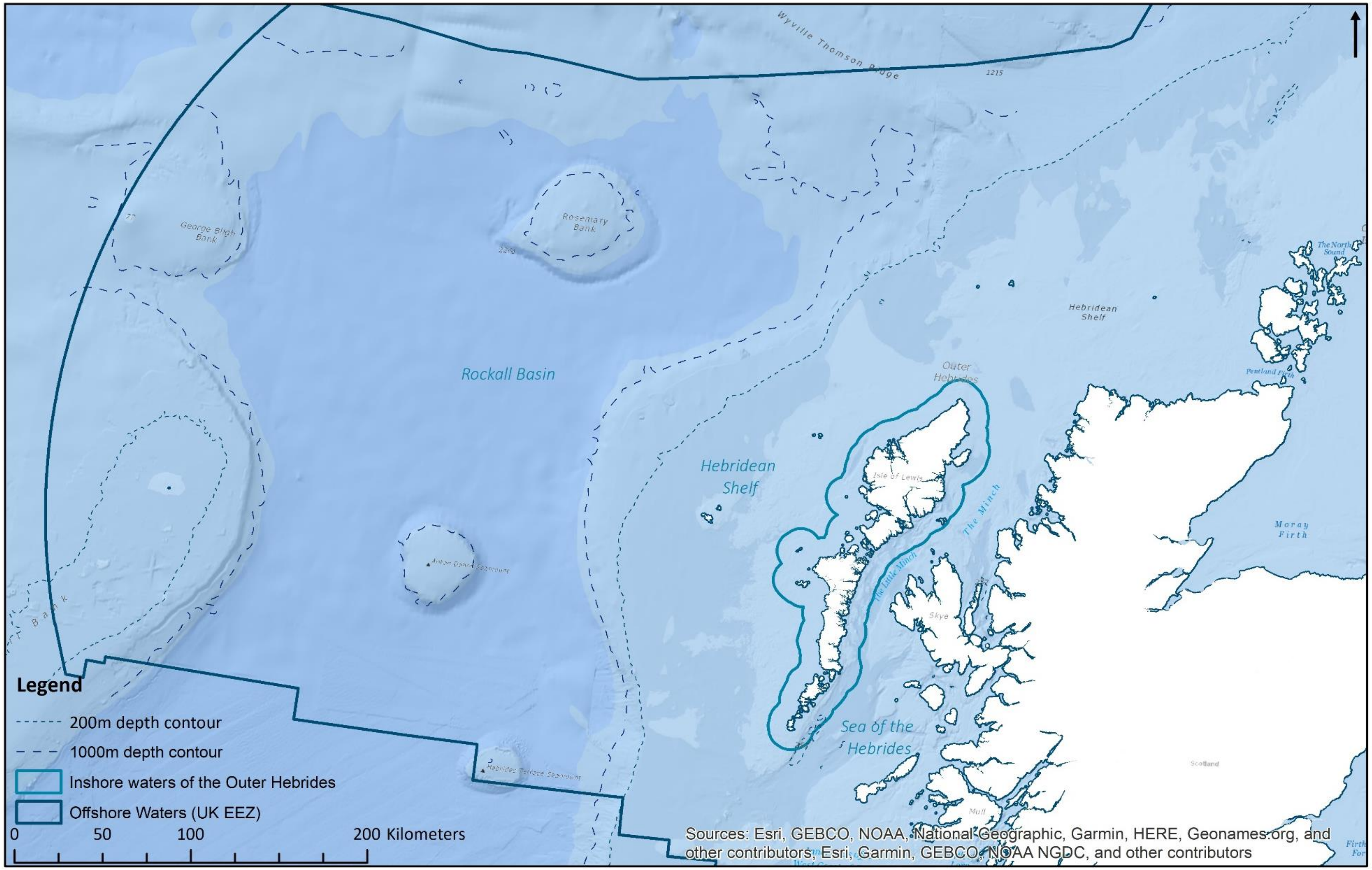
The Outer Hebrides are a curving island chain which lies around 40 miles off the west coast of Scotland made up of over a hundred islands and skerries (HWDT 2018: 23) (Figure 2). The main islands of the archipelago are Lewis and Harris, which form a single landmass at the northern end of the island chain, followed further south by North Uist, Benbecula, South Uist and Barra. The major sites under consideration in this thesis lie on South Uist.

2.1 COASTAL AND TERRESTRIAL ENVIRONMENT

The terrestrial landscapes of the Hebrides are extremely varied in character. Rugged hills, inlets and sea lochs define the shores of the Minch and the Sea of Hebrides which lie to the east of the Outer Hebrides, and to the west long sandy bays interspersed with rocky headlands and islets are backed by the sandy machair plain and grasslands which face out to the Atlantic (Connor and Little 1998: 373).

Major changes to the island landscapes have occurred since the end of the last ice age, including alterations to relative sea level and accumulation of the sandy planes which characterise the west coast today (e.g. Bradley et al. 2008, 2011; Milne et al. 2006; Shennan et al. 2006; Sturt et al. 2013). These changes to former coastlines are relevant for understanding the prospection and procurement of cetaceans by past communities. Relatively rapid sea level rise and inundation of coastal regions occurred following the retreat of the ice sheets (Barber 2003; Ritchie 1985), and by the mid-Holocene sea levels were between 3 and 5m lower than today. Rapid accumulation of sand occurred around, or just prior to, the start of the Neolithic period which established an environment similar to the sandy west coast plane which exists today (Sharples 2009, 2020: 1). Sea levels continued to rise and are thought to have reached their current levels in the Hebrides during the Late Bronze Age to Early/Mid Iron Age (between 3100-2100 BP) with the coastline around the current location, though some estimates indicate it may have been slightly further west (by c. 25- 150m) (Jordan et al. 2010; Cerón- Carrasco 2005: 59).

Variations in terrestrial landscapes are also relevant to archaeological investigation. The machair is formed of wind-blown shell sands and has a high PH and calcium carbonate content (Ritchie 1976, 1979). This contrasts with the acidic soils of the peatlands of the central belt and east coast, which forms an extremely poor environment for bone preservation. The majority of known archaeological sites in the Western Isles lie on the machair plane. As a result of these conditions archaeological sites on the west coast tend to have extensive and well-preserved zooarchaeological assemblages. This state of preservation extends to the biochemical make-up of the bone, and both the mineral and organic content has been shown to survive well in the machair (Parker Pearson et al. 2004), making the assemblages well suited to both morphological and protein-based analyses.



Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Figure 3 The marine environment around the Hebrides

2.2 MARINE ENVIRONMENT

While the terrestrial island landscape is bounded, the marine environment is expansive. Scotland's seas have been divided into different zones for modern marine management, and the boundaries used for these areas will be drawn on here for understanding marine exploitation and human-cetacean interactions in the past. Key definitions include the inshore and offshore areas. The inshore area covers waters within 6 nautical miles of the coast, and offshore area extends from six nautical miles out to the edge of the UK Exclusive Economic Zone (MarineScotland 2021). While specific boundaries are not generally reflected within the natural world, the broad areas do generally resonate with the habitats of different marine taxa, including cetaceans. Depth contours are also relevant to cetacean habitats. The 200m and 1000m depth contours are commonly cited in studies of cetacean distributions (e.g. Pollock et al. 2000) and are shown on Figure 3.

The areas shown in Figure 3 contain a range of different environments, with variations in physical oceanography (waves, currents, tides and ocean energy), geological oceanography (sediments, rocks and the structure of the seafloor and coastal margins) and chemical oceanography (the composition and properties of the seawater) all of which influence the biodiversity of the region (HWDT 2018).

2.2.1 INSHORE AND BETWEEN THE ISLANDS

The marine environment of the inshore area is complex, including shallow sounds, tidal straits and sea lochs which provide habitat for a wide variety of species (HWDT 2018: 22). Unusually deep waters, over 300m in depth, are present close inshore particularly near Raasay and the southern islands of the Outer Hebrides, while sea lochs can form sheltered, shallow bays. Other submarine features include submerged pinnacles, troughs and ridges. Large, scoured expanses of bedrock lie to the west of the island chain (EMODnet Bathymetry 2020), and a variety of sediment types are present on the seabed of the Sea of Hebrides and Minch to the east, including gravels, muds and sands (BGS 2020).

The diverse oceanography of the area influences local habitats and species. Warm ocean currents converge with cool coastal waters around the Hebrides and coupled with variations in submarine topography, this mixing pushes nutrient-rich waters toward the surface. Here the sun's light allows photosynthesis to occur creating areas of high productivity which form the basis for much of the area's marine life including a variety of fish species, basking sharks, and high-level marine predators including cetaceans and seals (HWDT 2018: 23).

2.2.2 OFFSHORE

Much of the area to the west of Hebrides, forming the Hebridean component of the continental shelf, is scoured bedrock. The continental shelf drop-off lies 50 miles west of the Atlantic coast of the Hebrides and is an important habitat feature. Water depths increase from c. 200m to over 1000m in this area and the change in topography causes upwellings which give rise to plankton blooms that form the focus for seasonal aggregations of fish and top-level predators including large baleen whales on seasonal migrations and a range of oceanic dolphins (Boyd and Boyd 1996). Many species, such as sperm whales, beaked whales, and the larger balaenopterids also migrate through this area and in deeper waters of the Rockall Basin, beyond the continental shelf (Figure 3).

The importance of both the inshore and offshore areas for different marine species is reflected by a variety of designations including Marine Protected Areas (MPAs) and Special Areas of Conservation (SACs). Around South Uist these include the Sea of the Hebrides MPA, which runs from the northern tip of Skye to Mull and is bounded by the Hebrides (including South Uist) on its west side (NatureScot 2020a). This area is protected for its importance to minke whales and basking sharks. The Inner Hebrides and the Minches SAC covers the waters east of the Outer Hebrides, extending southward to the Kintyre peninsula and thus incorporates a large tract of inshore waters of the west coast of Scotland, designated to protect harbour porpoises in this area (NatureScot 2020b). By far the largest protected area in offshore waters is the West of Scotland MPA which covers the continental slope, Rockall Basin and seamounts in this area. The MPA protects a range of seabed features, habitats and biological communities and marine processes. Corals, reefs, sponges and a variety of fish species inhabit the area and the Rosemary Bank and Anton Dohrn seamounts attract fish and marine mammals including the white-sided dolphin and sperm whale (JNCC 2020).

In addition to the living cetacean communities, stranded individuals are also relatively common along the Hebridean coastline, and particularly on the long sandy beaches which face out to the Atlantic (Natural History Museum (NHM) 2018). There is the potential for all species to strand, particularly as dead individuals, but mass strandings, often involving live cetaceans, are known for some species (Geraci and Aubin 1979). The tendency for some species to mass strand has been exploited by drive fisheries focused on herding species such as the pilot whale ashore in large numbers.

2.3 CETACEAN BIODIVERSITY IN SCOTTISH WATERS: PAST AND PRESENT

This section contains an overview of species which may occur within Hebridean and adjacent waters, and which may be likely to occur within zooarchaeological assemblages from the region. Information on the primary habitats and characteristics of these species are set out in Appendix 1.

Ninety cetacean species are currently recognised worldwide (Carwardine 2020) and those which are most common within inshore and offshore waters around the Hebrides today are shown in bold in Figure 4 below (HWDT 2018; Pollock et al. 2000). By their nature marine regions are fluid, and the cetacean species which inhabit them can travel considerable distances often beyond their primary habitats indicating that species may occur as rare visitors within an area with potential to be represented within zooarchaeological assemblages. Cetacean bone may also be traded and remains of species whose habitats lie far beyond the Hebrides may also occur on sites. Wide boundaries have therefore been used for this study (wider than those of Scottish waters off the west coast) to anticipate the potential for remains of vagrant individuals to this area and encompassing regions with which trade is most likely to have occurred in different periods. Thirty-one species have therefore been included within this study, encompassing all of those cited by the JNCC publication the Atlas of Cetacean Distribution in north-west European Waters (Reid et al. 2003), in addition to *M. grayii, E. robustus* and *B. mysticetus*. The bowhead whale is included here due to its likely presence in period of differing climate, while the gray whale is included because historically the range of this species included the north eastern Atlantic. Gray's beaked whale has been recorded within the study area by the presence of a single specimen which stranded in the Netherlands in 1927. The species primarily has a southern hemisphere distribution (Ellis and Mead 2017: 138), though has been included here due to the sparsity of knowledge about many beaked whale species[1].

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[1] Chapter 5 and Appendices 3 and 7 set out morphometric data relating to the identification of cetacean species. As it was not possible to collect morphometric data on all 90 species currently recognised worldwide it was necessary to define a study area and list of species for study. This is a recognised limitation. However, the effects of this limitation on the research set out within this thesis were mitigated through use of a large study area encompassing over one third of all species known worldwide.

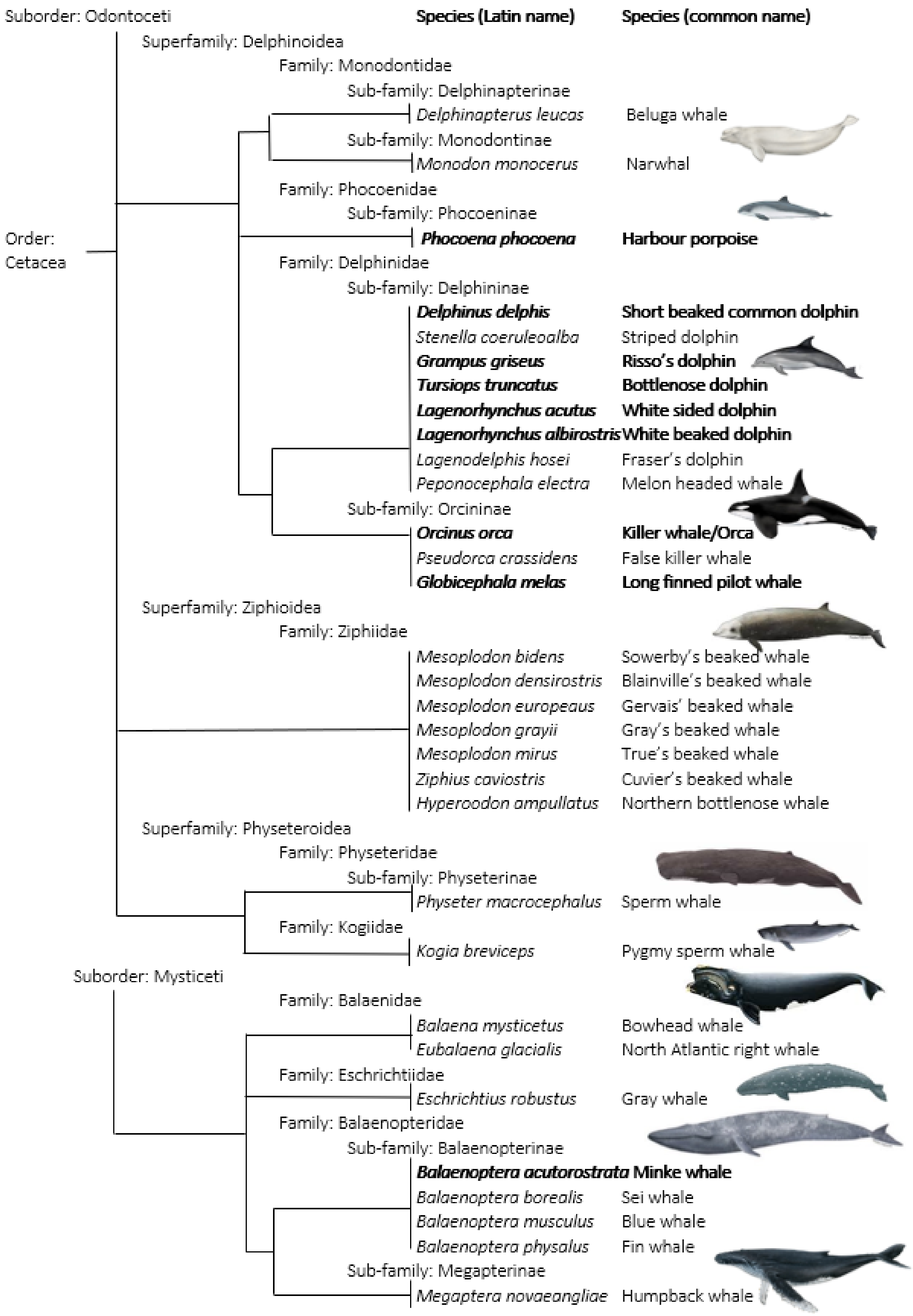

Figure 4 Cetacean phylogeny according to Mead (1975) and Perrin (1989). Images from www.fisheries.noaa.gov. Not to scale.

Figure 4 sets out phylogenetic relationships between the 31 species within this study. Relationships within the order Cetacea are not fully resolved and a variety of competing taxonomies exist (e.g. Mead 1975; Perrin 1989; LeDuc et al. 1999; Vollmer et al. 2019). These differences primarily affect the subfamilial placement of a number of species within the Delphinidae family (Buchholtz and Schur 2004: 383). Overall Perrin's (1989) classification system is used in this thesis, though Mead's (1975) classification of Delphinidae, based on a detailed examination of the nasal passages of that family, is used in place of Perrin's for that family only. This follows the work of other researchers of cetacean anatomy (e.g. Buchholtz and Schur 2004) which is important for method development undertaken within this thesis and discussed in later chapters (see Chapter 5).

These wider landscapes and seascapes and species which inhabit them formed the environmental contexts for past communities who lived in the Hebrides.

3 CETACEAN PROCUREMENT IN NORTH ATLANTIC AND HEBRIDEAN HISTORY AND ETHNOGRAPHY

This section provides an overview and insight into historical sources which contribute to the understanding of past knowledge of cetacean species, procurement and use. Wider narratives and literary trends concerning cetaceans are discussed here from a Hebridean or Scottish perspective wherever possible.

Several authors have studied literature concerning cetaceans and their exploitation in detail, and Lindquist (1994) and Szabo (2008) who focus on Norway, Iceland, Greenland, Faroe, Shetland and Orkney are of particular relevance here. Gardiner's (1997) work on historical documentation relating to whales and whaling in England is also valuable. There have been no scholarly studies relating to cetacean procurement in mainland Scotland or the Western Isles. However, recent legal studies have considered the treatment of cetaceans in Scottish Law, and the potential origins of these sections of law (Scottish Law Commission 2003: 28; CERWG 2006) and these are considered here with reference to cetacean procurement in the Western Isles.

Historical accounts which depict whale exploitation and use are generally rare but do exist in countries bordering the north east Atlantic. Some are factual or practical while others use cetaceans as vehicles for underlying narratives about religious beliefs, and others point to contemporary knowledge and understanding of the natural world (Szabo 2008). The identification of species within historical texts is fraught with difficulties, though detailed analysis has been possible in places (Szabo 2008; Lindquist 1994), allowing closer comparison with archaeological remains where species are identified.

Specific historical records relating to cetaceans are sparse in the period before the second millennium AD, though during this period cetaceans were often thought of and referred to as fish indicating the possibility that some texts which refer to the consumption of fish may include cetaceans. The classification of whales as fish is first recorded by classical authors. They used the word *ketos* to denote a large sea monster, fish, shark or seal (Szabo 2008: 34), though distinctions were increasingly made between different species of cetacean by authors such as Homer and Pliny. Classical scholars also provide the earliest descriptions of Britain and the Hebrides and their economies. Solinus, writing in the 3rd century AD claimed of the 'Iles called Hebudes fiue in number, the inhabiters wherof, know not what corne meaneth, but liue one|ly by fishe and milke' (Golding 1587). Archaeological evidence has refuted the claim that the Hebrideans did not cultivate corn, though the assertion that fish and milk were of importance during this period is to some extent supported by archaeological findings. However, the Iron Age inhabitants of the Hebrides certainly did not subsist off this diet (Serjeantson 2013: 10-11). While cetaceans are not mentioned specifically it is possible that they were included within the category of 'fish', and Solinus' text may therefore indicate the consumption of cetaceans by the Iron Age inhabitants of the Hebrides. Solinus also refers to the exploitation of cetaceans in a wider context and suggested that the people of Ireland 'doo trimme the hylts of theyr Swords with the téeth of monsters that swymme in the Sea', a claim which is supported by numerous records of cetacean bone and ivory sword hilts found in Ireland and Britain (O'Connor 2013).

The Life of Columba, written by Adomnan, the ninth abbot of Iona *c*. 100 years after St Columba's death in AD 597 provides an insight into the literary role of cetaceans in Scotland at this time, which may give an insight into local encounters. *The saint…said 'do not try to go directly to Tiree but instead take the roundabout route by the Treshnish Islands. Otherwise you may be terrified by a monster of the deep'…He set off and boarded his boat, but he went against the saint's advice….While crossing the open sea between Iona and Tiree he and those with him in the boat saw … a whale of extraordinary size, which rose up like a mountain above the water, its jaws open to show an array of teeth*[2]*. At once the men dropped the sail and took to the oars…but they only just managed to avoid the wash caused by the whale's motion*

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[2] Other translations indicate that the phrasing is 'was bristling with teeth' (Reeves 1874), which may be a reference to baleen rather than teeth. This corresponds with the large size of the whale and its behaviour.

(Reeves 1874). The story continues to recount how the faith of another individual protected him from the whale (Sharpe 1995: 125- 126). This encounter has echoes in literature across the medieval western world. Whales were often portrayed in Christian texts, as evil beings or, at times, mundane creatures (Szabo 2008). While this narrative may have been commonplace among religious institutions it does not necessarily represent the perspectives of other communities at the time. As a descriptive account the text points to a familiarity with large cetaceans in the waters surrounding the Inner Hebrides.

Later texts take an increasingly practical approach to cetaceans, and from the latter part of the first millennium AD, equating roughly with the beginning of the Norse period in the Hebrides, there is increasing evidence for active exploitation. Ohthere, a late 9th century visitor to the court of King Alfred, gives an important account of contemporary active whaling in Norwegian waters recorded by a translator at the King's court. He gives accounts of whaling expeditions in northern Norwegian waters, and indicates that '*in his own country*[3] *is the best whale hunting, there they are eight-and-forty ells long and most of them fifty ells long; of these he said that he and five others had killed sixty*[4] *in two days'* (Thorpe 1900: 251). There has been detailed debate about the exact size of a Norse ell (Lindquist 1994), though most proposals are around the order of magnitude of *c*. 18inches (Szabo 2008: 59). This would indicate that the whales targeted were *c*. 72-75ft in length (*c.* 22m – 23m/ 22.7m - 23.7m according to Lindquist 1994: 404). Allowing for some variations in size due to the uncertainty of the ell, exaggeration by the speaker, and the possibility that in the pre-commercial whaling era some species may have had larger sizes than represented within current populations a range of large Mysticeti are possibilities (Lindquist 1994: 232-233). Exploitation of the right whale seems most plausible, given their slow swimming speeds, tendency to float when dead, and preference for coastal waters (Clark 1947: 86; Szabo 2008: 59), though others believe blue or fin whales to be the prey (Lindquist 1994: 404). Nonetheless the text indicates that large baleen whales were actively hunted in northern Norway during this period. In addition to these details Ohthere also indicates that in his journeys he had travelled further north than the whale hunters go at their farthest. This may indicate exploitation of whales in their northerly feeding grounds, though this is not certain as no specifics of the whales are given. He also discusses hunting walruses for their ivory,

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[3] Halgoland is cited as Ohthere's home land, thought to be near to Tromsø northern Norway.

[4] There is some discrepancy regarding the number killed, and Lindquist suggests that the sixty mentioned actually refers to sixty walrus, rather than the whales (Lindquist 1994: 404).

and indicates tribute from the Fins, which included whalebone and ropes made from seal and whale hide (Thorpe 1900: 249-251).

Ælfric's Colloquy, written by the Abbot of Eynsham (955-1010) gives an insight into whaling in early medieval England. Ælfric uses the text to teach students in grammar, and it includes a series of conversations between students playing the role of different tradesmen including a fisherman. The fisherman is asked about sea fishing, and gives details of the species targeted which included herring, founder, plaice, salmon, sturgeon, shellfish (including oysters, crabs, mussels, winkles, cockles and lobster) and porpoises[5]. When asked if he catches whales, the fisherman states not '*because it is a dangerous thing to catch a whale. It's safer for me to go to the river with my boat than to go with many boats a-hunting whales… I prefer to catch a fish that I can kill than a fish that with one blow can sink and destroy not only me but all of my companions*', though the interviewer indicates that '*many catch whales and avoid danger, and get good money for it*' (Harris 2003: 121). This text is an important one, demonstrating not only that the fisherman's contemporaries engaged in the active hunting of large whales, but also giving an insight into the hunt (Szabo 2008 58). From it we see that the hunting of large whales was a cooperative activity, involving many men and boats. The text also shows that smaller cetaceans, perhaps including dolphins or porpoises, were thought of and caught differently, alongside fish.

The Spanish geographer, al-'Udhrī, writing in the 11th century, provides further evidence of active whaling at this time. He indicates that the Norse or Irish inhabitants *'hunt the young of the whale, which is an exceedingly great fish. They hunt … calves, regarding them as a delicacy…These calves are born in September and are hunted in the four months October to January'* (Dunlop 1957: 20; Szabo 2018). The text then goes on to describe the hunting method using multiple vessels and large blades which are hammered into the skulls of the inquisitive whales to kill them, after which they are towed ashore. The source serves to demonstrate active whaling and a focus on the calves of a large species of whale, killed for their meat. The description of the cetaceans, which include black skin, white flesh (likely referring to blubber), the winter calving season, and the fact that the whales float and can be towed once dead, may all point to the exploitation of migrating mothers and calves, potentially right whales (Szabo 2008: 194), though this is not certain and other species are possibilities.

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[5] The text translates literally as 'sea-swine' which may refer to porpoises or dolphins (Harris 2003: 127)

Other uses of cetacean products are also recorded at this time. During the early 1160s a decree was 'granted to Dunfermline Abbey, for providing lights before the altars of its church, half of all the fat of whales and other large fish taken between Forth and Tay' (Sanger 1985: 50) indicating the use of cetacean oil as fuel, and perhaps indicating active hunting in a Scottish context at this time.

Scandinavian sources are also very important for understanding human-cetacean relationships in the North Atlantic, and in particular legal codes, sagas and individual texts such the work of Albertus Magnus and the King's Mirror (Konungs skuggsjá), provide insights. The latter is a unique text dating to the mid-13th century, set out as a discussion between a father and son and containing necessary information for a courtier. In its discussion on the seas of Iceland and Greenland the text provides a detailed account of 21 species of cetacean, describing physical characteristics, behaviours and value (including whether they are good to eat). The text also comments on which species are hunted (Schnall 1993: 12). The detail within the text allows identification of many of the species under discussion (e.g. Lindquist 1994) and the document therefore provides an invaluable insight into human-cetacean relationships during this period.

Albertus Magnus's observations penned between 1193 and 1280, also include detailed observations of cetaceans, which clearly show distinctions between different species, though this is based on part on the writings of classical scholars. Where Magnus's text excels is in its description of hunting large whales which, as with earlier texts refers to the use of multiple boats along with harpoons (Szabo 2008:64), and of the butchery of a large cetacean which was '*cut into manageable sections of flesh and bones, [which] filled three hundred wagons. Such large whales are not commonly captured but our contemporaries often catch specimens that require one hundred and fifty to two hundred wagons…for haulage'* (Szabo 2008: 63). The extract clearly indicates that large cetaceans were caught at this date, and that both bones and flesh were valued.

Other Icelandic and Norwegian texts are also important and complex legal codes from these countries and other North Atlantic islands provide insights into cetacean procurement, including legislation governing rights to stranded hunted or driven ashore whales (Lindquist 1994). In some cases the law codes include a wealth of detail relating to the regulations surrounding cetacean exploitation. Different species are clearly referred to by these texts, and in many cases, these can be equated with species recognised today including a variety of Delphinoids, the sperm whale and many of the Mysticeti (e.g. Lindquist 1994). Various procurement strategies are also evident, which range from the exploitation of naturally stranded whales to open water spearing and harpooning. Many revolve around taking an active role in the strandings process, either by encouraging cetaceans to strand by various means or by wounding cetaceans at sea and waiting for them to drift ashore (Lindquist 1994, 1997; Szabo 2008). Strategies are discussed in more detail in Chapter 8.

Several Scandinavian legal codes deal with the exploitation of cetaceans and provide detailed information on both hunted and stranded whales demonstrating experience in the different ways cetaceans can be procured. Among the most influential was the *Gulathing* law, an early Norwegian code with specific references to cetacean exploitation and ownership. This included discussion of the ways in which cetaceans could be hunted (by driving them ashore or spearing), along with regulations on acquiring drifting whales and whales which had washed ashore. Complex rights to ownership are set out within the laws taking account of hunters, finders, landowners and other high-status individuals. All of whom could have claims to cetaceans in different situations and depending on the size of the whale and whether it is hunted or obtained while stranding either in the sea, a fjord or on the shore (Szabo 2008: 247). The code clearly indicates that *'A man may hunt whales wherever he can. If a man is chasing a whale and kills it out on the deep, the whale is his whether large or small. If a man shoots at a whale and hits [it] and drives [it] up on the shore, one-half of the whale belongs to him who chased it and one-half to him who owns the land. If a man shoots at a whale in a herring shoal and thus drives away the gift of God, he shall owe a fine of forty marks'* (Larson 2008: 126-127). The Gulathing Law is thought to have developed in the 10th century AD, though may have had earlier origins (Larson 2008: 7). The law was codified by King Magnus Lawmender in the 13th century (Jones 2012). This law is thought to have been the basis for later legal texts which developed in the Norse-colonised islands of the North Atlantic, including the *Seyðabrævið* (Sheep Letter) of the Faroe Islands and Grágás (Grey Goose) Laws of Iceland (Szabo 2008: 244). This law is also thought to have influenced the Udal Law in Scotland.

Udal Law is today found primarily in Orkney and Shetland, where it is used alongside Scots Law. Modern Manx Law is also based in part on Udal Law (Corrin 2019) and by extension, Gulathing Law. The existence of Udal Law within the Isle of Man is of importance, as it indicates that Udal Law extended down the western seaboard, and, prior to the Treaty of Perth (in which the Western Isles and Isle of Man were transferred to Scots Law) it is likely that Udal Law also existed in the Western Isles, as a known area of Norse settlement. While not applicable in the Western Isles today, the historic connection between the Western Isles and Udal Law is further supported by Hebridean place names such as 'the Udal'.

Udal Law is essentially a land tenure system. Key components of relevance to this study are the extent of ownership of the foreshore, which is greater than in other UK laws, and extent of the rights to cetaceans. A report by the Scottish Law Commission (2003) on the Udal Law in respect of the foreshore and seabed in Scotland considered both Scots Law and Udal Law. The study considered the rights of those which hold land under Udal Law, and found that rights to "privileges of Admiralty wrecks, wealth, whales, fishings great and small and other privileges pertaining to the said subjects" (Scottish Law Commission 2003: 28). These rights, which included access to cetaceans, were thought to derive from the Udal Law. The Law essentially granted the owner of the udal land rights to the aforementioned items should they become stranded or drift onto foreshore.

A separate legal study, by the Crown Estate Review Working Group, focused specifically on rights to cetaceans in modern Scots Law, and considered the origins of these rights (CERWG 2006). This study found that 'The Crown's right in England and Wales is to all cetaceans (whales, dolphins and porpoises), while the right of the Crown in Scotland is only to larger whales:- "according to the Law of Scotland: "whales, when large, belong to the Sovereign; when small, to the captors""' (CERWG 2006: 132). 'The right is also traditionally described in Scotland as "all large whales, other than the Bottlenosed and caa'ing species" However, it is not clear in other respects what species or size of whales are involved. The suggestion is made that a whale counted as a large whale if it was "too large to be drawn to land by a wain pulled by six oxen". However, the origin of this is not known and it does not sound like a prescription in Scots law' (CERWG 2006: 132). While the specific species may not be certain, it does appear to reflect the tailoring of Scots Law to allow for the capture and subsequent right to specific cetaceans in Scotland under Scots Law. The distinction of the size of cetacean which may be kept by the captors has interesting parallels with the Gulathing Law, and the stipulations of what sizes of cetacean could be kept by different classes of individual: 'An odal-born man, or a man of better status, has the exclusive right to a found whale eighteen ells long. But any other man half that long' (Lindquist 1994: 606). However, this stipulation applied to whales which were found. The Gulathing Law made other stipulations for cetaceans which were hunted. The incorporation of length criteria may suggest the modification of Scots Law to incorporate the Gulathing Law, likely through the Udal Law. As in other areas of the North Atlantic, the Gulathing Law may have been amended to suit the needs and activities of the particular area, and thus cetaceans including the pilot whale and Northern Bottlenose whale, which were hunted in the Western Isles and Northern Isles during the historic era, were permitted to be retained by the captors even by later Scottish law.

These commonalities between current Scottish Law and the Gulathing Law code as regards cetaceans, and the probable application of the Udal Law in the Western Isles prior to 1266 (the Treaty of Perth), demonstrates that it is reasonable to look to Norwegian sources in understanding human: cetacean relationships in the Norse period. While the Gulathing Law is of clear relevance, later texts may too be of relevance as although, for example, the law codes of Magnus Lawmender (Schnall 1993: 12), was written just after the Treaty of Perth, it is likely that the penning of this law code followed a development of practices since the Gulathing Law code. Thus, these practices are likely to have been developed during the period of Norse influence in the Western Isles, and may therefore be relevant to the situation in these islands.

The Icelandic sagas include detailed descriptions of cetacean exploitation, and contain complex narratives surrounding the acquisition of stranded cetaceans. However, written primarily between the 12th and 14th centuries, up to three hundred years after the events they allude to, they were recorded following a period of great change, including the acceptance of Christianity. Despite this the sagas clearly demonstrate a familiarity with large cetaceans and in many places events can be seen to play out laws set down within the Norse law codes, providing general verification perhaps not of the specific events but of the general awareness and likely familiarity with the practices of procuring and claiming cetaceans (Szabo 2008: 214-215). Many of the sagas include passages which relate to the use or sale of whales (Szabo 2008; 228) and a small number include reference to the active hunting of cetaceans. *Frostbroeða Saga for* example, set in Iceland, indicates that the protagonists travelled to the north of the country following a bad winter to obtain food by hunting, fishing and whaling (Szabo 2008: 229). Likewise characters in *Gunnars Saga Keldugnúpsfífls* also caught fish, seals and whales for survival when staying in the north-west of the country. However, most whales depicted in the sagas are stranded. *Eyrbyggja Saga* and *Grettir's Saga* for example recount in detail disputes over conflicting claims to stranded whales (Hight 1968: 22; Pálsson and Edwards 1989: 146-147). These conflicts focused on large rather than small cetaceans, likely due to the different, and much more complex, legal stipulations which concerned the great whales (Szabo 2008: 235). While these family sagas may represent practical concerns and approaches to cetaceans, other forms of saga portrayed whales as near mythical creatures, imbued with evil (Szabo 2008: 217). The sagas are set primarily in Iceland and Norway, though with reference to other North Atlantic Islands, they may provide insights into the exploitation of cetaceans elsewhere, particularly in areas under Norse influence, including the Hebrides.

From the 16th century historians and visitors to the Hebrides provide us with specific and detailed insights into the economy of the islands, including the use of wild resources. The whales which inhabit the waters surrounding the Hebrides have provided resources for island communities in the recent past and subsistence whaling on the Hebrides is known historically. This form of whaling tended to be opportunistic in nature, and focused on inshore species of delphinoid (i.e. dolphins or porpoises). Many accounts are thought to refer to the exploitation of pilot whales, although other taxa including dolphins and porpoises were also recorded as being taken (Baldwin 2008: 74; 114). These early texts dating to the 16th century are less specific in their descriptions, and often refer just to the taking of whales, though species may be inferred in some cases from accompanying details such as pod size and prey.

The earliest records of whaling in the Hebrides come from Donald Munro, writing in *c*. 1549, though the text is thought to be based on a 14th century document (Cowan 2000). The information set out relates to Lewis and an island to the north east, named as Ronay[6]. Munro states that *'A grait take of whailles is oftimes in this countrey…, ther comes 26 or 27 quhailles*[7] [whales] *young and ald',* (Monro 1549) suggesting that a pod of whales was taken by the inhabitants of Lewis. The species is not given, however the number of individuals cited suggests a species of small or medium sized delphinoid, such as dolphins or porpoise, are a possibility. The text goes on to give indications that other island communities partook in the practice of whaling. In relation to Ronay *'In this ile they use to take maney quhaills and uther grate fisches'* (Monro 1549).

Captain John Dymes, writing in the 17th century provides further evidence of the active procurement of cetaceans. He states that a *'great stoare of whales wch follows the other fish for prey…This last year [1629] there came in great stoare of young whales in to one of their Loughes wch the inhabitants inclosed wth boates and killed more than… one hundred of them…'* (Captain John Dymes cited in Baldwin 2008: 75). The writings of Captain John

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[6] The identity of this island is not certain. The description clearly indicates that the island referred to was situated 'Towards the north northeist from Lewis, three score myles of sea, lyes ane little ile callit Ronay' (Monro 1549).

[7] The spellings 'whailles' and 'quhailles' both appear to relate to 'whales'. Undiscovered Scotland, who have reprinted the original 1549 text online note that 'many of the spellings suggest that Monro was either not very familiar with Gaelic or that he was unable to write it well', perhaps accounting for the different spellings of the word.

Dymes are an important early indication of the connection between the presence of fish in the sea lochs and whaling, first seen in the Scandinavian laws which prohibit the killing of a whale in a herring shoal (Larson 2008: 126-127).

Later writers elaborate on this connection, and through the post-medieval period it becomes clear that the strongest connection is between herring caught in the eastern sea lochs of the Hebrides, and opportunistic whaling. Martin Martin, writing of the Outer Hebrides in *c.* 1695 noted that *'Cod and ling are of a very large size, and very plentiful near Loch Carlvay; but the whales very much interrupt the fishing in this place. There is one sort of whale remarkable for its greatness, which the fishermen distinguish from all others by the name of the gallan whale; because they never see it but at the promontory of that name. I was told by the natives, that …this great whale overturned a fisher's boat, and devoured three of the crew… There are many whales of different sizes, that frequent the herring bays on the east side [of Lewis]: the natives employ many boats together in pursuit of the whales, chasing them up into the bays, til they wound one of them mortally, and then it runs ashore; and they say that all the rest commonly follow the track of its blood, and run themselves also on the shore in like manner, by which means many of them are killed. About five years ago there were fifty young whales killed in this manner, and most of them eaten by the common people, who by experience find them very nourishing food...The bigger whales are more purgative than these lesser ones, but the latter are better for nourishment'* (Martin 2010:15-16).

This, rather lengthy, quote demonstrates several points. Firstly, the connection between fishing and whaling in the post-medieval period. This connection is evident in many other sources of this period. Pennant for example, writing in 1772, noted that '*whales, pollacks and porpoises'* followed the herring into loch broom (Baldwin 2008: 85). Secondly, Martin's description of the whales which are preferred for nourishment is indicative of the behaviour of the pilot whale, indeed the description of the method for hunting this whale is very similar to the pilot whale drives which occur on the Faroe Islands today. Thirdly, the text also indicates that other species of larger whale were also taken, though these do not appear to have been preferable for food.

Speaking in the 19th century, Harvie-Brown and Buckley (1888) wrote of the pilot whale that: 'Their occurrence among the Hebrides is rarer than at Shetland. More than 300 were taken in 1805, and 92 in 1882, at Stornoway Nearly 200 were taken there in 1869." Mr. MacDonald of Newton was at the killing of 100 of these animals some years previous to 1870. They were, as usual, pressed in confusion on to the shore of a small semicircular sandy bay not far from his house (Newton) on the Sound of Harris. Professor Duns also informs us that he was present at the death of a large herd of Ca'ing Whales, numbering in all ninety old and young' (Harvie-Brown and Buckley 1888: 38).

And of the harbour porpoise 'Common In the seas around the Long Island, but does not so often approach dose to land, nor can it be so easily induced to enter the sea-lochs as the [pilot whale]. Still, they are often found in quite narrow so lochs, and when food is abundant, we have seen the entrance to these places crowded with them. They are occasionally caught in the herring-nets' (Harvie-Brown and Buckley 1888: 38).

The quotes all demonstrate the importance of the east coast of the islands, in addition to the Sound of Harris, for both fishing and whaling.

During its more recent history the Hebrides have played host to commercial whaling operations. In contrast to the earlier subsistence whaling, these operations primarily focused on large species, including fast swimming offshore whales passing by the Hebrides in the deep waters to the west. The Bunabhainneadar whaling station was established in Harris in 1904 and was used intermittently up to the 1950s. It was originally built by a Norwegian company and was operated under the direction of Capt. Karl Herlofsen. The station was closed during the years of the 1st World War but re-opened after the War.

Between 1906 and 1914 over 90 northern right whales (*Eubalaena glacialis*) were brought in to Bunabhainneadar, more than were caught anywhere else in this period (Tønnessen and Johnsen 1982). Large numbers of other species were also procured from this station, including fin whales, sei whales, blue whales, humpback whales, sperm whales and bottlenose whales. The majority of these were caught on their migrations, passing between St Kilda and Rockall, although the sperm and northern right whales may have been caught from beyond this area, as they rarely ventured eastward of the submarine ridge which crosses the seabed between the Faroes and Iceland (Tønnessen and Johnsen 1982: 95).

Overall, the historical evidence provides insights into the exploitation of both stranded and hunted cetaceans for a range of reasons including the acquisition of meat, oil and bone. The documents also provide specific evidence of different modes of cetacean procurement which were employed in the North Atlantic and Hebrides in the past, for the exploitation of different species. A specific connection between fishing and cetacean procurement in the Hebrides is also evident from the time of the earliest records, indicating that a review of wider patterns of marine exploitation based on zooarchaeological evidence may provide insights into contemporary cetacean exploitation.

The following sections investigate the archaeological record, beginning with a review of archaeological work in the Outer Hebrides and leading on to the archaeological evidence itself and economies from the Bronze Age to Norse period with a specific focus on marine exploitation in each period.

4 A HISTORY OF ARCHAEOLOGICAL WORK AND THOUGHT IN THE OUTER HEBRIDES

4.1 ARCHAEOLOGICAL INVESTIGATIONS

The Outer Hebrides, with their iconic monuments and rugged landscapes, have a long history of archaeological investigation. The first investigations were characterised by the work of individuals who often sought to learn more about specific types of site. This began with early pioneers such as Martin Martin who visited the islands in late 17th century and recorded famous examples of Hebridean prehistory, such as the Callanish standing stones, while also providing us with accounts of the local marine and terrestrial wildlife (Martin 2010). Brochs became the focus for later visitors including Erskine Beveridge, who carried out extensive work on North Uist. Although the brochs were Beveridge's first object of interest he went on to investigate other features of the islands' past, including burial monuments and cave sites (Beveridge 1911). Beveridge was responsible for excavating several sites including Cnoc a'Comhdhalach, Dun Thomaidh, Eilean Maleit, Garry Iochdrach, Foshigarry, and Bac Mhic Connain (Sharples 2015), of which the worked bone assemblages from the latter two have undergone recent re-analysis (Hallén 1994). Other 19th-century antiquarians to visit the islands and record their heritage were Captain F. W. L. Thomas, who recorded the island's brochs alongside other stone structures, and Alexander Carmichael, primarily a folklorist, who recorded oral histories from the islands, as well as several inscribed stones (Sharples 2015).

During the First World War the Royal Commission on the Ancient and Historic Monuments of Scotland (RCAHMS) launched the first systematic survey programme in the Western Isles and Skye, with the aim of compiling an inventory of sites for these areas (RCAHMS 1928). Although many archaeological sites were identified, large areas of the islands, such as the machair, now known to be rich in archaeological remains, were sparsely represented in the inventory (Parker-Pearson et al. 2004). Around the same time Sir Lindsay Scott, a government official during wartime and later president of the Prehistoric Society, undertook excavations on the Hebrides at sites including the chambered tombs at Rudh an Dunain (Skye) and Clettraval (North Uist). During his excavations at Clettraval Lindsay also uncovered a wheelhouse settlement, and Iron Age settlement on the islands became the focus for his later excavations, including Tigh Talamhanta, Allasdale (Barra) (Sharples 2015).

Around the mid-20th century appreciation of the heritage within the machair landscape began to grow. A folkeloreist and ethnographer, Werner Kissling teamed up with Cambridge archaeologist, Tom Lethbridge to excavate a sand dune at Cille Phedair in 1950. These excavations, the first on South Uist, revealed an Iron Age wheelhouse (Parker-Pearson et al. 2004).

This focus on the machair sites continued through the 1950s, when proposals to construct a rocket range on the coastal strip of South Uist prompted a flurry of archaeological work. Several sites were put at risk from the proposals, and excavations were conducted at Iron Age wheelhouses at A'Cheardach Bheag (Fairhurst 1971), A'Cheardach Mhor (Young and Richardson 1960) and on North Uist a pair of wheelhouses, first investigated by Beveridge, were excavated at Sollas (Campbell 1991). Other hut circles were also investigated on South Uist and a Viking period longhouse was excavated at Drimore (MacLaren 1974).

During the 1960s freelance archaeologist Ian Crawford began investigating a series of mounds on the North Uist machair, which over the next twenty years revealed evidence of occupation spanning the Neolithic to post-medieval period. On one mound at the Udal evidence of a post-medieval village abandoned following a storm in 1697 was found to overlay medieval, Viking, Pictish and Iron Age settlements. Nearby, a second mound produced Middle Iron Age evidence, while a third held Early Bronze Age and Neolithic remains (Parker-Pearson et al. 2004). The results of these excavations have yet to be published in full, though a monograph has recently been published on the Neolithic and Bronze Age remains (Ballin Smith 2018), and post-excavation work on the Udal material continues although Serjeantson (2013) has reported on a portion of the bone assemblage.

Much of the archaeological work in the islands has been driven by development, as at the proposed rocket range on South Uist, or other pressures, the foremost of which is coastal erosion. In response to the risk of erosion surveys have been conducted along the coastline of the Hebrides, leading to the identification of over 100 at-risk sites (Shepherd and Shepherd 1978). Following on from these surveys John Barber of the Scottish Development Department excavated a series of Bronze Age and Iron Age farm mounds and midden sites on North and South Uist at Baleshare, Balelone, Hornish Point, South Glendale and Newtonferry, all at risk from erosion (Barber 2003).

In recent decades the Scottish Islands have formed the focus for many university-led excavations. The Hebrides are no exception. The Sheffield Environmental and Archaeological Research Campaign in the Hebrides (SEARCH) project began in 1987 and aimed to investigate human adaptations to an island environment. The project focused on the southernmost of the Outer Hebrides, and in particular on South Uist where excavations revealed Late Bronze Age and Early Iron Age houses at Cladh Hallan, an Iron Age broch at Dun Vulan and Norse houses at Cille Pheadair. This was followed by Cardiff University's survey and excavation of Iron Age and Norse settlement at Bornais. Cladh Hallan and Bornais are two of the principal sites under study in this thesis.

4.2 PERSPECTIVES IN HEBRIDEAN ARCHAEOLOGY

This short section provides an overview of key perspectives in Hebridean archaeology which have influenced the development of interpretations of the archaeological remains, discussed in detail in the next section.

Episodes of change, both gradual and punctuated, occur throughout the prehistoric and historic periods in the Hebrides and the themes of continuity/discontinuity are evident in many earlier studies, and have been a key focus of recent research on some sites (e.g. Armit 2006: 6; Sharples 2020, 2021: 461). While early researchers often saw cultural change as evidence of migration (influenced by major studies such as Gordon Childe's *Prehistoric Migrations in Europe* (1950)) (MacKie 1971; Scott 1947), the influence of processual and post-processualist thought on later groups is evident in the shift away from migration theory (e.g. Harding 1974; Lane 1987), often in favour of other explanations for change such as trade, exchange of ideas or local developments (e.g. Armit 1990; Parker Pearson and Sharples 1999: 360). However, evidence and interpretations are constantly evolving and there has been a return to interpretations favouring influxes of incomers in some periods, though only where there is strong supporting evidence rooted in detailed analysis of contemporary society, material culture, politics and economy (e.g. Jennings and Kruse 2005; Sharples 2021).

Investigation of change within the archaeological record has coincided with other key areas of study. Settlement distributions have been investigated, as have architectural styes, use of space, material culture and other aspects of society such as power and status (e.g. Armit 2006: 6; Parker Pearson and Sharples 1999; Parker Pearson et al. 2018). Economies have also been a focus for investigation within recent years (e.g. Sharples 2021: 461) and are a primary area of focus for this thesis. Detailed investigation of past economies has provided insights into local and regional patterns of resource exploitation, with demonstrated potential to contribute to understand of other key areas of research (such as debates on continuity/discontinuity (Smith and Mulville 2004)). Evidence of change through time has been found within the cetacean bone record (Mulville 2002) and this will be further investigated within this thesis considering wider patterns of economic change (Smith and Mulville 2004).

4.3 CHRONOLOGY AND ARCHAEOLOGICAL EVIDENCE

This section aims to provide an overview of chronologies and archaeological remains in the Outer Hebrides, from the earliest evidence for human activity to the close of the Norse period. The early prehistoric periods are dealt with briefly and later periods in more detail as this section aims to provide a background for understanding the case study sites, which are of Bronze Age to Norse date.

4.3.1 MESOLITHIC AND NEOLITHIC (C. 8000 BC – 2500 BC)

Following the recession of the ice sheets at the end of the last ice age human communities recolonised the UK. In a Scottish context the earliest secure evidence of human presence is from the Late Upper Palaeolithic though remains from this period are scarce (Finlayson and Edwards 2003; Saville and Wickham Jones 2012), and in the Western Isles the earliest activity dates from the Mesolithic period (Gregory et al. 2005).

The end of the ice age and onset of the Holocene is dated to around 8000 BC in Scotland and signalled the start of the Mesolithic period (Finlayson and Edwards 2003: 109). This period was characterised by mobile hunter-gatherer communities whose remains in Scotland primarily include lithic scatters, rock sites, cave shelters and middens (Saville and Wickham-Jones 2012). While Mesolithic remains are found across mainland Scotland and many of its islands (Saville and Wickham-Jones 2012) direct evidence of Mesolithic activity on the Outer Hebrides is scarce. No archaeological sites of this period have yet been found on South Uist. However, three Mesolithic sites have been identified on Lewis and Harris. At Northton, Harris, midden deposits, containing stone tools, flint knapping debris, charred hazelnut shells and animal bone have been dated to between c. 7000 – 6000 cal. BC (Gregory et al. 2005) and other late Mesolithic remains have also been identified at Bagh an Teampuill, Harris and Traigh na Beirgh, Lewis (Church et al. 2011a; Church et al. 2011b). Most other evidence is in the form of palaeoenvironmental remains which provide proxy indications of human activity in the Mesolithic period through changes in the pollen record associated with episodic horizons of charcoal, indicative of burning (Edwards 1996, 2000). Such evidence has been identified in peat cores taken from South Uist (e.g. Bennett et al. 1990; Edwards et al. 2000) as well as other Hebridean islands (Gregory et al. 2005). The current paucity of the Mesolithic record in the Outer Hebrides contrasts with that of the Inner Hebrides and west coast of Scotland, where numerous sites have been identified (Saville and Wickham-Jones 2012). It may relate to difficulties recognising the sites due to the later growth of blanket peats or may be due to coastal erosion and sea level rise which are likely to have affected coastal sites (Gregory et al. 2005). While no remains of this period are currently known on South Uist the palaeoenvironmental evidence from the island coupled with archaeological sites elsewhere on the archipelago suggests that Mesolithic activity probably took place here, remains of which may come to light in the future.

The Neolithic period, (dated to between c. 3800/3700 BC. – c. 2500 BC in the Hebrides; (Brophy and Sheridan 2012: 76)), saw the advent of agricultural economies which went hand in hand with increased permanence in settlements (though seasonal occupation is likely, at least on Hebridean sites; Henley 2005; Sharples 2009), monumental burial architecture and other changes including the introduction of pottery. While certain markers such as domestic plants and animals, and use of pottery, reflect the onset of the Neolithic period across wide geographic areas, other aspects of the 'Neolithic package' and the way in which it was adopted may have region variations (Armit and Finlayson 1992; Barclay 2003: 129). It has been suggested that the inhabitants of the Western Isles, for example, adopted farming more gradually than communities in other regions (Armit and Finlayson 1992).

The Neolithic period is well attested in the Western Isles and twelve settlements of this date have been identified on the archipelago (Sharples 2009: 153), including two on South Uist (An Doirlinn, Sharples 2005 and Loch a'Choire, Henley 2000). The distribution of the settlements demonstrates that the machair plain, which was the focus for later settlement, received little attention from Neolithic communities. Rather, Sharples (2009) has argued that the areas which are currently moorland were in the past wooded and fertile landscapes and attractive areas for Neolithic activities (Brayshay and Edwards 1996). Both settlements and chambered tombs demonstrate a focus on these areas (Cummings et al. 2004), though Neolithic settlements also occur on islands within lochs and on the coast (Armit 1996). Neolithic Hebridean settlements appear to have been seasonal, though some were occupied repeatedly over hundreds of years, and others only for a few seasons (Henley 2005; Sharples 2009).

4.3.2 BRONZE AGE (C. 2500 – 800 BC)

The Neolithic period in the Outer Hebrides drew to a close around the middle of the third millennium BC and the period which followed saw the introduction of the distinctive Beaker pottery to Scotland along with other innovations including copper alloy and gold metallurgy (Parker Pearson et al. 2004: 45). While the presence of Beaker pottery and associated artefacts were traditionally thought to reflect migrations of a 'Beaker people', later thinking indicates these changes were likely related to the movement of ideas (e.g. Burgess 1976) and although numerous changes took place over the Neolithic/Bronze Age transition in the UK, a continuation of some practices occurred, including the construction of stone circles (Bradley 2000b; 2005b; Sheridan, 2008).

The Chalcolithic followed the Neolithic (*c*. 2500 – 2200 BC) and was marked by the advent of copper metallurgy which paved the way for later Bronze metallurgy (Downes 2012; Sheridan, 2008). Little work has been done on the Chalcolithic within the Hebrides and earlier work tended not to recognise the division (Parker Pearson and Zvelebil 2014; Sharples 2009), though increasingly the Chalcolithic has been defined on Western Isles sites and may be characterised by the use of oval houses in this area, along with other indicators such as the presence of beaker pottery (Downes 2012: 18). The Chalcolithic has been included within the Early Bronze Age here, following wider conventions (Downes 2012).

The Bronze Age therefore, is defined as dating from *c*. 2500 BC to around 800 BC and can be divided into the Early Bronze Age (2500 – 1550 BC), in which Beaker pottery is found, Middle Bronze Age (1550 – 1150 BC) and Late Bronze Age (1150 – 800 BC) (Downes 2012; Parker Pearson et al. 2004). The Bronze Age is characterised in a broad sense by the advent of bronze metal working, the construction and occupation of roundhouses and an increase in the use of cremation as a funerary practice, along with a greater focus on individual, rather than collective, burials which had typified the preceding Neolithic period. Many settlements and burials dating to the Bronze Age have been identified on the Western Isles, however only a small proportion have been excavated and dated more precisely to the Early, Middle or Late Bronze Age.

The Early Bronze Age is characterised generally within Great Britain by the presence of metalwork such as daggers and axes. No metalwork of this period has yet been found in the Western Isles. In contrast, Early Bronze Age houses have been recorded on the Western Isles, while they are extremely rare in the rest of the UK. The houses tend to be irregular in plan and range from rounded ovals to U-shaped structures. In the Western Isles settlement sites of this period are typically found on the machair strip, which may represent a true focus of activity in this area or the relative ease with which sites are identified on the machair compared with the peaty uplands (Parker Pearson et al. 2004: 49; Sharples 2009). In all, seventeen Early Bronze Age settlements have been identified in the Western Isles, including Iochdar, Sligenach, Cill Donnain, Cladh Hallan, all on South Uist, the Udal on North Uist and Alt Chrisal on Benbecula (Parker Pearson et al. 2004: 47-48; Sharples 2009). Beaker pottery is found on sites from the Western Isles spanning most of the Early Bronze Age, to around 1700 BC, alongside Food Vessels, following which Collared/Cordoned Urns became more common until the end of the Early Bronze Age (Sharples 2009).

While cremation burials were popular during the Bronze Age, other burial styles were also in use. Early Bronze Age burial cairns, rare on South Uist, represent a continuation of the monumental burial architecture seen in the Neolithic period, although marking individual rather than communal burials. A cemetery of Early Bronze Age date has been excavated at Cladh Hallan in which inhumations and cremation burials have been recorded (Parker Pearson et al. forthcoming). Other burials of Early Bronze Age date have also been recorded at Allasdale, Barra, comprising four cists with burials dating to between 1880 – 1490 BC (Cook 2006). A multiphased Bronze Age cairn, with three separate burials (one a cist, and two cremation burials), has also been excavated at Cnip, Valtos, Lewis (Close-Brooks 1995).

Major shifts in architectural styles, settlement patterns and funerary practices occurred from the Middle to Late Bronze Age. These changes are thought to represent important social transformations, which saw the ‘landscapes of the dead’ which had typified the Late Neolithic to Early Bronze Age (with monumental funerary architecture such as cairns and barrows), replaced by ‘landscapes of the living’ (with field systems and settlements) (Parker Pearson et al. 2005: 543). Alterations to architectural styles also occurred during this period, in particular around 1400 BC. Although architectural variation increased after 1400 BC, the Middle Bronze Age in general was typified by greater coherence and less variety in architectural styles than the Early Bronze Age (Downes 2012: 28-29).

Remains from Cladh Hallan encapsulate the changes during the Middle Bronze Age, and the site has produced evidence of mummified human remains which were kept through the Middle Bronze Age and buried, potentially centuries after their death, beneath the foundations of the roundhouse row established on the site at the beginning of the Late Bronze Age (Parker Pearson et al. 2005: 543). Other Middle Bronze Age sites on the Western Isles include Huilish Point, a Kerbed cairn on the western side of Vatersay dated to the Middle to Late Bronze Age, between 1450-650BC (Branigan and Foster 2002: 66). Another cist grave has been excavated on the Cnip headland on the west side of Lewis, where in 1992 the remains of mature male skeleton were revealed in a short cist adjacent to a multi-period cairn. Radiocarbon dating of the skeleton placed it in the middle of the second millennium BC, the same date as an urned cremation burial which had been placed within the cairn (Dunwell et al. 1995: 279-88).

Pottery of the Late Bronze Age is undecorated, and known as the Plain Style, a type which continued to be used in the Early Iron Age. This causes some difficulty in distinguishing between settlements of these periods without use of scientific dating methods. However, a number of Late Bronze Age settlements have been identified and tend to be found close to their Early and Middle Bronze Age predecessors, hinting at a degree of continuity between these periods. Late Bronze Age settlements are known at Cladh Hallan, the Udal (although remains dating to this period are largely unexcavated on that site), Iochdar and Ormacleit. The excavation the settlement at Cladh Hallan has provided important information on this period, which had previously only been known from find spots including pottery, bronze swords, spears and a textile object of cow hair, horse hair and wool found at Sheshader dated to 1190 – 915 cal BC (ScARF n.d.) and a series of important Late Bronze Age hoards including the Adabrock hoard, from Lewis, which contained axheads, spreaheads tools, razors, a vessel, whetstones and beads which reflect wider patterns of Late Bronze Age hoard deposition seen around Scotland (Anderson 1911; Armit 1996).

Although settlement patterns suggest continuity from the Early to Late Bronze Age, a marked change in settlement architecture occurred during this period. The rise of the construction of substantial dwellings went hand-in-hand with the decline of monumental burial architecture during the Late Bronze Age (Parker Pearson et al. 2004: 60 -61).

4.3.3 THE IRON AGE (C. 700 BC – C. AD 900)

Definitions of the Scottish Iron Age are varied and a universally accepted chronology has not yet been agreed (Hunter and Carruthers 2012: 18). However, for areas beyond the reach of Roman invasion (though not beyond Roman influence) and where Scandinavian influence was of later importance the application of the 'long Iron Age' has been suggested. This chronological framework is of particular relevance to the Western and Northern Isles of Scotland and comprises an Early, Middle and Late Iron Age, each typified by a change in architectural styles, cultural characteristics or material correlates, assumed in some cases to represent economic and/or social developments.

Broadly speaking the Early Iron Age can be dated to between *c*. 700 BC/600 BC and 100 BC, the Middle Iron Age to *c*. 200 BC to AD 400, and the Late Iron Age to between AD 300 and AD 900 (Parker Pearson and Sharples 1999; Smith 2002). The latter has also been subdivided by scholars into two distinct periods: the Late Iron Age I (LIA I; AD c. 300-500), and Late Iron Age II (LIA II; AD c. 500-800/900), (Foster 1989). However, the date ranges for these periods are subject to regular revision, and different areas appear to have crossed the boundaries between the Early, Middle and Late Iron Age at different times.

The Early Iron Age on the Atlantic seaboard of Scotland has typically been associated with the use of roundhouse dwellings. However, the excavation of Cladh Hallan has shown that this roundhouse tradition may have originated in the Late Bronze Age in the Western Isles (Parker Pearson et al. 2004: 19; Sharples 2012: 16-17), a situation which may too have been mirrored on Orkney, though not Shetland. Likewise, the undecorated pottery style in use during the Late Bronze Age continued to be used in the Early Iron Age in the Hebrides, further demonstrating the apparent continuity between these periods.

The Middle Iron Age is typified by the advent of monumental roundhouse structures such as the brochs and wheelhouses which drew the attention of early archaeologists and dominate our perceptions of this period (Armit 1996). Many broch structures are known from the Western Isles, with twelve from South Uist alone (Raven 2005). A similar number of wheelhouses have also been recorded on the island, although it is thought that as many as 50 may be present (Parker Pearson et al. 2004). The monumental nature of the architecture from this period, coupled with an alteration in pottery styles toward a more decorated form, make settlement sites of the Middle Iron Age relatively easy to identify. At least 25 areas of Middle Iron Age settlement have been identified along the coast of South Uist, with as little as 1km between each (Parker Pearson et al. 2004, 102). The number of settlement locations represent what was probably a considerable increase in the population size during the Middle Iron Age, compared with earlier periods.

The Late Iron Age in Atlantic Scotland encompassed a time of social change marked by increased use of personal material culture such as pins and combs, and a general diversification of domestic architecture including the emergence of celluar ('jellybaby') houses, following the decline of the monumental architecture which typified the Middle Iron Age (Hunter 2002: 129; Parker Pearson 2012: 416-7; Sharples 2003, 2012: 338). Despite the increased popularity of personal items, this is not reflected in the, rare, burials of the period, which are predominantly devoid of grave goods. Pottery of the period also became less decorated than that of the Middle Iron Age.

The Late Iron Age I, represented at Bornais Mound 1, was a relatively insular period in the Hebrides, with slight evidence of an increase in contact with mainland Scotland (Sharples 2012, 2020). A period of considerable change followed the LIA I, evident in disruption within the settlement record and changes to material culture. By the LIA II the islands were connected to the wider political society of mainland Scotland, where the Pictish kingdom had become well established and powerful. Evidence from the Western Isles demonstrates strong Pictish connections from around the 6th/7th century AD (Late Iron Age II), and a Pictish phase can be identified on some sites of this period (Parker Pearson et al*.* 2004: 105-106; Sharples 2012: 339). Bornais, for example, has a 'Pictish' phase, identified on Mound 2 (Sharples 2020: 57). While term 'Pict' conjures up images of distinct cultural groups, the general consensus is that, in the Western Isles at least, social and material change into the Late Iron Age was relatively gradual and probably not associated with an influx of newcomers. Rather, it is argued that the change in Hebridean society reflected a response to the external political situation and the emerging location of the Hebrides between different kingdoms in mainland Scotland and in Ireland (Parker Pearson et al*.* 2004; Sharples 2012: 338-9) and the islander's retained some of their earlier traditions (Sharples 2020: 57).

Archaeological sites of the Iron Age from the Western Isles are numerous, and include settlement sites at the Udal, Bornais (Mounds 1 and 2), Dun Vulan, A Cheardach Mhor, A Cheardach Bheag, Bac Mhic Connain, Kilphedir, Allasdale, Clettraval, Sollas, Foshigarry (North Uist), Dun Cuier (Barra), Bostadh (Great Bernera), Dun Carloway and Cnip (Lewis) and Beirgh in western Lewis. Iron Age remains were also identified at Rosinish (Benbecula), however, the focus of excavation on that site was on earlier, Beaker, deposits (Serjeantson 2013: 8).

4.3.4 NORSE PERIOD (C. AD 800 – C. 1400)

The Norse period commenced in the latter part of the 8th century AD, with Viking raids around the UK coast. The first was at Lindisfarne in AD 793, soon after followed by attacks on establishments in Iona (AD 795) and the Hebrides (AD 798). The use of the term 'Viking' is contentious and is here restricted to references to the period and remains associated with raiding activities, following Crawford (1987: 2) and Sharples (2020: 29), (contra. Graham Campbell and Batey 1998: 155). In terms of chronology the Viking period forms part of the Norse period, which is here sub-divided into the Early, Middle and Late Norse periods. The start of the Early Norse period, which includes the Viking period, differs slightly between sites as it relates to the arrival of Norse incomers, which did not occur at the same time in all areas. Generally it is considered to begin at *c.* 800 AD, although on some sites the Late Iron Age continues past this date, such as at Bostadh Beach where Late Iron Age occupation continued to *c.* 950 AD (Parker Pearson et al. 2004: 129). Early Norse settlement on major sites such as Bornais and Cille Pheadair is date to the 10th century AD leading to the suggestion that there may have been around a century of Viking raiding prior to the Norse settlement of the isles (Sharples 2020: 94). The Middle Norse spans the period from the second half of the 11th century AD to the 13th century AD, and Late Norse from the 13th century AD to the early 15th century (Sharples 2020: 29, 538). The above sub-division of Early, Middle and Late is not in common use, but has been applied here due to the resonance of these sub-divisions with archaeological remains identified at a key site under study in this thesis (Bornais). Other key Norse sites include Cille Phedair, Drimore (South Uist), Rosinish (Benbecula) the Udal (North Uist), Uig, Bhaltos, Bostadh and Barvas (Lewis).

The archaeological evidence which spans the Late Iron Age/Early Norse transition is complex, leading some to argue that the Norse period is marked by major changes which are indicative of a possibly violent influx of newcomers: Vikings (e.g. Crawford 1981; Jennings and Kruse 2005; Sharples 2021), while others suggest the evidence points to a more gradual and peaceful integration (e.g. Ritchie 1974). Ritchie, who argued strongly for continuity, based this on material from Orkney which showed continuity of pre-Viking material culture traditions into the Norse period. However, Sharples (2021: 463) has recently warned against this interpretation, noting the degree of mixing between pre-Norse and Norse levels as the possible reason for apparent continuity. Earlier work by Sharples and Parker Pearson (1999) also argued for some level of continuity based on settlement distributions, noting that Norse dwellings tended to be located close to earlier settlements. However, it has since been suggested that this could equally reflect the need to exploit the good quality machair land as earlier communities had (Jennings and Kruse 2005). Clearer evidence for change comes from the considerable alterations to the economy (Jennings and Kruse 2005; Sharples et al. 2016; Sharples 2021) and architectural styles which shifted from the prehistoric roundhouse tradition to the longhouses which characterised the Norse period (Sharples 2021). Changes in material culture, such as comb and pin types, are also evident (Sharples 2021: 462). Excavations at the Udal have also provided possible evidence of upheaval and although the site has not been published in detail, interim reports suggest that the Early Norse settlement activity was accompanied by a small but robustly built enclosure situated on the highest part of the site and interpreted by the excavator as a fort (Crawford and Switsur 1977: 131). The small structure was abandoned very quickly (Crawford and Switsur 1977) and although the detailed results of excavation are unpublished some have suggested that the small size and short lifespan may have reflected a need for short-lived local defence (Graham-Campbell and Batey 1998: 173; Raffield 2013: 16).

However, there is also some evidence for continuity. Across the Norse North Atlantic steatite, rather than pottery, was commonly used to produce vessels. While steatite vessels are found on Hebridean sites, pottery was also produced (Lane 2007). This represents an important difference from Norse sites in other regions and may suggest some form of continuity from Late Iron Age pottery traditions in the Hebrides (Parker Pearson et al*.* 2004: 131), though shifts in pottery styles compared with earlier periods also indicates change (Lane 2007: 14). The remains have therefore been interpreted as a remnant population of potters, forced to adapt to new cultural and social practices (Sharples 2021: 463).

There is compelling evidence therefore for change at the Late Iron Age/ Early Norse transition with some indications of continuity. On balance, the evidence appears to suggest a significant influx of newcomers, who perhaps integrated and interacted with the local inhabitants. The nature of the interactions varied and hostility and violence may have characterised some of this contact (Sharples 2021: 463).

Many of the Early Norse settlements continued to be used into the Middle Norse period, although often the domestic structures of the earlier period were often demolished to make way for new structures. However, the form of these buildings followed the longhouse tradition of the Early Norse period, such as those at Bornais or Cille Pheadair.

The latter part of the Norse period encompasses the years after 1266, when the Scottish Crown had gained control of the Western Isles from Norway following the indecisive Scandinavian defeat at the Battle of Largs and death of Earl Hakon in Orkney (Parker Pearson et al. 2004; Pryor 2010). However, the political situation was complex (Sharples 2021) and while the Western Isles communities may have begun to draw away from Scandinavian influence in the Middle Norse period, the Late Norse period has strong evidence for the re-establishment of these relationships from the 13th century through combs and comb workshops with Scandinavian influences (Sharples 2021: 465). Overall, the evidence demonstrates no great changes over these periods and Sharples (2021: 466) indicates that 'the evidence suggests a gradual development of a regional economy and culture that evolves organically from the Scandinavian culture in the ninth century', a pattern also seen in other Norse colonised areas**.**

Although the term Later Norse is used here, the remains from this period can also be understood as Scottish Medieval (Sharples 2020: 29). As with the Iron Age/ Early Norse interface there is disagreement about the extent of continuity into the Late Norse period. Some argue for a complete takeover by Gaelic lords from the latter part of the 12th century, based particularly on evidence from the Udal (Crawford 1975), while others emphasise continuity though with an increasing emphasis on contacts with the south (Sharples and Parker Pearson 1999) and Scandinavian influences are clearly evident (Sharples 2021: 465). Domestic architecture is characterised by the longhouse tradition, although in a modified form and some sites are characterised by smaller dwellings with no internal divisions, but instead have associated ancillary structures.

Toward the end of the 14th century and into the 15th century the west coast settlements began to be abandoned, thus ending thousands of years of occupation of the machair strip. Later settlements tended to focus around the lochs and rocky areas further east (Sharples et al. 2004), which remains the focus of settlement today.

4.4 KEY SITES: CLADH HALLAN AND BORNAIS

The following sections provide introductions to the key sites under study within this thesis, and their zooarchaeological remains in the context of wider Hebridean economies. The primary aims of the sections are to set out important contextual information which will allow the cetacean bone assemblages from these sites to be interpreted with reference to an understanding of wider changes in marine and terrestrial exploitation. As Yesner (1995) recognised, presence of cetaceans within the local area is important for exploitation. It is therefore necessary to define what marine areas the inhabitants of Cladh Hallan and Bornais were active in, for later discussions of procurement (Chapter 8). The following sections therefore consider the evidence for marine exploitation in inshore and offshore areas during the different periods.

4.4.1 CLADH HALLAN

Cladh Hallan lies on the machair area of South Uist. Archaeological excavations on the site revealed evidence of Early Bronze Age to Iron Age activity (Parker Pearson et al. forthcoming). In all, 16 phases of activity have been identified at the site. The earliest phases include evidence of Early Bronze Age cultivation and settlement with Beaker (Phase 1), and Cordoned Urn sequences (Phase 2), along with a cremation cemetery (Phase 3). A Middle

Bronze Age house (Phase 4) was then constructed on the site, and later demolished (Phase 5).

There is then evidence of ploughing associated with a number of structures including a very small roundhouse, a cigar-shaped structure and pit alignment (Phase 6). Activity associated with these features was followed by the insertion of foundation deposits (Phase 7) relating to the construction of a row of four or possibly more roundhouses (Phase 8). The foundation pits contained human burials, animal remains and other special deposits, such as pottery.

The northern three roundhouses of the row were fully excavated. These roundhouses (from north to south: House 1370, 401 and 801 (Figure 5)), were all sunken-floored buildings with central hearths. The houses were first occupied during the Late Bronze Age (Phase 9) and all appear to have shared the same model of use, with the north-eastern half associated with death and sleep, and the south-western half associated with birth, living and eating (Parker Pearson et al. 2005). These associations were born out by the sub-floor burials and evidence of use on the house floors. Burials tended to be focused in the north-east while smashed pottery deposits tended to be found in the south. In addition to these similarities there were also important differences.

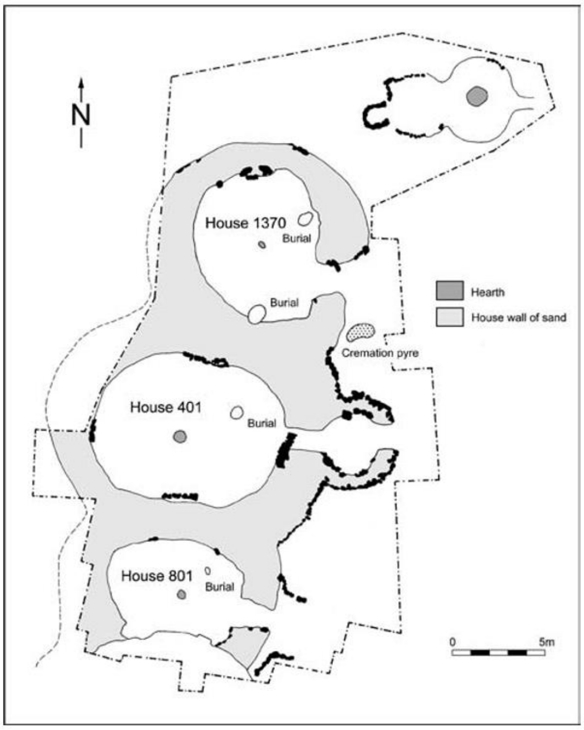

Figure 5 Roundhouse row at Cladh Hallan during Bronze Age phases 8 and 9, from (Parker Pearson et al. 2005)

House 401 was the largest and occupied longest, for a period of over 600 years spanning the Late Bronze Age to the Iron Age (Phases 9 to 16) (Parker Pearson et al. forthcoming). The inhabitants of the house are thought to have been well-off, with evidence for bronze-casting, weaponry, ornaments and the construction of the forecourt demonstrating this. Offerings included three bronze chisels, sacrifices of dogs and cremated sheep burials inserted as foundation deposits. In contrast, House 801 was the smallest and poorest of the group, abandoned after a single phase of occupation (during Phase 9) and associated with two large stone chopping tools thought to be offerings. House 1370 was again different. The structure itself was insubstantial compared with House 401 and underwent a number of episodes of rebuilding and occupation (Phase 9-10). The house also contained evidence of ten sub-floor deposits containing human remains (including the burial of one newborn), and a cremation pyre was situated directly outside the house. These remains are thought to indicate a stronger association with death at this house, compared with others in the roundhouse row.

The early Iron Age remains (from Phase 13), include the continued occupation of House 401, and the construction and occupation of a new structure, house 1500 (Phase 14). House 401 was abandoned and reoccupied in phase 15. Additional houses were constructed later in the period (Phase 16), including a double roundhouse (house 150) and a figure-of-eight shaped house (house 640) which was excavated into earlier midden layers. Phase 16 represented the final phase of occupation for House 401 (Parker Pearson et al. forthcoming).

The site produced a substantial bone assemblage, including many cetacean bone fragments, elements and artefacts. Cetacean bone was recovered by hand and from sieved samples. All site deposits were dry sieved with a 10mm mesh and all floor deposit and environmental samples were processed by floatation with a 1mm mesh, all of which resulted in the recovery of cetacean bone. The wider zooarchaeological assemblage is discussed below and marine resource exploitation and zones of exploitation considered in detail, in the context of other Bronze Age and Early Iron Age economies. Discussion of the cetacean bone from this site and Bornais is the focus of the remainder of this thesis.

4.4.2 BORNAIS

Bornais lies mid-way along the South Uist machair, just to the north of the rocky outcrop (Rubha Àird a' Mhuile) on which the Iron Age site of Dun Vulan is situated. The Bornais site consists of a series of three main mounds and two subsidiary mounds, representing the remains of a settlement occupied almost continuously from the fifth to the fifteenth century AD. Late Iron Age and Early to Middle Norse activity was identified at Mound 1. Remains consisted of a Late Iron Age wheelhouse occupied between the 5th – 6th centuries AD during which time it was burnt down and rebuilt. The Late Iron Age structures were abandoned and systematically robbed early in the 6th century AD and the area lay unoccupied until Norse settlers reoccupied the mound. Norse activity on this mound appears to have begun between AD 720 – 990, when a series of features including pits, one with a cetacean bone tool, were excavated into the mound. A group of four Norse structures was identified by the geophysical survey and one of these was partially excavated and dated to before the 12th-13th centuries. The structure was later infilled with midden that indicate the continued occupation of this mound through the Middle and into the Late Norse period (Sharples 2012: 49, 102 and 137).

The occupation of Mound 2 began during the Late Iron Age II period, between c. AD 630 – 775 (95% probability) (Sharples 2020; Sharples et al. 2016: 253 - 254). The LIA II occupation of the mound ended between AD 690-840 and was followed by Early Norse activity which began between AD 790 – 965. Occupation on this mound continued throughout the Early, Middle and Late Norse Periods. The mound appears to have been the central focus for the settlement during the Norse period (Sharples 2012: 4-5). The mound is dominated by three successive high status Norse houses (houses 1,2 and 3, representing the Early, Middle and Late Norse phases respectively).

Mound 2A produced evidence of Early, Middle and Late Norse occupational activity (Sharples 2012, 2020; Sharples et al. 2016). The earliest activity comprised ploughsoils dated to between AD 800 – 970 (95% probability), which contained a large assemblage of finds and animal bones probably deposited to fertilise the soils. Two hearths were located in the upper parts of these ploughsoils, which may have been associated with structures which were not identified. Following this activity grey sands began to accumulate on the mound, in *c*. AD 980 -1040 (95% probability). The ploughsoils and accumulation of grey sand are roughly contemporary with the occupation of house 1 on mound 2 and are thus from the Early Norse period.

After this short break in activity, a series of houses and ancillary buildings were constructed on to the grey sands. Most of the principal domestic structures (houses) were located on the south side of the mound and were not excavated. In the northern half of the mound (which was excavated), a pair of furnaces were identified, first used around AD 1040 – 1150 (95% probability), and thus roughly contemporary with house 2 on mound 2 (Middle Norse). The kilns were followed by two ancillary buildings with contemporary midden layers which surrounded the mound. These were roughly contemporary with house 3 on mound 2, although the use of the ancillary buildings continued after house 3 was abandoned. The first of the ancillary buildings is thought to have been constructed between AD 1140 – 1260 (95% probability), and the associated midden began to accumulate around the same time (between AD 1140 - 1250, (95% probability)), from the Late Norse period. Another structure lay above these ancillary buildings, which may have been a house. Activity on mound 2A ceased prior to 1500 (Sharples et al*.* 2016: 256-258).

Excavation of a trench at Mound 3 revealed a sequence of complex structural activity. The majority of the structures on this mound remain unexcavated, and detailed investigation was limited to a single house (Trench D) and an ancillary building associated with the house (Trench F), identified as a probable barn with attached corn-drying kiln (Sharples 2005a: 187). The beginning of activity on the mound was dated to cal AD 1050 – 1140 (68% probability) and the end of occupation to cal AD 1410 – 1475 (68% probability) (Marshall 2012). Thus activity on this mound generally spans the Middle and Late Norse periods.

The excavations at Bornais resulted in the recovery of a large archaeofaunal assemblage, including a substantial number of cetacean bone fragments, elements and artefacts. Cetacean bone was recovered by hand and from sieved samples. All floor deposits and environmental samples were processed by floatation with a 2mm mesh, and all soil layers on site were sieved with a 10mm mesh. The zooarchaeological assemblage is considered below and marine exploitation and zones of exploitation discussed in detail, in the context of other Late Iron Age and Norse economies**.**

4.5 CLADH HALLAN AND BORNAIS ZOOARCHAEOLOGICAL ASSEMBLAGES IN THE CONTEXT OF BRONZE AGE TO NORSE HEBRIDEAN ECONOMIES

4.5.1 BRONZE AGE TO EARLY IRON AGE

Cladh Hallan's zooarchaeological assemblage shows a focus on terrestrial resources, fitting with the wider pattern demonstrated by Bronze Age and Early Iron Age economies on other sites (e.g. Barber 2003; Finlay 1984: 113-114; Finlay Aird 2018: 105; McCormick and Buckland 2008: 99-100; Parker Pearson et al. 2005: 80; Smith and Mulville 2004: 53). However, a minor marine component is likely at Cladh Hallan, as at other sites and fish, marine mammals and bird species were all identified within the zooarchaeological assemblage, all of which can provide insights into the zones of marine exploitation during the Bronze Age and Early Iron Age, relevant for the interpretation of cetacean procurement (Chapter 8).

The bones of immature saithe dominate the Cladh Hallan fish assemblage throughout all phases. The fish assemblage from Cladh Hallan is directly comparable with other contemporary assemblages from the Hebrides, such as Dun Vulan, Cill Donnain Sollas (Finlay 1991), Hornish Point and Baleshare (Halsted 2003) and from sites on the islands of Pabbay, Sandray and Mingulay (Mulville and Ingrem 2000) which also show a focus on immature saithe (Cerón-Carrasco 1999). Saithe remain in their nursery grounds for up to two years in northern climes (Ingrem 2012: 225) and within Hebridean waters nursery grounds for saithe are found to the east of the Outer Hebrides, in the Minch. Although other species were much scarcer within the assemblages at Cladh Hallan eel, ballan wrasse, flatfish and gadoids are also represented, all of which can be caught in inshore waters at different times of the year (Ingrem forthcoming). A more generalised fishing strategy is evident at the Udal during the Bronze Age (Finlay Aird 2018: 105), however, the strategy of inshore fishing is mirrored at this site, and the Udal community shifted to a focus on gadoids in the Iron Age (Finlay Aird 2018: 105). Overall, the remains from Cladh Hallan and other Hebridean sites indicate that Bronze Age and Early Iron Age communities practiced an inshore fishing strategy focused on the exploitation of young saithe. The species have been caught historically from nets or rod and lines deployed from the shore, or from small boats close inshore (Ingrem forthcoming) and a number of artefacts including double ended needles were identified at Cladh Hallan which may have been used in net production (Slater and Davies forthcoming).

Seal were also represented in small numbers at Cladh Hallan, in phases 7-13, 15 and 16. Both the Atlantic grey and common seal were identified. Grey seals frequent the exposed west coast of the Hebrides, while the common seals favour the more sheltered east coast (Boyd 1963). The former spend longer on the shore, though common seals also come ashore for shorter periods (Duck 2007). Common seal mating occurs in the water though pupping occurs onshore though pups are able to swim with the next incoming tide. Grey seals move farther ashore making them easier to hunt (Duck 2007). The numbers represented do not indicate a focus on these species, and they may have been acquired opportunistically or by predation when colonies or individuals came ashore, during nightly haul-outs, or on breeding or pupping grounds. Exploitation of the grey seal on pupping grounds in the Hebrides is recorded historically by Martin Martin (Martin 2010: 48). Writing in the 18th century Martin records how hunting parties would encircle the seals; some from behind and some waiting close inshore with boats. Those behind would beat the seals and scare them toward the sea while those in boats would shoot at them. Martin also records the use of nets for catching seals in narrow channels in the islands of Heirskir, an island group which still supports a grey seal population (Martin 2010: 47) which has been exploited since at least 1549 (Monro 1549). Martin also records the hunting of seals during pupping season on other west coast islands, again indicating capture of the grey seal. However, he also notes that the seal pupping on the east coast occurs in a different month (indicating knowledge of common seals), but does not indicate if these were hunted (Martin 2010: 48). The presence of seals therefore likely represents exploitation in an intertidal or coastal environment, rather than suggesting any offshore exploitation. Seal remains are also found on other Bronze Age and Early Iron Age sites, though typically in small numbers as at Cladh Hallan (Smith and Mulville 2004: 50).

Avian resources from South Uist sites show a distinctly marine focus from the Bronze Age to Norse periods (Best 2013: 166). Middle Bronze Age, Late Bronze Age and Early Iron Age phases at Cladh Hallan produced bird bone, and the Late Bronze Age deposits in particular produced a sizable assemblage. The Middle Bronze Age assemblage, though small, produced a grey goose, curlew/oystercatcher, gannet, wader and northern diver (Best 2013: 178), while the Early Iron Age assemblage, also small, produced gannet, cormorant, goose, herring gull, puffin and a range of other species all in low numbers. The Late Bronze Age produced a much larger assemblage, with at least 34 species represented. Gannet made up around one third of the NISP for the LBA, and puffin, herring/lesser black backed gull, little auk and Manx shearwater, and a range of other seabirds were also present (Best 2013: 178). The predominance of gannet though, and the presence of a juvenile, indicated exploitation at breeding colonies. No gannet colonies are today found on South Uist, though remains of this species are found on a range of other archaeological sites including Cille Phedair and Dun Vulan (Best and Mulville 2013: 423). The repeated presence of this species on South Uist sites has been interpreted as evidence 'either that the surrounding environment was different enough to support them, that they bred more widely in the past, that the birds were caught at sea, or that they were captured beyond the immediate vicinity of Cladh Hallan' (Best and Mulville 2013: 423). Other species from the site demonstrate exploitation of a range of different environments including the machair, moorlands, lochs, rocky coastlines, shores and sea cliffs and the presence of eggshell indicated exploitation of nesting sites. Overall, most species could have been acquired from the islands themselves, though the uncertainty regarding gannets does leave some possibility of seaward travel to cliff-side nesting sites, as found on St Kilda today, though other possibilities exist.

Evidence for waterborne travel in the Bronze Age and Early Iron Age is sparse, though log boats, paddles and oars have been found around the coasts of mainland Scotland and may date to these periods (Pollard 1994: 84). Other finds within the UK include sewn plank boats, though none have been recovered from Scottish contexts (Downes 2012), and collections of Bronze Age materials on the seabed interpreted as lost cargos from wrecked vessels e.g. the Middle Bronze Age Langdon Bay hoard found just off Dover (Historic England 2017). Despite the current paucity of direct evidence for vessels in the Western Isles in the Bronze Age and Early Iron Age, maritime activity and the existence of seagoing vessels in this period can be inferred from evidence for Bronze Age activity on St Kilda, which requires a crossing of over 50 miles from the Outer Hebrides (Fleming and Edmonds 1999).

4.5.2 MIDDLE TO LATE IRON AGE

Many Iron Age sites have been excavated on the Hebrides and results of detailed analysis of faunal assemblage have been published for a number of these sites, providing useful comparison for the Bornais material (Smith and Mulville 2004: 53). Analysis of material from these sites has shown that the Middle and Late Iron Age economy was a subsistence one, rooted in the Hebridean environment and based primarily on agriculture (Serjeantson 2013: 98). Although broad patterns in the economies of this period are evident, there are clearly site-specific differences in the way the Hebridean communities used their surrounding landscapes and seascapes (e.g. Cerón- Carrasco 2005; Jones and Mulville 2016: 675; Parker Pearson and Sharples 1999). While domesticates formed the mainstays of economies during these periods there is evidence of an increase and diversification in the exploitation of wild and marine species, in particular deer though birds, seals, fish, and cetacean bones are consistently present in assemblages (Serjeantson 2013) though focal species differ between sites and evidence suggests that exploitation was focused in the local environments of each site (e.g. Mulville and Powell 2012; Mulville and Ingrem 2000). The location and nature of marine exploitation has implications for cetacean procurement and is considered below in further detail.

In contrast to the rest of Britain where communities appear to have actively avoided marine resources, in northern and coastal Scotland there does appear to have been an increase in the use of marine species during the Iron Age (Barrett 2016b). While there is a relatively minor aquatic signal in Orcadian diets during this period (Barrett and Richards 2004: 260), in the Western Isles aquatic resources appear to have gained in importance from the Middle Iron Age evidenced by increases in fish bones and isotopic signatures indicating consumption of aquatic proteins in humans (Jones and Mulville 2016: 675). However, the aquatic focus was generally lower than on contemporary Scandinavian sites and later Viking Hebridean sites.

Fish assemblages have been analysed from several sites at this period, including Bornais (Evans and Ingrem 2021; Ingrem 2012), Dun Vulan (Cerón-Carrasco and Parker Pearson 1999), Cnip (Cerón- Carrasco 2006), Hornish Point, Baleshare (Jones 2003), Bostadh, Beirgh (Cerón- Carrasco 2005), Pabbay, Mingulay and Sandray (Mulville and Ingrem 2000), while others await publication. Though there are variations between sites in general the assemblages show an increase in the abundance in fish remains compared with earlier periods. Immature saithe continued to be the principal species, though other inshore species were also taken. Overall remains are indicative of a continuation of the inshore fishing strategies seen in the Bronze Age though with evidence of some intensification (Cerón-Carrasco 2005; Evans and Ingrem 2021; Ingrem 2012, 2021; Jones and Mulville 2016: 674; Smith and Mulville 2004: 54).

Assessment of the Late Iron Age fish remains from Bornais, present on Mound 1 and 2, has revealed comparable evidence to most other Late Iron Age sites (Sharples et al. 2016: 261). On Mound 1, fish bones were recovered from the Late Iron Age house (CB), the 5th century midden (CG) and the infill layer (CC). The middens on Mound 1 are the only Late Iron Age deposits where larger quantities of fish bones were recovered, dominated by immature saithe aged below 2 years, and salmonoid bones, with cod, hake and sea sturgeon also present (Ingrem 2012: 196-200). While large cod are rare inshore today, both large and small cod and saithe are thought to have been present in inshore waters during this period, and maps produced in the 18th century (Figure 6) depict their presence in this area. Other species were found to be present but in such low numbers the catches are likely incidental. These species include eel, herring, flatfish and rockling (Ingrem 2012: 226), all of which can be caught inshore. The fish assemblage from Late Iron Age deposits on Mound 2 is very small, and derived from floor and infill layers (BAB and BAC). Fish remains from those groups consists of only 5 identifiable specimens, including 3 from small saithe, one from a small eel and one from a medium sized gadid all of which can also be caught inshore (Evans and Ingrem 2021: 321).

Common seal and grey seal are also consistently present in low numbers on most sites, though they are absent from Late Iron Age levels at Bornais (mound 2) (Evans and Ingrem 2021: 325) and rare in the mound 1 assemblage, represented by only 5 fragments of grey seal bone (Mulville and Powell 2012: 191). Grey seals are most common within assemblages of this period, likely due to the ease with which they can be captured (Duck 2007; Smith and

Mulville 2004: 54) and as in earlier periods it is likely that their presence reflects predation on haul-out or breeding sites, where these species are most vulnerable to human predation (Duck 2007: 35). However, remains of the common seal were identified at Cnip (McCormick 2006: 171) and at Pabbay the species made up an unusually high proportion of the overall archaeofaunal assemblage which has been interpreted as a reflection of the struggling agricultural economy on the site (Smith and Mulville 2004: 54). The common seal spends less time ashore and is considered more difficult to catch (Duck 2007; Mulville and Ingrem 2000: 261). It is possible that this species was caught at sea (inshore), perhaps using nets and local features such as gullies as traps, as reported by Martin Martin (2010), though exploitation during their restricted time on the shore is also a possibility. The remains from Pabbay otherwise showed a relatively normal pattern of Iron Age marine exploitation, with fishing focused on immature saithe (though red bream were also favoured) demonstrating exploitation of inshore environments.

Exploitation of avian resources continued during the Iron Age, and the focus remained on marine species (Best 2013: 166, 248). Although bird remains are consistently present in assemblages from this period, the relative percentage of avian remains compared with overall archaeofaunal assemblages is still relatively minor (c. 2-3%), slightly lower than in the Bronze Age, and much lower than the subsequent Norse period, in which the relative percentage increased to c. 8% (Best 2013: 151). However, there are exceptions to this and bird remains made up 9% of the Mound 1 assemblage at Bornais, and up to 14% in the Late Iron Age midden, suggesting that birds made up an unusually high component of the diet at Bornais (Cartledge and Serjeantson 2012: 342). Remains from this period on the Shiant Islands are also dominated by bird remains, which make up c. 90% of the NISP from the Iron Age roundhouse site, while sites on Pabbay and Mingulay (noted for their unusual reliance on wild species; Mulville and Ingrem 2000) have assemblages composed of 13% and 18% avian remains (Best 2013: 232). Late Iron Age sites on South Uist also show other unusual patterns, and the large assemblages from Dun Vulan and Bornais both show a very high reliance on seabirds suggesting a targeted strategy on South Uist which focused on these species (Best 2013: 167). Generally, the species exploited on the South Uist sites, which include gannets, shags, puffins, razorbills and guillemots, appear to suggest a fowling strategy focused toward exploitation of cliff-nesting seabirds, perhaps indicating exploitation of cliffy coastlines some distance from the generally low and rolling hilly lands of South Uist (Best 2013: 183).

Figure 6 Huddart’s 1794 chart of the Hebrides showing markers for herring shoals and large gadoids in inshore waters

Faunal assemblages, and in particular evidence indicating the exploitation of birds on sea cliffs, and also potentially inshore exploitation of saithe may have required the use of vessels. A possible stone anchor has also been identified at Dun Tomaidh (North Uist) (Beveridge and Callander 1931: 321) possibly providing evidence of maritime technology, although the stone is not depicted within the report and alternative interpretations may be possible. The excavators of this site also suggest a harbour may have been associated with the dun (though dating was not undertaken). Although no unequivocal evidence of boats has been found within Hebridean assemblages from this period, wider evidence of maritime activity in the Iron Age comes from iconography and historical documents. A Pictish carving on St Orland's Stone in Angus clearly depicts what is probably a clinker-built vessel, propelled by oars and with a crew of six (Graham-Campbell and Batey 1998), and Irish Annals dated to the 10th century, though potentially with 7th-century AD origins, describes boat crossings from Ireland to Scotland (Céron-Carrasco 2005: 48). While the evidence is sparse it does demonstrate maritime capabilities in the Iron Age.

While marine (and wild) resources tend to be present on most sites, evidence of farming is dominant in most cases. However, at some sites, such as Annat (RI41A) Rough Island (Shiant Islands), Pabbay and Mingulay (Mulville and Ingrem 2000) wild, as opposed to domestic, fauna form the bulk of the assemblages. On these sites the predominance of wild resources is coupled with clear evidence of failing agricultural economies (e.g. high numbers of neonatal cattle and sheep). These sites are situated on small Hebridean islands, and their location is suggested as a possible cause for the failure of agricultural economies. In these situations, it appears that the small island communities turned to nearby wild resources (puffin colonies on the Shiant Islands, and seal colonies and to a lesser extent avian remains on Pabbay), to overcome the shortfall (Best and Mulville 2010; Smith and Mulville 2004: 54). While these sites are anomalies, the exploitation of wild resources on the Middle and Late Iron Age sites generally tends to be focused in the near vicinity of the site (though with cliff-side fowling activities as a possible exception), a pattern which may also be seen in the evidence for inshore exploitation.

Settlement distribution and wider landscape use may also provide insights into potential areas of exploitation. By the Middle Iron Age settlement density is thought to have been high, and at least 25 areas of settlement with as little as 1km between each have identified along the coast of South Uist dating to this period (Parker Pearson et al. 2004: 102; Parker Pearson 2012: 38). Although the recognition of sites dating to this period is easier than for the periods preceding and succeeding periods due to the diagnostic decorated pottery, this density of settlement is still thought to be far in excess of that in earlier periods (e.g. Sharples 2012). The likely increase in population which accompanied these high settlement densities is thought to have gone hand in hand with a re-orientation of farming from north-south, to east-west. It is probable that this orientation marks an extension of cultivation lands eastward, across the peaty black lands, to cope with the increasingly crowded machair. On a larger scale, pre-clearance townships divided the island into large strips reaching from the east coast to the west. Each strip included machair, blacklands, mountains and sections of the east coast as well as the west (Parker Pearson et al. 2004: 103). The alteration in orientation of farming strips and the increase in settlement numbers in the Iron Age suggests that this system of land division may have its origins in this period, giving inhabitants of the settlements formalised access to a wide range of resources including marine resources from two coasts. Although settlements are focused on the machair strip of the west coast, remains dating to the Iron Age have been found on the east coast including activity at West Kirkland and Usinis (Moreland et al. 2012; Thomas 1870). Regular activity on both coasts may have had implications for the range, regularity and environments of encounters with cetaceans.

4.5.3 NORSE

The settlement at Bornais underwent a series of changes in the Norse period, including alterations to the domestic economy and increased exploitation of wild and marine resources (Sharples et al. 2016). These changes can be understood against the wider backdrop of Scandinavian settlement of the North Atlantic region and complex evidence indicating potential continuity of some Iron Age traditions and disruption of others (Sharples et al. 2016)**.** The extent to which Norse practices influenced or dominated the economy and other aspects of society at Bornais and other sites is still open to debate (see Jennings and Kruse 2005; Sharples and Parker Pearson 1999; Sharples et al. 2016). The issue is of relevance for understanding cetacean procurement due to the potential evidence of whaling in Scandinavia in the Late Iron Age (e.g. Clark 1947; Lindquist 1994), and consideration of possible continuity with Scottish Iron Age practices with implications for potential procurement methods and foci.

The Norse settlement of the North Atlantic heralded large-scale changes in marine exploitation and establishment of 'landnám'[8] economies in previously unsettled regions

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[8] Literally, 'land-take', a Norse term typically applied to the period of settlement and colonisation of North Atlantic Islands and other areas by the Norse.

such as Iceland; an economic strategy based on Scandinavian perceptions of an 'ideal farm' employed during the Norse settlement of the North Atlantic region. This was mirrored by economic changes in areas with existing settlements, such as the Scottish islands. The Early Norse 'landnám package' was characterised by reliance on a range of marine and terrestrial resources of which the latter included cattle, pig, sheep, goats, horse and dog which can be seen in zooarchaeological assemblages from across the North Atlantic (Arge et al. 2009; Dugmore et al. 2005:27; Madsen 2014; Perdikaris and McGovern 2007:198; Vésteinsson et al. 2002: 108). The influence of these economic changes can to some extent also be seen the remains from Bornais and there are striking differences between the Late Iron Age and Early Norse economy (Sharples et al. 2016). During the Early Norse period farming intensified on the site, with a reliance on pig, sheep and cattle. Pig in particular are represented in high numbers in the Early Norse period compared with the Late Iron Age and later Norse remains on the site (Sharples 2016: 261) which appears to reflect the importance of this species in landnám economies across the North Atlantic. However, there are also differences and sheep are the dominant species at Bornais, in contrast to the 'ideal farm' strategy which favoured cattle. Following initial settlement the landnám strategy altered in many regions, likely in response to improved understanding of local environments. Caprines became dominant and in the Hebrides the incidence of pig on settlement sites declined, possibly in realisation of the destructive effects of this species on the fragile machair (Sharples et al. 2016).

In addition to changes to terrestrial economies, there were also major changes to the exploitation of marine and wild taxa. Use of wild resources increased drastically in areas of Norse settlement, particularly during the Early Norse period and archaeofaunal assemblages from the time of the landnam in many cases are dominated by local wild and marine species (Arge 2014; Dugmore et al. 2005). In Greenland, for example, seals and caribou were exploited (Dugmore et al. 2005) while in the Faroes fish and shellfish predominate though birds were also of importance, as they were on many Icelandic sites (Arge 2014; Brewington 2011; Church et al. 2005; Dugmore et al. 2005: 29). Exploitation of wild and marine species also increased drastically in the Hebrides during this period including fish, birds, deer, otter, seal and cetaceans (Best 2013; Smith and Mulville 2004).

The marked increase in the exploitation of fish is demonstrated both in zooarchaeological assemblages and by the rise in consumption of marine resources indicated by isotopic analysis, both of which are evident within remains from the Western Isles (Barrett and Richards 2004: 262-4; Dunwell et al. 1995; Jones and Mulville 2018; Serjeantson 1984; Smith and Mulville 2004: 55; Tim Neighbour pers. comm. in Barrett et al. 2000b). The increased focus on fish occurred in two stages. The first stage occurred as part of the 'introduction of Norwegian foodways during the Viking Age colonisation', i.e. as part of the Early Norse landnam package, while the second, termed the 'Fish Event Horizon' occurred from around AD 1000 and was associated with a drastic increase demand for fish in urban centres which was mirrored by increases in marine resource consumption in Scottish contexts, though the precise reasons for this change are still under debate (Barrett and Richards 2004; Barrett et al. 2004a, b).

Although intensification was widespread, regional variation in patterns of fish exploitation are evident. While in the Northern Isles cod were the target species, the Western Isles followed a different trajectory, and herring and large gadoids were the focus. This pattern is seen at sites including Bornais, Bostadh Beach, Cille Pheadir and the Udal (Cerón- Carrasco 2005; Evans and Ingrem 2021; Ingrem 2005, 2018, 2021; Serjeantson 2013: 74). The marked increase in the exploitation of fish, and specifically herring is evident from the earliest Norse deposits at Bornais, though later Norse deposits on mound 2 demonstrate consistently higher densities of fish bone (Sharples et al. 2016: 263), possibly representing increasing exploitation through the Norse period. The fish assemblage from the house floors is dominated by herring vertebrae, primarily from the abdominal region, and a scarcity of cranial bones suggests the herring arrived at Bornais in a decapitated form. This may be indicative of trade, or of processing off site (Sharples et al. 2016: 263). However, stable isotope analysis has demonstrated that marine protein formed part of the diet of pigs at Bornais and it is therefore also possible that the fish heads could have been fed to the pigs (Jones and Mulville 2018: 348). Herring, therefore may have arrived on the site whole and may have been prepared for consumption or trade (Ingrem 2005a, b). Saithe and other gadoids were also present on the site, although in smaller numbers and represented by both cranial and vertebral bones. Analysis of the fish remains from Bornais Mound 3 also showed that herring were the most numerous fish remains encountered on site.

Herring remains dating to the Norse period from mounds 2, 2A and 3 indicate the exploitation of fish measuring between 235 – 300mm in length (Ingrem 2005a, b, 2021; Evans and Ingrem 2021). Fish of this size are generally around 3 years old, around which time herrings begin to participate in cycles of spawning and offshore feeding. It was initially suggested that herring from Bornais may have been obtained from offshore waters at the edge of the continental shelf (Ingrem 2005a, b), primarily on the basis of the size of the fish represented within the assemblage and the associated species. However, further assessment demonstrated that fish of this size can also be found on inshore spawning grounds which are known around the coast of the Hebrides (Baxter 1958; Evans and Ingrem 2021; Geffen et al. 2011; Saville et al. 1966). Given the inherent danger of long offshore voyages, exploitation of spawning grounds near the coast is considered more likely than exploitation in offshore waters (Evans and Ingrem 2021: 321). Exploitation of spawning shoals around the Hebrides is apparent in historical records indicating that a fishery existed in this area from at least the 15th century onward (Knox, 1785: 214; Macleod 1998; HM Stationary Office, Parliamentary Papers Vol 23 1846: 30-31) and the presence of herring shoals in these areas is also shown on historic maps, e.g. to the east of North Uist. Accounts from the 18th century also indicate that little was known of the area to the west of the Hebrides at that time, suggesting that the fisheries had historically been focused to the east, in the Minch and nearby waters (Knox 1785: 207). Modern fisheries also focused in this area (Saville et al. 1966). Given the development of the herring fisheries in the Minch it appears unlikely that activity in the Norse period extended to the deep waters of the continental shelf edge. It is much more likely that herring were exploited close to home in the bays of the east coast of the Hebrides, and in the Minch.

In addition to herring the Norse assemblage at Bornais (and other sites include Cille Pheadair and the Udal (Ingrem 2018; Serjeantson 2013)) also produced evidence of large gadoids (cod, pollack, hake and ling), immature (second-year) saithe and salmonid species. Larger saithe became more common in the Late Norse at Bornais period and other species are present in very small numbers suggesting they are incidental catches or gut contents of larger species (Ingrem 2021). As in previous periods immature saithe may have been caught inshore and while large gadoids such as cod and hake may have been caught offshore (Ingrem 2018: 508) these species also move inshore during summer, and Joseph Huddart's chart from 1794 (Figure 6) marks the presence of 'cod and ling of a great size' just off the west coast of South Uist indicating that these too may have been targeted in inshore waters (Evans and Ingrem 2021). Additionally, individuals of these species and other gadoids such as saithe are commonly found in association with herring spawning grounds, preying on the herring (Vabø and Skaret 2008). Thus these species could also have been caught off the coast of the Hebrides.

As in earlier periods seals were identified in the Norse deposits at Bornais, though in low numbers indicating that they were not exploited regularly. The range of elements indicates that complete carcasses were occasionally brought to the site, and unfused bones indicates that juveniles were exploited at times potentially representing exploitation of shoreline pupping sites. However, the low numbers of bones indicates that exploitation may have been the result of incidental encounters rather than targeted exploitation (Evans and Ingrem 2021: 325). Remains from other sites such as the Udal also show low incidences of seal bones (Serjeantson 2013: 64- 65).

Exploitation of birds also increased drastically in the Hebrides during the Norse period (Best 2013) and remains from Bornais mounds 2 and 2A demonstrate a focus on seabirds, which could have been exploited at sea or on onshore breeding and nesting sites (Best 2021: 345). As in earlier periods cliff-nesting species such as gannet, guillemot and razorbill are present, and may indicate travel to exploit cliff side nesting sites today found on offshore islands such as St Kilda (Best 2021: 345).

Overall, the evidence from the zooarchaeological assemblage at Bornais demonstrates an economy focused on terrestrial resources which is likely to have had Norse influence, particularly represented by the Early Norse focus on pig, and a drastic intensification of marine exploitation (Sharples et al. 2016) Unlike in the Northern Isles (Barrett et al. 2001, 2004a, b), Bornais and other Hebridean sites show a focus on herring which are likely to have been caught in inshore waters on spawning grounds around the coast of the Hebrides, and in the Minch, along with other species such as immature saithe (Evans and Ingrem 2021). Evidence of marine exploitation sits within the wider context of well-demonstrated maritime capabilities in the Norse period. Direct evidence for maritime remains from the Norse period has been found at Rubha an Dùnain on Skye, where remains of a possible Norse harbour, quay, canal and associated boat nausts have been identified. The features lie in association with a loch on the west coast of the island, which is likely to have been used as a harbour during the Norse period and remains of a ruined quay have been found below the waterline. This is an important site and has also produced timbers from vessels dating to c. AD 1100. One of the vessels was interpreted as a rowing boat around 6m in length, while a second has been interpreted as a larger sailing vessel of c. 10+m (Martin and Martin 2010).

The evidence from the Bronze Age to Norse periods indicates that inshore cetacean taxa are likely to have been encountered more frequently than offshore taxa due to the inshore focus of marine activities over this time span (see Appendix 1 for a review of cetacean habitats). Hebridean cetacean bone assemblages are considered in more detail below.

4.6 CETACEAN REMAINS ON SCOTTISH ARCHAEOLOGICAL SITES

This section sets out an overview of cetacean bone from archaeological sites in Scotland, in order that the remains from Cladh Hallan and Bornais can be understood in context. In particular this section gives an introduction to the material covered by archaeological excavations, from antiquarians to modern research efforts, the types of site cetacean bone has been recovered from and the chronological time span of cetacean bone use and procurement. Data on cetacean bone assemblages from the Western Isles dating from the Bronze Age to the Norse periods has been collated in Appendix 2 and is referred to within the following discussion.

Cetaceans have been an important resource throughout history, and cetacean bone is a common find on Scottish coastal archaeological sites from the earliest periods of prehistory through to the modern era (Mulville 2002). Previous studies have identified over 70 Scottish sites with cetacean bone (Mulville 2002: 39) and van den Hurk's (2020) assessment identified cetacean bone on hundreds of sites spanning north-west Europe. Although most cetacean tissues such as meat, baleen, skin, sinew, oil, teeth and bone can be utilised, and likely were, it is typically only bones and teeth which survive in archaeological contexts and therefore form the focus for investigation.

Cetacean bone is found on Scotland's earliest prehistoric sites, from the Mesolithic shell middens of Oronsay (Mellars 1987), to the Neolithic settlement of Skara Brae (Childe 1929). Evidence of exploitation continues through the Bronze Age on settlement sites such as Cladh Hallan and Sligeanach on the Hebrides (Sharples et al. 2012) and into the Iron Age when the number of sites with cetacean bone increased drastically (e.g. Hedges 1987; Szabo 2005, 2008) though this may be related, at least in part, to the preference for investigating these sites in the past, likely due to their visibility in the landscape. Although fewer Norse sites have been excavated on the Hebrides compared with Iron Age sites, for those which have been investigated cetacean bone has been a common find, both on settlements and burial sites excavated in Scotland generally (e.g. Batey 1994; Morris et al. 1994; Mulville 2002; Sharples 2005a; Szabo 2008). Later medieval sites (Serjeantson 2013), post-medieval sites potentially connected with the whaling industry (Perry 2000: 103; Smith 2000: 233) and modern sites which include the iconic whale bone arches (Redman 2004) have all produced evidence of cetacean procurement. While Scottish sites provide ample comparisons, other North Atlantic sites and accompanying studies of cetacean material also provide important sources for understanding cetacean bone found on Scottish sites (e.g. Petersen 1951; Sjøvold 1974; Szabo 2008).

Although a variety of site types are represented, the majority of cetacean bone assemblages come from settlement areas. There are, however, a small number of important exceptions. The Carse of Stirling provides an important example in this regard. Exposures of the former seabed in this area produced the remains of 20 skeletons from large cetaceans including a blue whale, with evidence of Neolithic tools which may have been used for butchery or killing of the cetaceans (Szabo 2008: 168). More recent processing sites, such as the possible 19th-century pilot whale drive site at Cata Sands in Orkney also falls into this category (UHI 2019a). These sites are rare and provide valuable insights into shoreline processing, and importantly what remains may be absent on many settlement sites.

Cetacean bone is common on Scottish coastal settlement sites (Mulville 2002; van den Hurk 2020). However, methods of excavation have materially affected the cetacean bone record, and up until recently few excavations recovered or recorded fragmentary cetacean bone. Early excavations rarely employed sieving and thus would not have recovered many fragments, which tend to form the bulk of cetacean bone assemblages (see Chapter 6). Although reports of these excavations recorded cetacean bone finds (often reported in the *Proceedings of the Society of Antiquaries of Scotland*), few included full accounts of all cetacean bone fragments and elements. Later excavations have in some cases provided a greater level of detail on the cetacean bone assemblages including enumerating fragments and elements in places, though remained focused on finds (e.g. Hallén 1994: 190), and it has been left to modern excavations to store and record all cetacean bone fragments. Excavations using modern techniques and extensive sieving campaigns have resulted in the recovery of much larger cetacean bone assemblages. The assemblages from Cladh Hallan and Bornais for example total well over 1000 pieces of cetacean bone each. It is likely therefore that other sites, and particularly those which have produced substantial cetacean bone artefact assemblages, such as the Iron Age sites at Foshigarry and Bac Mhic Connain (Hallén 1994) also had large numbers of fragments not recorded during the original excavations which were undertaken without systematic sieving. Thus while many assemblages contain cetacean bone in the majority of cases the focus has been on recording artefacts. The shortcomings of earlier excavations have limited the number of assemblages which can be used for comparison, a factor which is compounded by the low level of investigation in terms of taxonomic identification and quantification the existing assemblages have seen. Appendix 2 contains details of cetacean bone assemblages from the Western Isles from the Bronze Age to the Norse periods and contains information on quantities of bone fragments, elements, artefacts and taxa where this information was available in published sources.

There are some sites which provide important comparable assemblages for the material at Cladh Hallan and Bornais (see Appendix 2). In a Hebridean context these include the ongoing post-excavation work on the material from the Udal, which is also likely to form an important assemblage for comparison with Bronze Age, Iron Age and Norse material (Serjeantson 2013). Few other comparable sites from the Bronze Age have been excavated, although, the Bronze Age phases of Northton on Harris produced a cetacean bone assemblage with some elements morphologically identified and at least some fragments recorded (Finlay 1984, 2006). Small cetacean bone assemblages have also been recovered from the Early Bronze Age phase of Sligeanach on South Uist (Sharples et al. 2012) and from Machair Mheadhanach, also Early Bronze Age in date (Hamilton and Sharples, 2012). Many of the Iron Age Hebridean sites contain cetacean bone (e.g. Hallén 1994), though many suffer from the issues set out above. Dun Vulan is an exception and includes a relatively large cetacean bone assemblage (Mulville 1999, 2002; Parker Pearson and Sharples 1999) and Cnip also provides information on fragmentary and worked cetacean bone (McCormick, 2006; Hunter 2006). The aforementioned Iron Age sites at Foshigarry and Bac Mhic Connain also contained considerable quantities of cetacean bone including a substantial assemblage of cetacean bone tools (Hallén 1994). In a wider context the assemblage from Pool, Orkney (Szabo 2008), and ongoing analysis of the Iron Age sites of the Cairns, which has a substantial cetacean bone assemblage (UHI 2019b) and Mine Howe will provide important comparisons. Cille Pheadair, Bostadh and Drimore also include small published assemblages which form an important comparison for Viking and Norse material (Cerón- Carrasco 2005; Parker Pearson et al. 2018; Young and Richardson 1962).

Identification of species is rare and to date none of the assemblages set out above has been studied in detail using modern methods of analysis for taxonomic identification. However, some identifications have been set out based on bone morphology (e.g. Finlay 1984, 2006; McCormick 2006; Mulville 2002; see Appendix 2 for full details) and small numbers of samples from a selection of sites including Cladh Hallan, Bornais, A Cheardach Mhor (South Uist) and Galson (Lewis) have been analysed using peptide mass fingerprinting (Buckley et al. 2014). The ongoing work on the Cairns and Mine Howe also includes DNA analysis, which forms part of the wider *Norse Marine Mammal Project.* This project is undertaking analysis on sites in Iceland, Greenland, North America, the Faroe Islands and Orkney spanning the period from AD 800 to 1500 (Szabo 2018) and will provide important comparable material once published in full, though in the interim blog posts have provided an insight into the early findings of DNA analysis from Iron Age and Norse sites (e.g. Kitchener 2019; UHI 2019b).

The paucity of taxonomic identification, and other issues with quantification, have hampered interpretation of the use and particularly procurement of cetaceans on Scottish sites. Mulville's (2002) study which assessed 568 pieces of bone including pieces from the two sites under study here: Cladh Hallan and Bornais, in addition to Dun Vulan, Pabbay, Mingulay, Sanday and Kilpheder and identified 30 to species (5% of the cetacean material), went on to discuss use in terms of meat, architectural, artefact and fuel utility in addition to potential modes of procurement. Patterns were identified, such as an abundance of unfused bones indicative of younger animals and an increase in the range of cetacean species and artefacts in Norse periods, though it was noted that a variety of factors could be responsible for these patterns ranging from modes of procurement to longevity or size of the sites (Mulville 2002: 39). Others such as Hallén (1994) have also commented on procurement. However, in general appreciation of procurement has been hampered by site formation processes and methodological issues concerning identification and quantification.

Chapter 4 sets out the methods used within this thesis for the analysis of cetacean bone assemblages from the Western Isles. It is followed by Chapter 5 which sets out to address the identification issues by providing a new method for the identification of cetacean bone from archaeological contexts.

Chapter 4: Methodology: An integrated approach to cetacean identification and interpretation

1 INTRODUCTION

This chapter sets out the methods used for the assessment, analysis and interpretation of cetacean bone assemblages from Cladh Hallan and Bornais. The methods and analysis have been employed to achieve the aims of this thesis, set out within Chapter 2, and which are principally concerned with achieving identification of the assemblages and assessing cetacean use and procurement through time. An overview of the methods is included in the flowchart below (Figure 7). Key stages of the methodology are in bold and relevant sections of this chapter signposted.

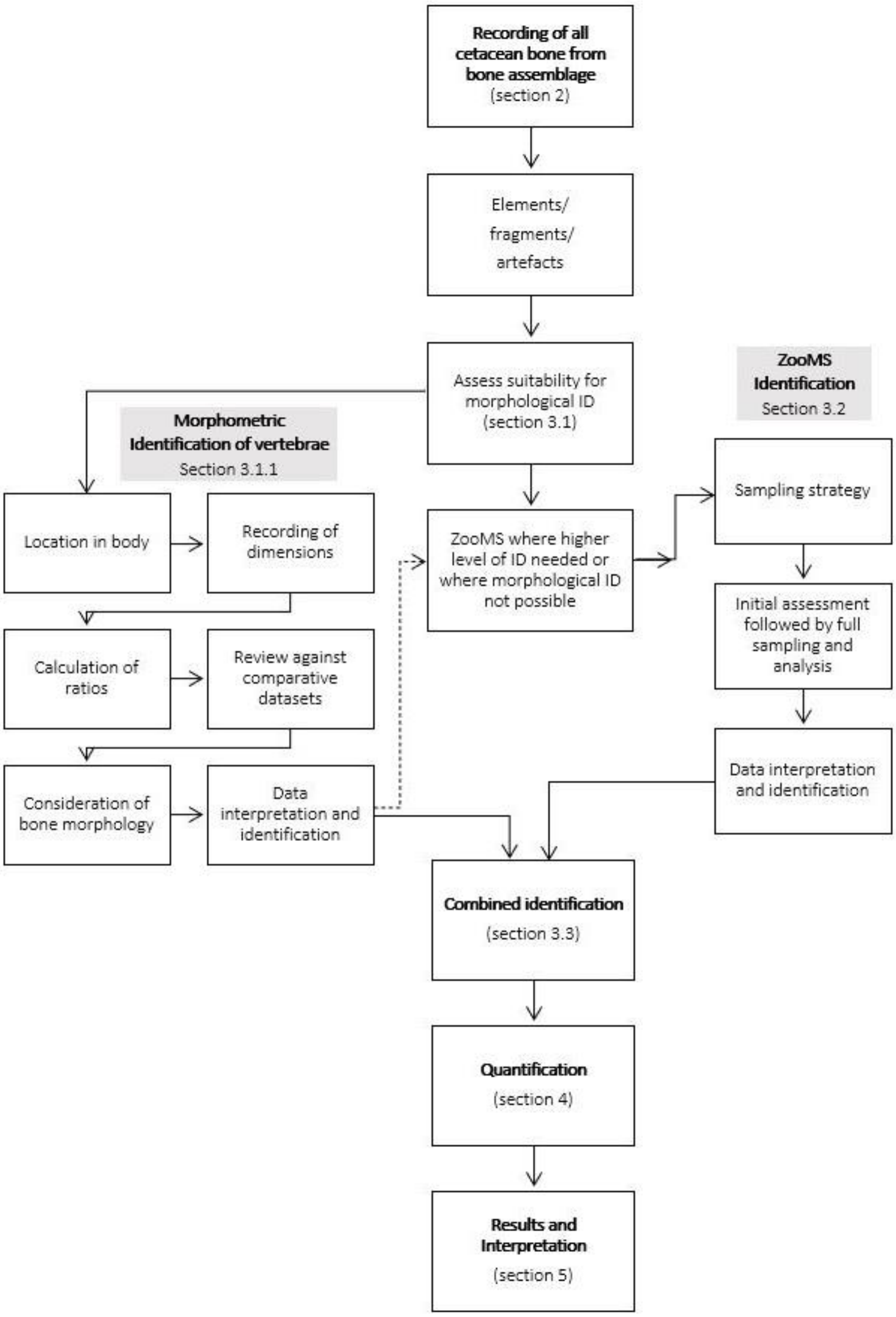

Figure 7 Flowchart showing the methodology employed in this thesis

2 CETACEAN BONE RECORDING AND ASSESSMENT

All cetacean bone from Cladh Hallan and Bornais was assessed and recorded in the cetacean bone registers (Appendices 4 and 5). The assessment considered best practice guidance for zooarchaeological recording (English Heritage 2014) but has been amended due to the unique challenges of identifying and analysing highly fragmentary and worked cetacean bone assemblages.

All site, phase and contextual information was recorded for each piece of bone, along with any identifiers including context numbers, sample numbers, small finds numbers as appropriate. Bone was identified to element with reference to published sources and reference collections set out in Appendix 3. Where identifiable the state of fusion was also recorded. Other details recorded included evidence for butchery practices or taphonomic processes such as burning.

Unlike other zooarchaeological assemblages, modification is key to analysis and was therefore recorded next. Following the nature of the assemblages the bone was recorded and quantified in terms of the number of bone pieces categorised as: elements (modified and unmodified), fragments (worked and unworked) and objects. While other terminology may be used for classifying bone fragments (for example cetacean bone pieces are often classified according to the categories of primary and secondary working stage debris (e.g. Betts 2007), originally derived from lithic analysis (Yerkes and Kardulias, 1993)), these terms are loaded and imply that fragmentation is a product of bone working. Cetacean bone may become fragmented for a range of reasons including artefact production, oil extraction and taphonomic processes. The categories set out above were established to highlight specific issues within cetacean bone assemblages and to investigate patterns of utility across the assemblages.

Artefact types were also recorded. Types followed those set out in existing worked bone reports and artefact catalogues for Bornais (Clark et al. 2012; Smith and Sharples 2021). The worked bone report for Cladh Hallan is forthcoming and the cetacean bone tool categories have followed those set out in the forthcoming work (Davies and Slater forthcoming). However, not all cetacean bone tools have been assigned a type yet and where this was the case artefacts have been assigned to generic categories following descriptions of form such as ‘perforated rectangular piece’ or ‘flat notched implement’, rather than typologies as such. It was necessary to categorise the artefacts in some way in order that any patterns of species selection within the artefact assemblage could be assessed.

Measurements were also taken. The greatest length, width and breadth of artefacts and fragments were measured, and dimensions for elements were recorded following the methodology for morphological identification set out in the next chapter (see also Evans and Mulville 2018). A general description of the bone was also recorded.

This initial record and assessment provided the basis from which the sampling strategy and analysis plan was formulated. This included consideration of which bones retained sufficient characteristics for taxonomic identification by morphometrical analysis (principally unmodified and modified elements) and those which would require identification via ZooMS (primarily fragments and artefacts) to address the research questions of this thesis.

3 TAXONOMIC IDENTIFICATION

3.1 MORPHOLOGICAL IDENTIFICATION AND MORPHOMETRIC ANALYSIS

Following the initial recording and assessment of the assemblage, suitable bones were identified morphologically with reference to texts and reference collections referred to in Chapter 5 and Appendices 3 and 7.

3.1.1 MORPHOMETRIC IDENTIFICATION OF VERTEBRAE

For vertebrae, identifications were assigned following the method set out in Chapter 5. In summary, precise position along the spine was identified, absolute measurements were recorded, and relative dimensions calculated (see Figure 7). This data was then compared against the comparative datasets established (see Chapter 5 and Appendices 3 and 7), and finally a review of other morphological features of the vertebra was conducted. Chapter 5 and Appendix 6 provide details of morphometric identification of vertebrae within the Cladh Hallan and Bornais assemblages.

3.2 PROTEOMICS: ZOOMS ANALYSIS

The following sections set out the methodology for ZooMS analysis. As established in Chapter 2, Zooarchaeology by Mass Spectrometry, or ZooMS, allows for analysis of collagen peptides for the identification of animal materials, including bone, tooth, antler, skin, baleen and eggshell. Collagen has a triple helical structure and analysis of the chains within this structure have demonstrated that the COL1a2 chain shows more variation than the other polypeptide chains in the collagen triple helix, allowing for this chain to be used in the discrimination between taxonomic groups (Buckley et al. 2009, 2014). The differences within the COL1a2 chain which occur between species, genera, families and orders are based on variants to the amino acid composition of each peptide within the COL1a2 chain. Differences between the amino acid make-up of the peptides can be identified by measuring the weights of peptide chains, using mass spectrometry. Identifications are then made by comparing the mass spectra with sequences for known species, focusing on locations which are known to be of particular use for identification due to divergence between species reflected by differing peptide weights at these locations (Buckley et al. 2009).

The sections which follow discuss the aims of the sampling strategy and results of an initial assessment of bone preservation and ZooMS processing methods. This then fed into the main methodology.

3.2.1 SAMPLING STRATEGY AND TECHNIQUES FOR ZOOMS

The sampling strategy was developed to allow the primary research questions of this thesis to be addressed. In particular it sought to investigate:

- Taxa present through time;
- Spatial patterns in the deposition of bones of different taxa; and
- Taxa represented by different forms of bone (i.e. elements, fragmentary bone and artefacts).

A key issue in the analysis of cetacean bone assemblages is the potential for assessing and analysing multiple parts of the same whale, due to the large amount of bone which can come from a single whale (e.g. Mulville 2002). To avoid potential issues of sampling different fragments of the same element or bone from the same animal in general only one sample per context was taken. An exception to this is when sampling artefacts from the same context as fragments. This is due to the likelihood that the creation of artefacts was not directly contemporary with the formation of the context in which they were finally deposited as it is likely that artefacts underwent a period of use before deposition making them less likely to be deposited in the same context as debris from their manufacture. Two contexts from Cladh Hallan (Phase 9 house floor 1311, and Phase 15 house floor 455=466=453=479) were also chosen for more intensive sampling, in order to test the assumption that bone fragments within the same context are all likely to be from the same species/ individual/ element. A small number of contexts from Bornais were also chosen for more intensive sampling for this reason, and to determine whether any species preferences were evident within the worked bone assemblage (e.g. GCD, 1101 and 1113).

Sampling for ZooMS from both Cladh Hallan and Bornais was undertaken on cetacean bone from a range of phases to investigate temporal patterns. Sampling at Cladh Hallan was focused on contexts derived from phases 8 to 16, spanning the Middle Bronze Age to Early Iron Age occupation. Earlier phases produced little cetacean bone, and as such were excluded from ZooMS sampling. Although the number of fragments from Iron Age deposits is considerably less than Bronze Age deposits, bone from these deposits was sampled to provide comparison with material from other Iron Age sites, and to investigate any temporal patterns in cetacean exploitation and use. Likewise, sampling at Bornais spanned the different phases of the site and included material from the Late Iron Age to Late Norse deposits. As at Cladh Hallan the Iron Age cetacean bone assemblage available for ZooMS sampling was relatively small (though a large amount of bone was recovered from Late Iron Age deposits on mound 1, this was primarily burnt, precluding ZooMS analysis), though samples were taken to allow for assessment of temporal patterns of change. At both sites cetacean bone from disturbed deposits, robber trenches and wall core deposits was excluded from sampling, due to the possibility that this material originated from earlier or later phases and may thus confuse any temporal patterns.

Spatial distributions were also investigated at both sites. At Cladh Hallan most bone fragments were recovered from areas within the houses, and some houses had considerably more cetacean bone than others. Sampling focused on areas within the structures, to assess differences or similarities between houses and cetacean bone from other features such as underfloor pits was also investigated. At Bornais sampling was undertaken from deposits across the site, representing the Early, Middle and Late Norse houses and ancillary structures, as well as associated deposits such as middens.

Morphological assessment resulted in identifications for many elements and ZooMS was therefore focused on sampling of artefacts and fragments, most of which could not be identified morphologically. Elements were only targeted where a higher level of identification was required. Particular elements were investigated by ZooMS, including vertebral epiphyses which were found on both sites and are a ubiquitous find on many other Scottish sites (e.g. Mulville 2002).

In total 109 samples were taken for ZooMS analysis from Cladh Hallan and 164 from Bornais. The samples taken are recorded in the cetacean bone registers in Appendix 4 and 5. The analysis was funded by the Society of Antiquaries of Scotland and Cardiff University.

3.2.2 INITIAL ASSESSMENT OF BIOMOLECULAR PRESERVATION AND SAMPLING TECHNIQUES

The success of ZooMS is reliant on the survival of collagen within the material under study (in this case, bone). An initial assessment of bone collagen preservation on the sites was undertaken using ZooMS on thirty pieces of cetacean bone from Bornais to confirm the suitability of ZooMS as a method for identification. The use of ZooMS as a method for assessing overall levels of biological preservation has been noted on other sites (Evans et al. 2016; von Holstein et al. 2014).

Different ZooMS techniques were also trialled during this initial assessment. Most samples were taken as small pieces of bone, using a scalpel. However, as some of the samples were taken from complete artefacts, to avoid damage to the objects a non-destructive rubbing technique was used in several cases, whereby eraser rubbings are taken from the objects to obtain collagen (McGrath et al. 2019). Thirteen of the samples were extracted using the rubber method (sample numbers 12681-12693), and eighteen of the samples were bone chips (sample numbers 12663- 12680) (see Appendix 5 for sample numbers). These thirty samples were subjected to ZooMS analysis using non-destructive (Korsow-Richter et al. 2011) collagen extraction techniques. The eighteen samples which had been taken as bone chips were re-run using destructive collagen extraction techniques followed by ultrafiltration (Buckley et al. 2009). Further detail on the precise methods used are set out within Section 3.2.3 below.

The rubbing method was found to be less effective and achieved results of lower precision than samples taken using bone chips. All samples identified to species level were from bone chips while samples taking using the rubbing method did not produce identifications above the family level.

A general improvement in the level of success and precision was also observed between the results of destructive and non-destructive analysis. Destructive analysis was conducted only on bone-chip samples, while non-destructive analysis was trialled on all samples. The former resulted in identifications with a higher level of success and precision due to the greater collagen yields obtained from this method of analysis.

This assessment also demonstrated that in general biomolecular preservation across the site was good, though bones which were fully burnt had low biomolecular preservation and as such a poor success rate.

Overall, the results of the initial assessment indicated that sample extraction from unburnt bone using bone chips, run using the more aggressive destructive technique, followed by ultrafiltration formed the optimal strategy for obtaining the best results in terms of success rate and precision. The analysis of the 109 samples from Cladh Hallan and remaining 134 samples from Bornais followed this method. The next section sets out the methods for all analysis discussed here, primarily following Buckley et al. (2009) and Korsow-Richter et al. (2011) and used by the author in previous works (e.g. Evans et al. 2016).

3.2.3 ZOOMS SAMPLE PROCESSING AND ANALYSIS USING MASS SPECTROMETRY

Non- destructive method

Between 10-30mg of bone chips, or 20-40mg of rubbings (depending on which sampling method was used) from each sample were placed in separate Eppendorf tubes. Samples were incubated in 100µl of 50mM ammonium bicarbonate (AmBic) solution (pH 8.0) overnight at 37˚C and centrifuged following incubation. Following centrifugation, the supernatant was discarded, and samples were re-incubated in the AmBic solution, at 65˚C for one hour. Trypsin digestion and collagen purification were conducted following the method listed below.

Destructive method: demineralisation and ultrafiltration

Between 10-30 mg of bone from each sample was placed in Eppendorf tubes and immersed in 250 µl of 0.6M hydrochloric acid and stored at room temperature. Immersion lasted between 48 hours and two weeks to bring about demineralisation. Samples were then centrifuged, and the supernatant discarded. Samples were then incubated in an additional 250 µl of 0.6M HCl for three hours at 65˚C to gelatinise the collagen. The gelatinised collagen was ultrafiltered with Amicon Ultra-4 centrifugal filter units (30,000NMWL, EMD Millipore) to remove impurities. The supernatant was concentrated to approximately 100 µl, washed three times with 200 µl AmBic solution, and concentrated to a final volume of 50 µl. Trypsin digestion and collagen purification were conducted following the method listed below.

Trypsin digestion and collagen purification

Fifty ul of the supernatant was incubated with 1ug[CFS2] of trypsin, acidified to 0.1% trifluoroacetic acid (TFA), and purified using a 100ul C18 resin ZipTip® pipette tip (EMD Millipore). The C-18 tips were conditioned and eluted with 50% acetonitrile and 0.1% TFA, while 0.1% TFA was used for the lower hydrophobicity buffer. To ensure sufficient collagen retrieval, the sample was transferred completely through the tip at least ten times and eluted with 50 µl of conditioning solution into a new Eppendorf.

MS, spectral processing, and taxonomic identifications

One µl of collagen extract was mixed with an equal volume of matrix (one µl of α-cyano-hydroxycinnamic acid) and spotted onto a 384 spot MALDI target plate, along with calibration standards for processing within the mass spectrometer. Each sample was spotted in triplicate, and was run on a Bruker ultraflex III MALDI TOF/TOF mass spectrometer with a Nd:YAG smart beam laser. A SNAP averagine algorithm was used to obtain Moniosotopic masses (C 4.9384, N 1.3577, O 1.4773, S 0.0417, H 7.7583).

Spectra were individually quality checked visually using mMass software (Strohalm et al. 2008). Poor-quality spectra (i.e. with few to no discrete peaks or low signal to noise ratios) were eliminated from the dataset. Good-quality spectra from replicates of the same sample were averaged, cropped and peak-picked (Buckley et al. 2014).

3.2.4 INTERPRETING ZOOMS EVIDENCE: TAXONOMIC CLASSIFICATION OF CETACEANS USING ZOOMS

Papers by Buckley et al. (2009, 2014) on the use of ZooMS for identification of peptides provide the basis for the methodology used for taxonomic identification via ZooMS. Their work involved identification of diagnostic m/z values for different specimens at various taxonomic levels. Identifications made within this thesis were achieved using comparison of the spectra with an established index published in Buckley et al. (2009, 2014). Taxonomic identifications were assigned at the most conservative level of identification based on the presence of unambiguous m/z markers.

Studies which have been undertaken following the earlier work of Buckley et al. (2009, 2014) have proved that the method produces reliable results and identifications correspond with those gained through other methods such as aDNA and morphological analysis (e.g. Evans et al. 2016; McGrath et al. 2019). However, there are a couple of issues which require consideration to ensure identifications are reliable. While Buckley et al. (2014) assert that ZooMS can identify to subfamily and in some case species level, differences between classification systems and the existence of unsequenced species may place some uncertainty around this claim in some circumstances. These issues have implications for the resolution of the taxonomic identifications derived from ZooMS analysis and are discussed further below.

There are currently several different classification systems for cetaceans and phylogenetic relationships within the Order Cetacea are not fully resolved. Within the present study area these differences affect the placement of species within the family Delphinidae affecting the subfamilies Delphininae and Orcininae. The placement of Risso's dolphin for example differs depending on which classification system is used. Perrin (1989) places this species within the subfamily Delphininae, while Le Duc et al. (1999) place it alongside *G. melas* and *P. crassidens.* Thus, while Buckley et al. (2014) indicate that subfamilial identifications are possible, this is only the case if classifications such as Le Duc et al. (1999) (which is based on molecular evidence, and thus resonates with the ZooMS data) are used. This thesis has used Perrin (1989) and Mead's (1975) classifications. For these reasons identification of Delphinidae to subfamily level based purely on ZooMS results has not been carried out here. Subfamily identifications within this family have only been made where they are supported by morphometric data. Where this is the case taxonomic classification follows Perrin (1989) and Mead's (1975) systems.

The existence of unsequenced species and implications for the resolution of the taxonomic identifications derived from ZooMS also requires consideration. While most of the species which inhabit the North Eastern Atlantic have been sequenced, including all species common in Hebridean waters, there are a number of species whose range includes the North Eastern Atlantic which have not been sequenced. These include five members of the Ziphiidae family, most of which are of the genus Mesoplodon. Several rarer species including Fraser's dolphin, the Melon headed whale, within the family Delphinidae, and the pygmy sperm whale, within the family Kogidae (superfamily Physeteroidea), have also yet to undergo sequencing. Additionally, there is no published sequence for the bowhead whale, although, Buckley et al. (2014) indicate that it is indistinguishable from the only other member of the Balaenidae family in the North Atlantic: the right whale. Buckley et al. (2014) established m/z markers which were consistently found in all sequenced members of each family (supported by analysis of partial genomic data; Buckley et al. 2009: 3845), thereby demonstrating precision in identifications to family level at least. It is therefore expected that unsequenced species of the same families would also show these markers. For this reason identifications have been given to family level for those families which have unsequenced members, i.e. for the Delphinidae, Ziphiidae and Balaenidae. Neither member of the Kogiidae family, which includes the pygmy sperm whale and dwarf sperm whale (*K. sima*) have been sequenced and there may therefore be potential for overlap between this family and its sister family, Physeteridae (containing the sperm whale). However, in general ZooMS has been shown to reliably distinguish between cetacean families (Buckley et al. 2009, 2014) and the separation between the Kogiidae and Physeteridae families has been confirmed by other studies of amino acid sequences (Shan et al. 2019). It is therefore anticipated that ZooMS would also be able to distinguish between these families.

In other families all members have been sequenced and in some cases unique markers have been established allowing species level identifications. This is the case for the sperm whale (the single species within the family Physeteridae) and all Mysticeti except for the balaenids. For these cetaceans species-level identifications using ZooMS are considered reliable.

3.3 COMBINED IDENTIFICATION: MORPHOMETRICS AND ZOOMS

While both morphological and ZooMS analysis provide separate powerful tools for cetacean identification, the methods can be used in combination to further refine identification (e.g. van den Hurk 2020a, b). For example, although morphology can be successfully used to identify many different species (see Chapter 5), in some cases ZooMS can be helpful to distinguish between morphologically similar species. This is the case for the white beaked and white sided dolphins for example, which share very similar vertebral osteology but can be differentiated based on peptide analysis. Therefore, using a combination of ZooMS analysis and morphological identifications can allow results with greater precision.

Using a combination of morphological analysis and ZooMS analysis the majority of cetaceans can, theoretically, be identified to species level (though identification in practice requires a sufficient level of molecular and morphological preservation).

The value of using the methods side by side has been further reinforced by the findings of previous studies. Buckley et al. (2014) found that most of the fragmented bone within their study was from large cetaceans. Fragmented remains are much less likely to be identifiable using morphological methods, while more complete elements are much more likely to be identifiable. The correlation between fragmented remains and large cetaceans, and elements with small cetaceans (see Chapter 6) is therefore fortunate considering the capabilities of ZooMS. Where morphology would likely fail, ZooMS is likely to succeed due to the presence of unique identifiers for most large species, and where ZooMS is limited to family but not species level identifications, morphology is more likely to succeed as elements tend to be from smaller species.

4 QUANTIFICATION

Zooarchaeological methods of quantification generally rely on NISP and MNI. Here cetaceans have primarily been quantified using the NISP. Where fragments can be refitted and clearly form part of the same bone they have been counted as single fragments, with a single species and element identity (where known). Where a fragment cannot be refitted with others these have been counted as separate pieces, and each identifiable fragment has been counted individually within the NISP. This applies, for example, to the large number of sperm whale skull fragments from Cladh Hallan (see Chapter 6). In these cases the NISP may appear artificially high and consideration of the MNI is useful.

The assemblages were assessed morphologically to establish the MNI. Element and taxonomic identifications using both morphometrical and proteomic analyses provide further indications as to the quantity of cetaceans, with different species representing different individuals and elements used to identify MNI as in other species. DNA analysis has not been undertaken to investigate MNI. For the sperm whale skull fragments it is very likely that for example large numbers of skull fragments from individual contexts represent the same fragmented skull, species and individual and would thus therefore likely have an MNI of one. However, without further investigation for example using DNA this cannot be proven.

As the success of calculations of MNI was limited, and an MNI of one could generally only be identified for each species, the Minimum Number of Species (MNS) was calculated for different areas of the sites. This allowed a broad indication of the quantity of cetaceans in use in different areas at different times without inferring a number of individuals (MNI) as these counts are likely to be flawed. The MNS was calculated to compare the number of species through different phases and areas, as previous studies found indications of changing numbers of species in different phases (Mulville 2002) which could relate to procurement patterns.

Although the number of fragments, elements and artefacts provides an indication of the quantity of cetacean bone present on the site it has not been possible to compare this data with that of other species found at Cladh Hallan and Bornais as the issues with quantification in particular mean that comparison could be potentially misleading. However, this data does provide a basis for understanding the relative quantity of cetacean bone per phase and area. The results of taxonomic identification and quantification are set out in Chapter 6 and Chapters 7 and 8 interpret these results.

5 RESULTS AND INTERPRETATION

Results and interpretations are set out from Chapter 6 onwards. Interpretation has involved consideration of the uses of cetacean bone on the sites of Cladh Hallan and Bornais, and investigation of the likely nature of procurement. Further discussion on the approaches to interpretation are given within the introductions of the relevant chapters (Chapters 7 and 8).

Chapter 5: Development of a New Method and Toolkit for Morphometric Identification of Cetacean Bone

1 INTRODUCTION

As set out in Chapter 2, taxonomic identification is a major hurdle in the analysis of cetacean bone assemblages and the absence of a method for morphological identification means that these assemblages often forgo identification (e.g. in a Scottish context Foxon 1991: 134; Hallén 1994; Pollard 1994).

A key component of the work undertaken as part of this research has been the development of a novel method for the identification of cetacean bone using metrics and morphology, and provision of a comparative dataset to guide identifications of archaeological cetacean bone (see Evans and Mulville 2018). Together the method and comparative dataset form the toolkit for identification. This chapter sets out this methodology along with a series of graphs based on the dataset of measurements collected from cetacean specimens in museum reference collections and published sources (referred to as the reference dataset), to demonstrate which taxa can be distinguished based on bone morphology and metrics. The chapter then goes on to demonstrate identification of cetacean bone from Cladh Hallan and Bornais through comparison of the archaeological specimens with the reference dataset and graphs.

The data presented here focuses on the vertebrae of cetacean species. This is primarily for two reasons. Firstly, due to the frequent presence of these elements on archaeological sites (Mulville 2002), including Cladh Hallan and Bornais, and secondly as detailed (though non-archaeological) studies already exist for other parts of the cetacean skeleton, including the skull (e.g. Gray 1868; Mead and Fordyce 2009) and flipper bones (Benke 1993) (See Appendix 3 for further references). While non-archaeological studies of vertebrae also exist and provide important information (e.g. Buchholtz 2001, 2007; Buchholtz and Schur 2004; Buchholtz et al. 2005; Crovetto 1991; Slijper 1936, 1962) they have not been created for the purpose of taxonomic differentiation amongst archaeological specimens and do not set out data which allows for comparisons of all species within the current study area.

Despite recent attempts to develop a combined proteomic and morphological approach to the identification of cetacean bone conducted concurrently with the present work (van den Hurk 2020a, b), widely applicable morphological criteria and comparative datasets remain elusive. Recent work (van den Hurk 2020a, b) has combined use of ZooMS and morphological assessment, though reporting focused on application of proteomics analysis followed by morphological assessment. Although the combined application provides a successful means of characterising assemblages (van den Hurk 2020a, b) due to the analytical costs associated with proteomic analysis prior to detailed morphological identification this protocol would be unsuitable on most zooarchaeological assemblages.

The chapter reports on the methodological development of morphometric identification of vertebrae. The key objectives of this chapter are set out within a series of steps:

- Step 1: Set out which features and metrics can be used for the reliable identification of cetacean vertebrae (supported by information in Appendix 3);
- Step 2: Establish a method for the identification of the cetacean vertebral column;
- Step 3: Using the lumbar region as a case study, present data (based on the reference dataset) on the features and metrics of the vertebral column for the 31 species within the study;
- Step 4: Determine which taxa can be reliably differentiated based on the features and metrics identified in step 1 and data set out in step 3; and
- Step 5: Demonstrate identifications of archaeological specimens using the method established in step 2 and the reference dataset depicted in step 3.

A key aim of this work has been to demonstrate which features of cetacean bone may be reliably used for taxonomic identification (Step 1). Driver (1992) emphasised the importance of large datasets for the identification of osteological traits which are true indicators of taxonomic identity. For cetacean specimens, reliance on relatively small datasets is imposed by the size of the specimens and the storage capacity of research institutions which can typically hold only one or two examples of the large species. The method set out here has therefore used existing studies in comparative anatomy, cetacean phylogeny and functional morphology to distinguish traits and osteological features and metrics which may be reliable indicators of taxonomic identity (e.g. Buchholtz 2001, 2007; Buchholtz and Schur 2004; Buchholtz et al. 2005; Crovetto 1991; Slijper 1936, 1961, 1962; Viglino et al. 2014). A detailed summary of these sources and key osteological features of use in identification set out within Appendix 3.

The traits and metrics defined in Step 1 have then been recorded by the author and supervisor within the bones of 97 cetacean specimens. These records have been collated with published data. The combined dataset of 442 specimens includes all 31 species within the study area (set out within Chapter 3) and forms the reference dataset. Analysis of the reference dataset was undertaken to develop a methodology for cetacean bone identification (Step 2) and the data is presented here in a manner which allows for comparison with archaeological specimens aiding identification (Step 3). The lumbar region is used as an example of the way in which the data can be displayed to allow for comparative analysis. Data on all regions of the spine is included in Appendix 7, allowing other researchers to utilize this data in the manner demonstrated within this chapter. The reference dataset is further analysed to explore variation between taxa and to demonstrate where differentiation is possible (Step 4), and then identifications of archaeological specimens are made to demonstrate use of the toolkit (Step 5).

This chapter is supported by a series of Appendices. Together the chapter and the appendices form the toolkit for identification and provide examples of its use. While the current chapter demonstrates the methodology for cetacean bone identification, the process for the method development (including background information, methods and data used) is discussed in detail in Appendix 3. Appendix 6 presents examples showing the identification of archaeological cetacean vertebrae using the toolkit (in addition to those presented within the current chapter). Appendix 7 presents the full reference dataset collected in its raw form, allowing other researchers to use this data to compare and identify their archaeological specimens, following the method and means of displaying the comparative data which are set out within this chapter (Steps 2 and 3).

1.1 CHARACTERISTICS OF THE CETACEAN VERTEBRAL COLUMN

This section provides an overview of the cetacean vertebral column to frame discussions of vertebrae. The cetacean spine can be sub-divided into distinct regions. Although different approaches to this division exist (e.g. Buchholtz and Schur 2004; De Smet 1977) for the purposes of identifying vertebrae from archaeological contexts the following five divisions are proposed (Figure 8), as they are associated with morphologically distinct elements and, for the most part, relate to regions of the cetacean which can be defined in fresh specimens:

- Cervical vertebrae: Comprising the first seven vertebrae of the spine, located between the skull and the first true rib (i.e. not a cervical rib) (De Smet 1977: 78), generally very compressed along the caudo-cranial axis in cetaceans, and representing the neck of the cetacean. All cetaceans have seven cervical vertebrae, though they are fused in some species.
- Thoracic vertebrae: Comprising those vertebrae associated with articulating ribs and displaying articular facets on the transverse processes. Some thoracic vertebrae also exhibit an articular facet on the centrum associated with the rib capitulum. The transverse processes of the cranial thoracic vertebrae insert relatively high up

(dorsally) on the centrum or neural arch, with those situated further caudally inserting lower (ventrally) upon the centrum. The centra also increase in length along the region, and the breadth of the neural arch decreases slightly from the first to last thoracic vertebrae. These vertebrae represent the chest region (Buchholtz and Schur 2004). The thoracic-lumbar border may be difficult to pinpoint in cetaceans, with a variety of different characteristics blurring this boundary, including the presence of rudimentary ribs, ribs on one side of the vertebrae, ribs not connected to the vertebrae (Slijper 1936) and ribs connected to the last thoracic and the first lumbar (Rommel and Reynolds III 2002; Slijper 1936: 290-291; Turner 1882a).

- Lumbar vertebrae: Vertebrae situated within the central area of the cetacean and without any associated ribs or chevron bones. These vertebrae are associated with a single keel on the ventral aspect of the centra in many cetaceans. This changes to a double keel in the caudal region, associated with the articular facets of the chevron bones (Wilkie Tinker 1988). As with the thoracic vertebrae, the breadth of the neural arch continues to reduce throughout the lumbar region.
- Caudal vertebrae: The lumbar-caudal boundary generally occurs in line with the anus, and thus the abdomen is situated cranially from this point, and the tail is situated caudally (Eschricht et al. 1866: 105; Slijper 1936: 302). The caudal vertebrae comprise those which are associated with the chevron bones. The first caudal vertebra is considered to be the first vertebra with articular facets for these chevron bones, on the caudo-ventral border (following Rommel 1990 and contra Slijper 1936: 303) and the last has a convex face (Buchholtz and Schur 2004: 394). While Slijper (1936) proved an anatomical relationship between the chevron bone and the succeeding vertebrae (meaning the first caudal vertebra would be the one succeeding the first chevron bone) the evidence required to determine the first caudal vertebrae according to his classification would not survive in most archaeological cases (articulated vertebrae and chevron bones would be necessary).
- Fluke vertebrae: Small, dorso-ventrally compressed vertebrae located in the flukes, with no associated chevron bones and as such no articular facets on the caudo-ventral border, and no processes (Buchholtz and Schur 2004; Rommel 1990: 44). This region begins with the ‘ball vertebra’, located directly posterior to the anterior insertion of the flukes (Fish and Lauder 2006: 215).

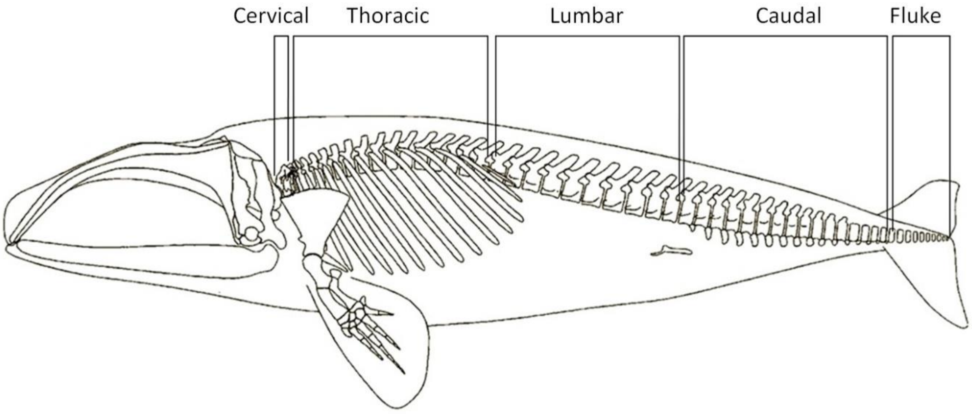

Figure 8 Regions of the cetacean vertebral column referred to here. Illustration modified from (Rommel and Reynolds III 2002), skeleton of Eubalaena glacialis

2 STEP 1: DETERMINING OSTEOLOGICAL TRAITS FOR IDENTIFICATION

This section sets out traits which may be used when identifying cetacean vertebrae. The primary discussion supporting this section is set out within Appendix 3. Osteological traits which are of potential use in identification are identified within that Appendix, determined with reference studies in evolution and functional morphology which have demonstrated differences between taxa based on these traits (e.g. Buchholtz and Schur 2004; Slijper 1936; Viglino et al. 2014). In summary, the osteological traits and dimensions likely to be of use for identification are as follows:

- Number of vertebrae;
- Relative centrum length;
- Neural process and neural spine height;
- Neural arch inclination and neural spine inclination;
- Height and breadth of the neural arch;
- Elevation and form of metapophyses;
- Transverse process breadth and length;
- Location of the transverse processes relative to the centrum;
- Number of ribs and nature of rib articulations (thoracic region only); and
- Location and form of key arterial foramen and grooves.

These traits are all clearly visible and relatively easily recorded. While these major areas of difference have been established through a review of previous works (e.g. Buchholtz 2001; Buchholtz et al. 2005; Buchholtz and Schur 2004; Slijper 1936), other smaller-scale differences are also likely to have evolved. Thus, this list is not considered to be exhaustive though it does provide a framework for analysing taxonomic differences.

While the work of previous studies in evolution and functional morphology (e.g. Buchholtz 2001; Slijper 1936) has provided a framework for analysing taxonomic differences, these works do not provide a dataset against which archaeological material can be easily compared for identification purposes. For this reason metrical data relating to features outlined above were gathered as part of this thesis and investigated within the dataset of 442 specimens (see Appendix 7 for the full dataset). Further detail on data used is set out within Appendix 3 and an overview of the specimens is included within Table 1.

Family	No. of species in family	Number recorded
Balaenopteridae	5	79
Eschrichtiidae	1	9
Balaenidae	2	25
Kogiidae	1	13
Physteridae	1	20
Ziphiidae	7	70
Delphinidae	11	174
Phocoenidae	1	29
Monodontidae	2	23
Totals	**31**	**442**

Table 1 Number of specimens recorded per family and number of species per family

Data from these specimens were recorded, and measurements were collated (Table 2; Figure 9). Measurements included centrum length (CL) and centrum height (CH). The latter is referred to as height of facies cranialis (HFcr) by some (e.g. von den Dreisch 1976). Neural process (NPH), neural spine height (NSH), height of metapophyses (MPH), height of the neural arch (HNA), breadth of the neural arch (BNA), transverse process breadth (BPtr) and length of the transverse processes (GLPT) were also measured. Additional measurements were also collected by this study, following von den Driesch (1976) and zooarchaeological norms, these included centrum width (CW), overall height (H), breadth of facies caudalis (BFcd), and height of facies caudalis (HFcd) (the latter two are not depicted on Figure 9 but are the equivalent of CH and CW taken on the caudal face of the vertebra).

Other metrics including neural arch and spine inclination (NAI, NSI) are also thought to be of use for the identification of cetacean taxa (Buchholtz and Schur 2004; Gillet et al. 2019;

Slijper 1936, chapter 14), however, obtaining these angular measurements was found to be difficult to reliably replicate and as such these metrics were not collected by the author. Neural spine inclination was measured by Gillet et al. (2019), and that data has been used here. Other morphological features of the bone were also recorded (see Appendices 3 and 6 for further details).

Abbreviation	Definition
CL	Centrum Length
CH (HFcr)	Centrum Height
CW (BFcr)	Centrum Width
NPH	Neural Process Height
NSH	Neural Spine Height
MPH	Metapophysis Height
HNA	Height of Neural Arch
BNA	Breadth of Neural Arch
BPtr	(Greatest) Breadth of Processus Transversii
GLPT	Greatest Length of Processus Transversii
H	(overall) Height
BFcd	Breadth of Facies caudalis
HFcd	Height of Facies caudalis
NAI	Neural Arch Inclination
NSI	Neural Spine Inclination

Table 2 Measurements collected on cetacean museum reference specimens

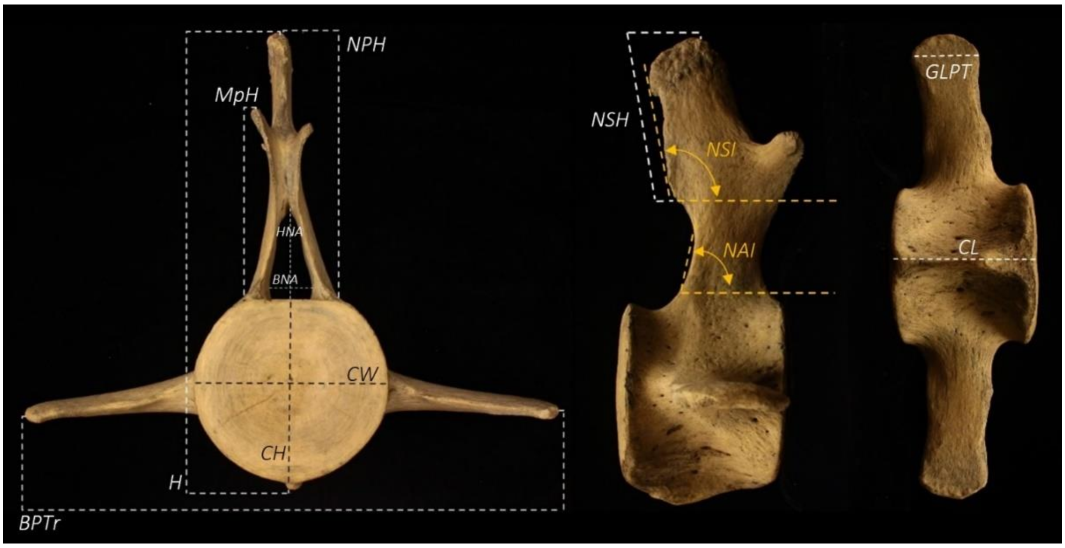

Figure 9 Measurements recorded on cetacean specimens demonstrated on the lumbar vertebra of a killer whale

Measurements were recorded for multiple specimens of each species. Most data were gathered for the thoracic, lumbar and caudal regions. Frequently the small posterior caudal vertebrae including the fluke vertebrae are lost and thus do not form part of most datasets (Buchholtz and Schur 2004: 387; Gillet et al. 2019). For this reason, some studies such as Gillet et al. (2019) consistently excluded the posterior caudal and fluke region from data collection. This area is therefore poorly represented within the dataset and comparisons are generally not possible due to the smaller dataset. This is also true for the cervical vertebrae.

3 STEP 2: METHOD FOR THE IDENTIFICATION OF CETACEAN BONE

This section gives an overview of the method for the identification of cetacean bone. The method broadly follows the necessary steps for identification of faunal remains generally, though investigation of the reference dataset was undertaken to ensure specific relevance for cetaceans. The findings of this investigation indicate that the following steps can enable identification:

- Determination of the precise position along the spine;
- Recording of absolute measurements;
- Calculation of relative dimensions;
- Comparison with reference datasets (set out below); and
- Analysis of bone morphology

These steps were followed for the identification of cetacean vertebrae undertaken within this thesis (see Figure 7, and Section 5 of the current chapter) and can be undertaken by other researchers analysing cetacean bone assemblages. The importance of each step is summarised below.

3.1 POSITION ALONG THE SPINE

There is a high degree of variability within the spine of each individual cetacean (see Figure 10 showing differing centrum lengths in a single blue whale, and Appendix 3). This variability affects all dimensions and the overall form of each vertebra and therefore has the potential to influence identifications. If the precise position along the spine can be identified then the effects of this variable on taxonomic identification will be reduced. Thus, this forms an important part of the identification process. Identification of the region from which the vertebra originated can be made with reference to the details set out in section 1.1 of this chapter, and by comparison with reference collections.

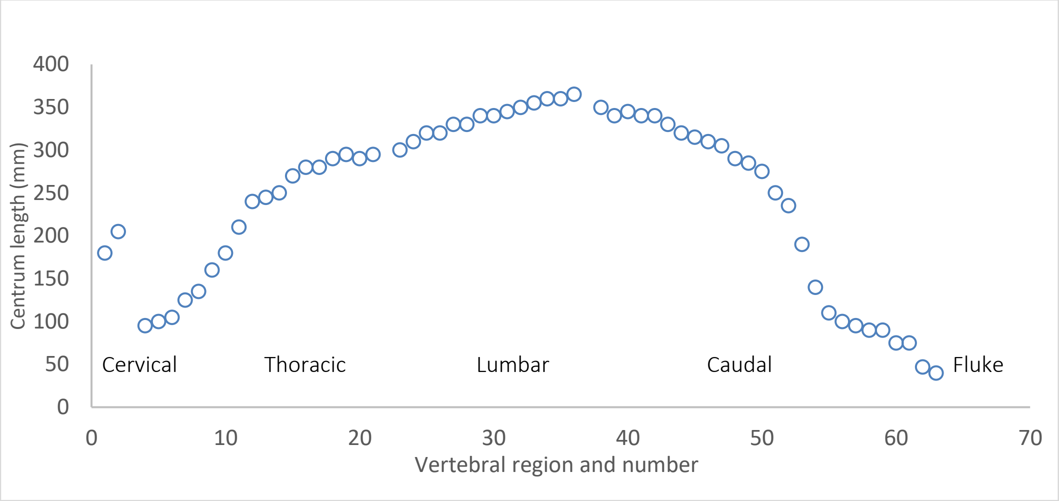

Figure 10 Change in centrum lengths along the spine of a 25m long adult specimen of B. musculus (Specimen: Húsavík, Iceland).

3.2 ABSOLUTE AND RELATIVE DIMENSIONS

Turning to differences between taxa, absolute size is of clear importance in a group which ranges from the diminutive harbour porpoise to the blue whale. However, size alters with age (see Appendix 3 for discussion) and there is therefore considerable overlap between taxa, which hampers identification. Consideration of other factors is therefore desirable to aid identification.

Appraisal of the relative dimensions is also often a key focus for bone identification (e.g. Prehn et al. n.d; Hillson 2009), and has been used by number of authors to investigate the spines of both terrestrial and marine mammals (Bucholtz 2001; Buchholtz and Schur 2004; Carillo et al. 2014; Evans and Mulville 2018; Slijper 1936: 355; van den Hurk 2020a, b). Ontogenetic changes to the relative dimensions of cetacean vertebrae are investigated in Appendix 3 following indications that age may influence relative proportions in some taxa (Buchholtz and Schur 2004; Buchholtz et al. 2005). This investigation demonstrated that for most taxa the relative dimensions of each vertebrae stay the same regardless of age and are therefore of use for taxonomic identification. The exception to this is species within the sub-family Delphininae, which exhibit ontogenetic changes to relative dimensions of their vertebrae (see Appendix 3). Sexual dimorphism may also affect the data. Information about sex was not consistently available for specimens within the current dataset (see Appendix 3), and the effects of this potential source of variation on the dataset should be assessed in future work.

Figure 11, which includes both immature and mature specimens, shows the levels of differentiation afforded by the relative and absolute measurement, demonstrating their usefulness for identification when considered in tandem. Absolute measurements following those set out in Table 2 and Figure 9 should therefore be recorded when studying archaeological specimens, and relative dimensions should be calculated.


Centrum length in lumbar vertebrae of young and adult specimens

Relative centrum length to height (CL/CH) in lumbar vertebrae of young and adult specimens

Figure 11 Relative and absolute centrum lengths in the lumbar region of all species within the study area showing immature and mature specimens

3.3 BONE MORPHOLOGY

Assessment of overall bone morphology is also a key step in identification. Morphological features which aid identification are cited in Appendix 3 and 6, though not exhaustively as this part of the analysis relies on close comparison of subtle features which often defy descriptions and measurements. Morphological assessment is therefore based on the skill and experience of the analyst, along with access to comparative reference material (Sabin 2005). The current chapter therefore does not focus on bone morphology instead primarily assesses the use of metrical data relating to the osteological traits discussed above for taxonomic identification. Relevant morphological features are, however, cited in Step 5 of this chapter, which identifies archaeological material.

4 STEP 3 AND 4: COMPARATIVE DATASETS AND DIFFERENTIATION BETWEEN TAXA

The following sections use relative and absolute measurements, and position along the spine, to demonstrate which taxa can be differentiated based on metrical data relating to osteological traits outlined in previous sections. This information can be used when undertaking identification of archaeological cetacean bone.

Absolute and relative dimensions for all 31 species within this study are depicted on a series of graphs set out within this section. The graphs depict metrics which resonate with evolved differences in vertebral osteology (Appendix 3), and those which show differentiation between different taxa. These graphs also demonstrate how the data in Appendix 7 can be presented and used to guide identification of archaeological specimens through comparisons.

The graphs depict lumbar vertebrae only as internal variation is less within this region, compared with other regions of the spine (e.g. see Figure 10 showing differences in centrum length within each region). Lower internal variation highlights differences between taxa rather than variation within a specimen/species, and therefore aids identification.

Adult specimens only are shown within the figures, due to the inclusion of the absolute size parameter, and the ontogenetic variation in relative dimensions within Delphininae. However, for most taxa relative proportions will be in line with those depicted for adult specimens (with the exception of Delphininae). Logarithmic scales are used to de-emphasise the magnitudes of difference between small and large cetaceans (following Buchholtz et al. 2005: 417). Shapes on the figures represent different families – triangles represent Ziphiidae; circles represent Delphinidae; stars represent Monodontidae; crosses represent

Phocoenidae; squares represent Physeteridae and Kogiidae; diamonds (no fill) represent Balaenopteridae and Eschrichtidae; diamonds (filled) represent Balaenidae. Species are represented by different colours. Metrics for numerous specimens of each species were used in the creation of the figures, and measurements from along the spine of each specimen are included. Further details on the data used are included in Appendix 3 and the raw data is presented in Appendix 7.

Centrum characteristics are dealt with first as this part of the vertebra is more robust, and generally has a higher rate of survival in zooarchaeological assemblages compared with vertebral processes. However, as will be seen, a combination of characteristics are typically required to achieve species-level identifications.

4.1 CENTRUM CHARACTERISTICS

4.1.1 CENTRUM LENGTHS

Step 1 (above) and Appendix 3 established that centrum length is a key metric with potential to aid identification. Relative and absolute centrum lengths for species under study here are demonstrated by Figure 12. CL relative to height CH has been calculated (Buchholtz et al. 2005), to provide an overall indication of the relative centrum length: whether it is elongated compared with height, or discoidal and foreshortened. CH has also been chosen to demonstrate the absolute size in order that only two measurements are required (i.e. centrum length and height), to ensure reliance on the smallest number of measurements possible, in order to improve the chances of success when working with broken bones common in zooarchaeological assemblages.

Figure 12 demonstrates that many of the taxa within the study area can be broadly differentiated based on relative centrum length and absolute centrum height, largely resonating with the findings of earlier studies (Buchholtz 2001; Slijper 1936). Delphinoidea and in particular species within the subfamily Delphininae have compressed centra which is borne out by the short relative centrum lengths. *L. albirostris* (the white beaked dolphin) which forms part of this subfamily displays the most extreme shortening of relative centrum lengths, with CL/CH reaching as low as 0.3. At the other end of the scale the beaked whale family (Ziphiidae), can be identified by their long relative centrum lengths which reach CL/CH values of up to 2 in *M. mirus* (True's beaked whale), and species within the genus Mesoplodon generally display the highest relative centrum lengths. Elongated centra therefore broadly represent beaked whales, while foreshortened or discoidal centra represent delphininae.

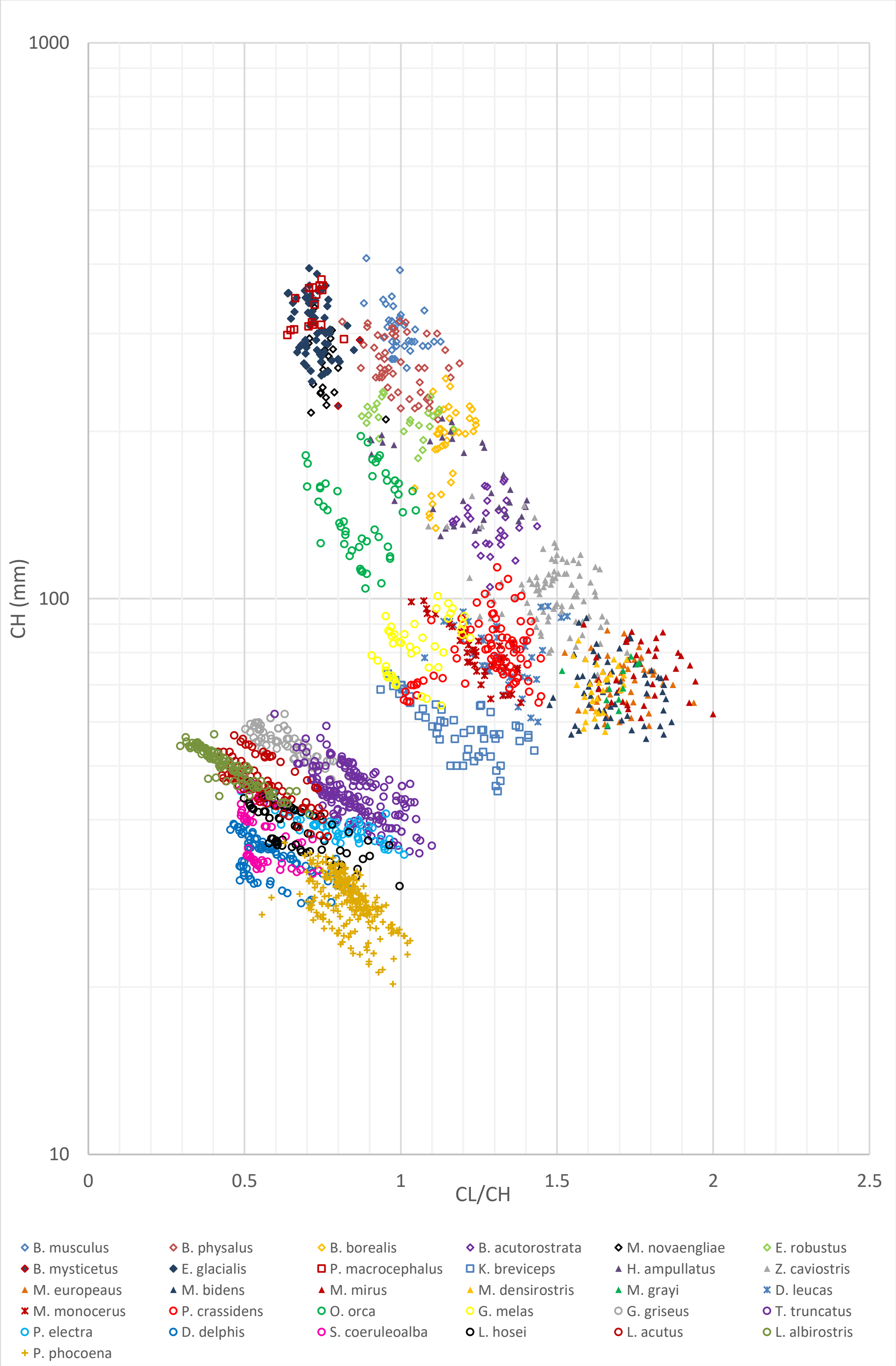

Figure 12 CL/CH and absolute CH in lumbar vertebrae of cetacean species. Y axis is depicted with a logarithmic scale

There is greater overlap between taxa from different families within the centre of the graph (between CL/CH of c. 1-1.5). This area includes members of the families Kogiidae, Monodontidae, Delphinidae, Balaenopteridae and Ziphiidae. The pygmy sperm whale can be distinguished by virtue of its small size compared with others in this group (the exaggerated ventral keel also distinguishes this species), though there is some overlap with the Monodontidae and members of the subfamily Orcininae; of which the false killer whale has the longest relative centrum lengths, and the killer whale has the shortest (defined also by its larger size). Larger species within the group in the centre of the graph include the northern bottlenose whale and minke whale, though Cuvier's beaked whale also overlaps with this group. Different characteristics and metrics are therefore required to distinguish between these species in most cases.

The larger taxa form a cluster with the largest absolute centrum heights. While they are clustered there is a clear distinction between the large balaenopterids (blue whale, fin whale and sei whale) and the gray whale, which generally have longer relative centrum lengths compared with the humpback whale, the balaenids, and sperm whale.

As established above, position along the spine is also important and the three variables (position along the spine, absolute and relative dimensions) are illustrated on Figure 13. This figure depicts morphologically similar species (*T. truncatus* and *G. griseus*) as an example. When position along the spine is considered differentiation between similar species is more marked.

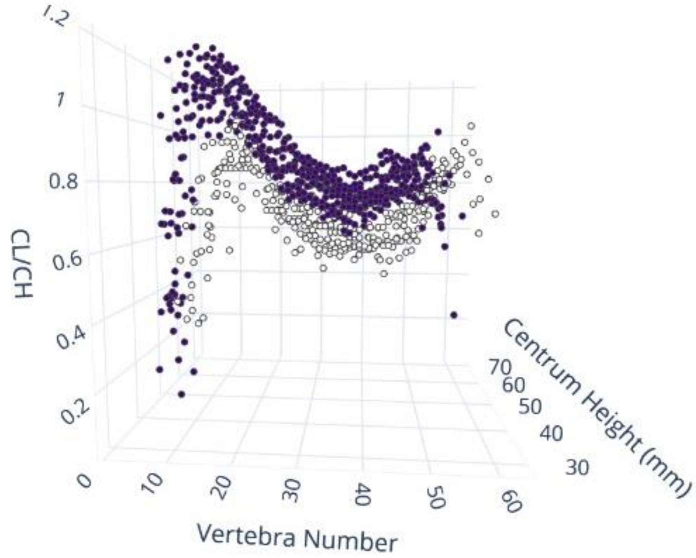

Figure 13 Relative and absolute centrum length and position along the spine for individual vertebrae in specimens of G. griseus (grey) and T. truncatus (purple)

Overall, the figures demonstrate that differentiation between cetacean taxa is possible when considering relative centrum lengths, and variations within these metrics generally demonstrate family and in some cases subfamily groupings, within which some species show distinct metrics which would facilitate identification. However, the level of differentiation and certainty of identifications that can be borne out of comparisons varies between taxa, and those which have CL/CH ratios of between 1 – 1.5 show the greatest overlap of taxa from different families and subfamilies.

4.1.2 CENTRUM WIDTH

While centrum length is the key variable allowing differentiation between taxa other centrum dimensions allow for discrimination between specific species. Centrum width is generally less varied and therefore of lesser use in taxonomic identification, however, it does allow the generally greater CH relative to CW of the sperm whale to distinguish this species from the Mysticeti, which tend to have wider centra, reflecting their broader bodies (see Figure 14; Buchholtz 2001: 181).

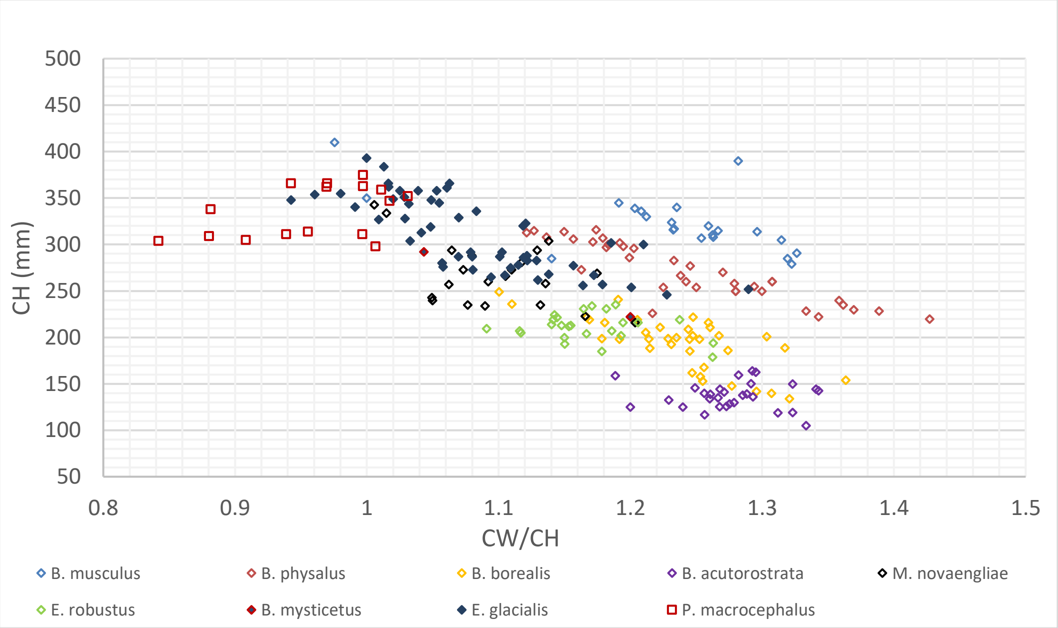

Figure 14 CW/CH and CH in lumbar vertebrae of large cetaceans

4.2 PROCESS CHARACTERISTICS

The following sections look at morphometric variation between taxa based on a consideration of process characteristics, including neural processes, metapophyses, neural arch characteristics, neural process inclination and transverse process characteristics.

The neural and transverse processes form muscle attachment sites[9], and the metapophyses form a key area of attachment. Throughout their evolutionary history most cetacean species had relatively short neural processes which were consistently posteriorly inclined, with low metapophyses (Buchholtz and Schur 2004: 395). However, as established in Appendix 3, differences to these traits have evolved between cetaceans, which allow for taxonomic differentiation.

4.2.1 NEURAL PROCESSES

Appendix 3 demonstrates that the flexibility of the spine varies between taxa, and that osteological traits including centrum length and neural process height influence spinal flexibility. Differences between taxa based on CL/NPH are depicted in Figure 15.

This figure shows largely the same groupings as CL/CH though some taxa overlap more closely, and beaked whales generally do not form a clear differentiable group on the basis of NPH/CL. However, NPH/CL allows for further differentiation within the Delphininae sub-family reflecting the greater degree of regionalisation (areas of increased flexibility/stability) within the spines of these taxa. The white-beaked dolphin has the greatest NPH/CL values (Figure 16), indicating that this species has regions of the spine with greater inflexibility than all other species reviewed here. It can be differentiated from other delphinoids on this basis, including from the white-sided dolphin, with which it is otherwise very similar. Additionally, while the melon headed whale was very similar to the common dolphin, striped dolphin and Fraser's dolphin on the basis of CL/CH, its lower NPH/CL value allows it to be distinguished from this group of small delphininae.

There is also a degree of separation within the Monodontidae, with the beluga whale generally exhibiting lower NPH/CL values than the narwhal, though there is some overlap. Other taxa are generally only distinguishable using the absolute size parameter thus NPL/CL is primarily of use for the investigation of Delphininae and can support species-level differentiation within this subfamily in some cases.

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[9] Transverse processes in the thoracic region also articulate with ribs.

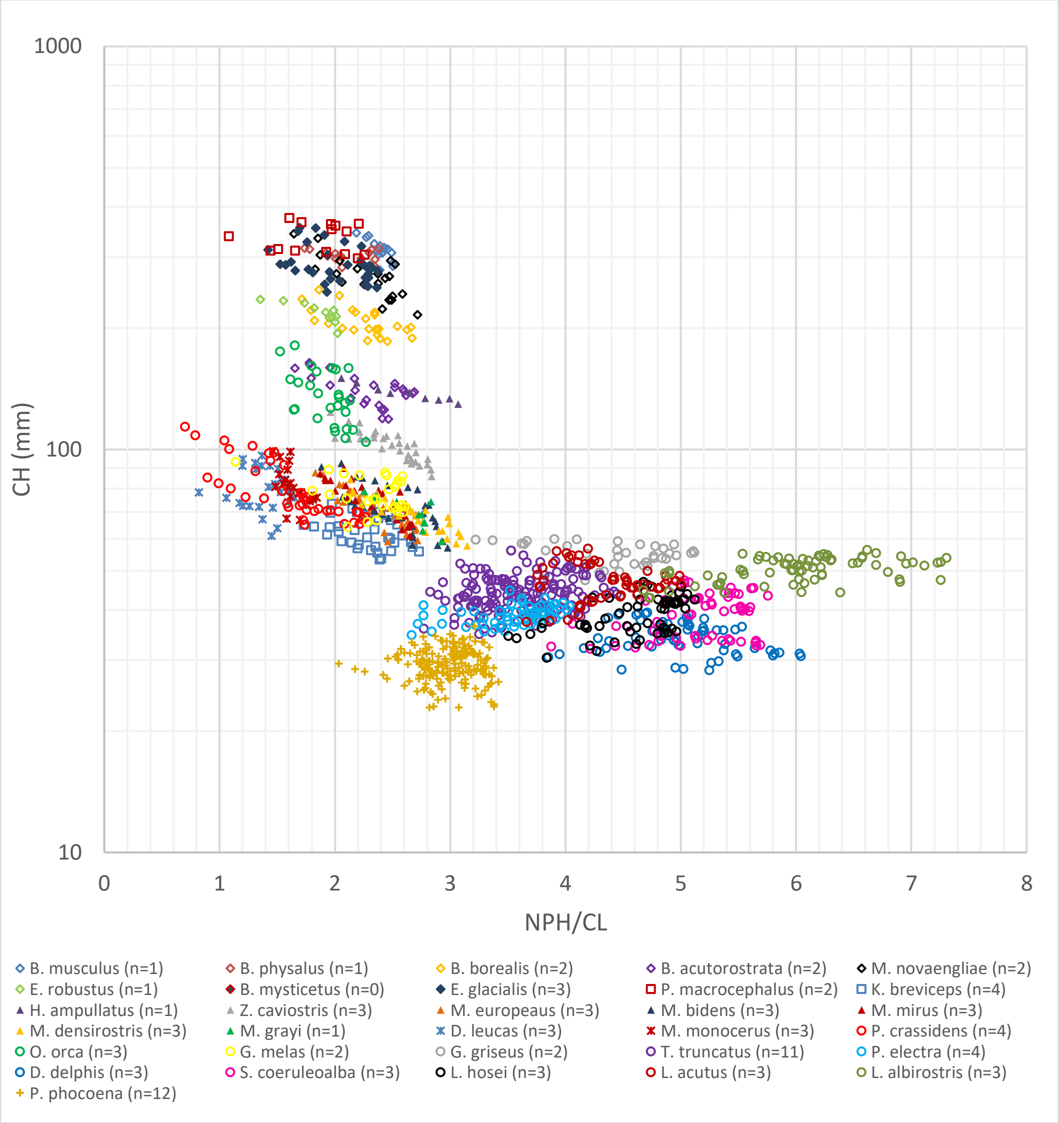

Figure 15 NPH and CL in lumbar vertebrae of adult cetaceans. Y axis is depicted with a logarithmic scale

Figure 16 Articulated lumbar vertebrae of *L. albirostris* showing long neural processes and short centrum lengths (photo by author from NHM Wandsworth)

4.2.2 METAPOPHYSIS ELEVATION AND CHARACTERISTICS

The relative height of the metapophyses is represented by the ratio MPH/NPH in Figure 17 which demonstrates the relative elevation of the metapophyses compared with the top of the neural process. Values around 1 indicate that the metapophyses are situated at the top of the neural process, with lower values indicating metapophyses which are situated further ventrally. Figure 17 shows that differences in metapophysis height can be used to make broad distinctions between different cetacean families. Broadly the beaked whales are characterised by low metapophyses and high neural processes (reflected by the low MPH/NPH value), while the Mysticeti have slightly higher metapophyses. The metapophyses in sperm whales are regionally elevated within the lower lumbars (depicted by the high MPH/NPH values). This is also a feature of many of the Delphinoids, except for the harbour porpoise which shows no such regional elevation.

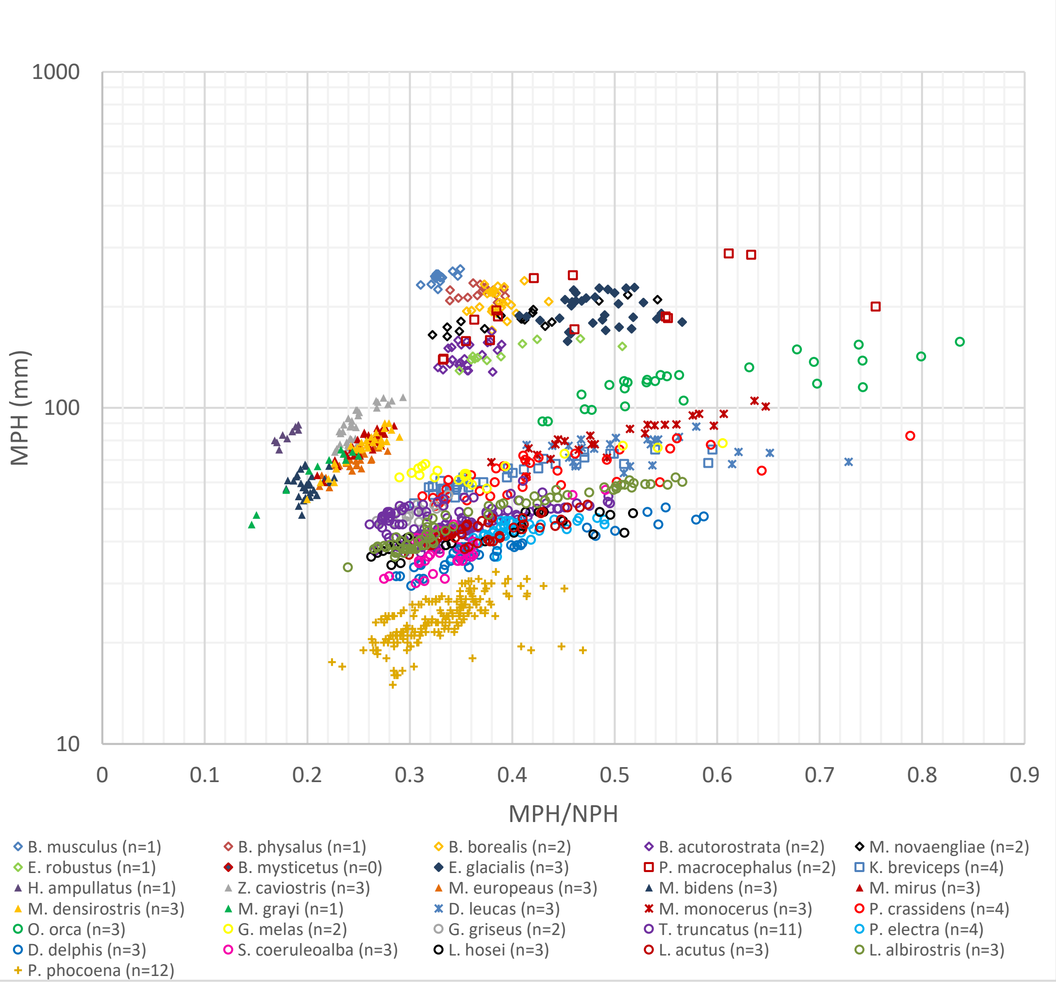

Figure 17 MPH and NPH in lumbar vertebrae of adult cetaceans. Y axis is depicted with a logarithmic scale

While separation between families is clear, species-specific differences are generally lower (Figure 17). The harbour porpoise (the only porpoise species present within the dataset) is an exception to this, as are the northern bottlenose whale and Cuvier's beaked whales which can be clearly separated from other beaked whales on the basis of absolute metapophysis height. The killer whale can also generally be separated from other Delphinidae based on the extreme relative height of the metapophyses, which occur near the top of the neural process in the posterior lumbar region of this species.

These osteological differences relate to swimming styles and reflect the development of key muscle groups, which differs between cetacean taxa: in Delphinoids the multifidus is relatively well developed, while in Mysticeti, and in particular Ziphiidae the longissimus system is dominant (Slijper 1936: 437; see Figure 18 for muscle locations). This is discussed further in Appendix 3 in relation to vertebral osteology.

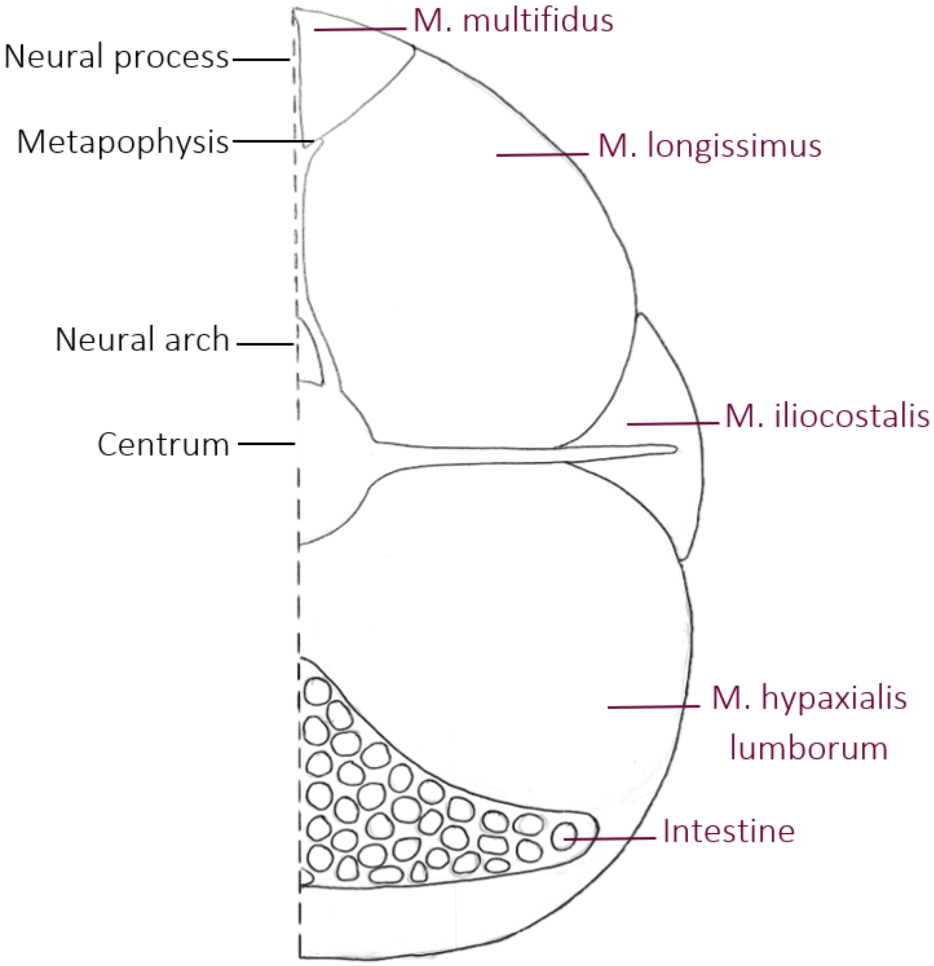

Figure 18 Musculature associated with lumbar vertebrae in cetaceans. Example shows a diagrammatic cross section of musculature within *D. delphis*. Illustration by author based Slijper (1936: 225) and Huggenberger et al. (2019).

Other differences between metapophyses are also extant between cetaceans. These include regional loss or extreme reduction of the attachment sites, seen only in some species of delphinid (Figure 16 shows this on *L. albirostris*) (Buchholtz and Schur 2004: 386), and differences in the shape of the metapophyses. In Mysticeti the metapophyses are generally well developed and leaf-shaped with wide bases at the interface with the neural process, while in most Odontoceti metapophyses tend to be cone shaped with narrow bases (Slijper 1936: 414). Ziphiidae are an exception, and tend to have smaller flattened metapophyses situated on the sides of the neural arch in the posterior lumbar and caudal regions, thought to correlate with an increased importance of the tips of the neural processes as a muscle attachment site in the same regions (Slijper 1936: 422). Metapophysis form is also different between Delphinoids. Delphinapterids have elongated metapophyses, while those of the Delphinidae are generally more reduced (though *O. orca* retains relatively large metapophyses).

Metapophysis size also differs amongst other taxonomic groups. In Balaenopterinae and Eschrichtidae the size of the metapophyses decreases in the posterior lumbar and anterior caudal regions, while in Megapterinae (*M. novaengliae*) and the balaenids there is an increase in metapophysis size in this area, coupled with a decrease in the length of the neural spine.

4.2.3 HEIGHT OF THE NEURAL ARCH

The relative height of the neural arch and neural spine also allow for taxonomic differentiation. Slijper's (1936) work proved a relationship between the height of the neural arch, metapophysis height and neural process dimensions, and therefore as expected there is a broad correlation between the species differentiation supported by these measurements (evident through comparison of Figure 17 and 19). However, the height of the neural arch allows for further distinctions than the relative MPH, particularly among the Delphinidae. Clear distinction between the Delphininae and Orcininae subfamilies are evident when looking at the HNA/HNS ratio (though Delphinapterids and pygmy sperm whale overlap with both Delphindae subfamilies) and these relative dimensions also allow distinction of the melon headed whale from other Delphininae. While the vertebrae of the melon headed whale are very similar to those of other Delphininae when considering other traits (see Figures 12 and 15 for example), the relative height of the neural arch to the overall height of the neural spine sets this species apart. The ratio of HNA/HNS in the melon headed whale is more consistent with members of the Orcininae sub-family (Figure 20), with which some classifications group this species (e.g. Perrin 1989).

This ratio also broadly allows for distinction between balaenopterids and balaenids, following the same pattern as MPH/NPH.

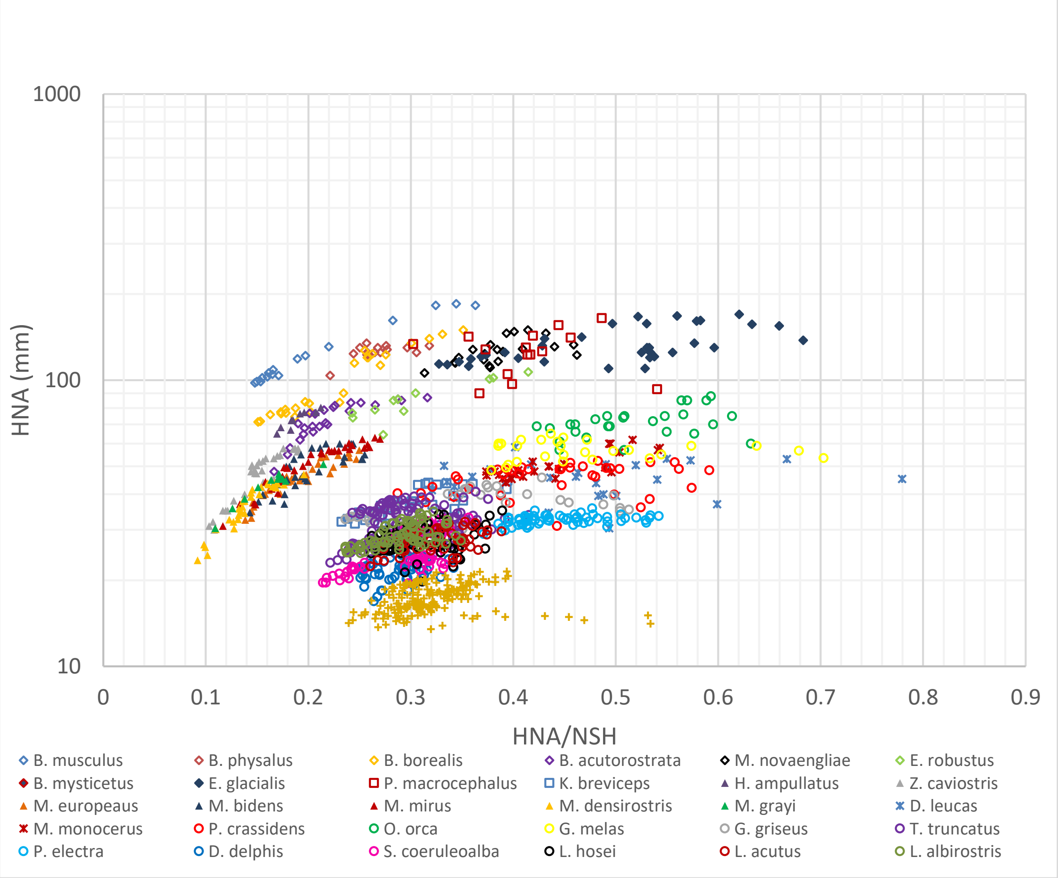

Figure 19 HNA and NSH in lumbar vertebrae of adult cetaceans. Y axis is depicted with a logarithmic scale

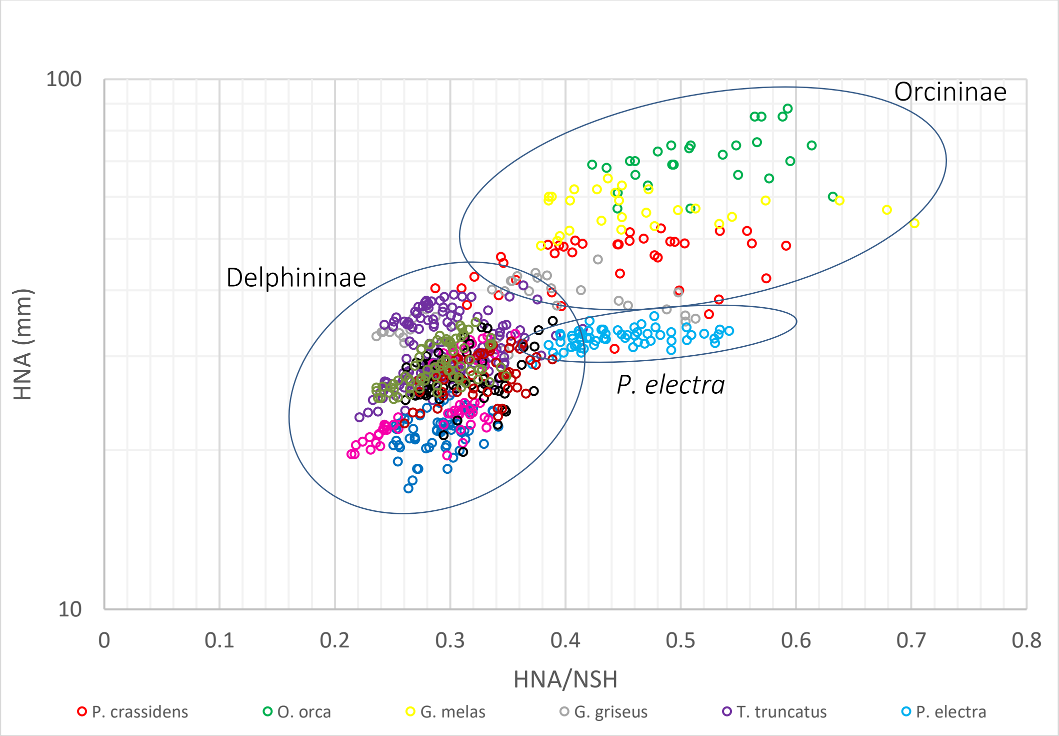

Figure 20 HNA and NSH in lumbar vertebrae of adult Delphinidae. Y axis is depicted with a logarithmic scale

4.2.4 BREADTH OF THE NEURAL ARCH

Although not included within some earlier work (e.g. Slijper 1936), the breadth of the neural arch also provides a means of discrimination between different taxa (Omura 1958: 42). However, the current dataset contains fewer of this measurement than others. This is primarily because access to the neural arch is restricted when specimens are articulated, hindering attempts to take this measurement. Additionally, data collected by other studies including Gillet et al. (2019) did not include this measurement. Thus, the number of overall measurements for this dimension is relatively small within the current dataset. Information is greatest for the larger species, and so it is only these which are considered here. As with other important measurements a ratio was created which compares the breadth of the neural arch to the centrum height. The latter was chosen as a relatively stable measurement with which to highlight the differences in the relative breadth of the neural arch between cetacean taxa. The position along the spine is a key variable affecting the breadth of the neural arch, and as such this has been plotting along with the BNA/CH ratio.

BNA/CH for large taxa, including Mysticeti and *P. macrocephalus*, was plotted (Figure 21). While this figure shows clear differences between balaenids and balaenopterids in some regions of the spine (in particular the lumbar region), in other areas the distinction is less clear cut. Figure 22 demonstrates that inclusion of absolute size, along with the BNA/CH ratio and position along the spine would aid taxonomic identification. It also shows that the breadth of the neural arch differs between groups and can be used to differentiate between balaenopterids and balaenids, being wider in the latter (Omura 1958) for most of the length of the spine.

The differentiation between balaenids and balaenopterids is also apparent when considering the height of the neural arch (Figure 19) demonstrating the importance of neural arch dimensions for differentiating between these families. The breadth of the neural arch also allows for separation of the sperm whale from the balaenids.

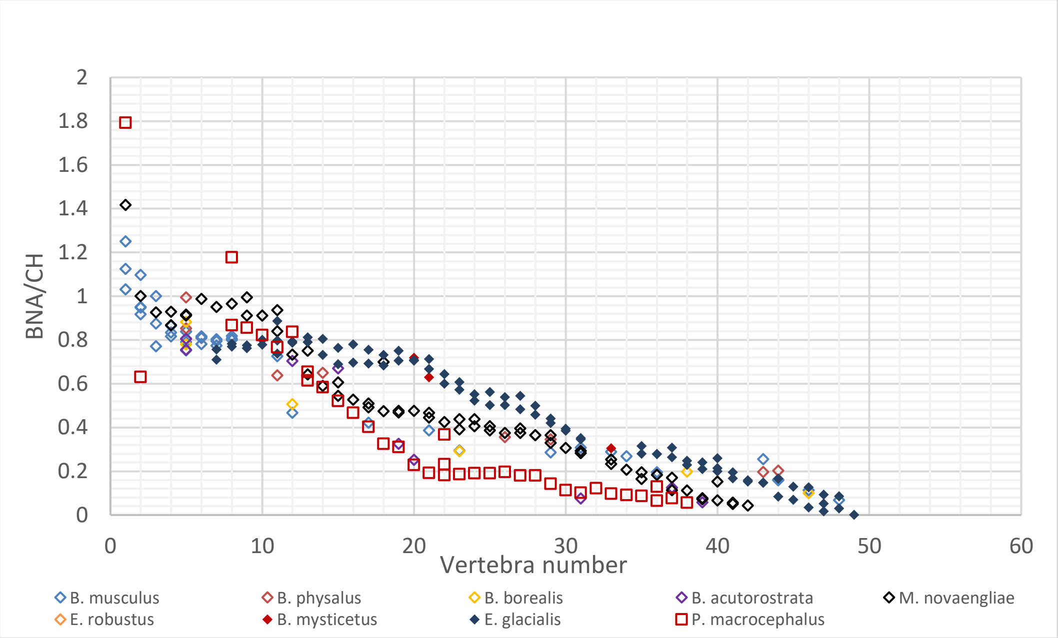

Figure 21 BNA/CH in specimens of Mysticeti and P. macrocephalus

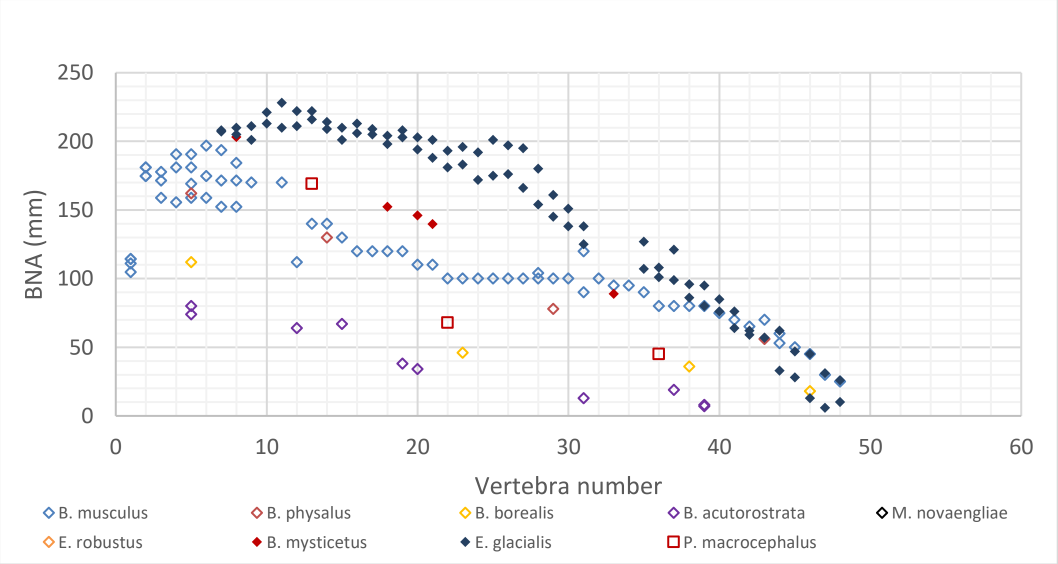

Figure 22 BNA in mature specimens of Mysticeti and P. macrocephalus

4.2.5 NEURAL PROCESS INCLINATION

While early cetaceans had neural processes which were uniformly inclined posteriorly, and many of today's taxa retain this trait, changes to the angle of inclination have evolved within some taxa in certain regions of the spine (Buchholtz and Schur 2004: 386; Slijper 1936: 437).

In some taxa just the neural arch inclination has altered, while in others both the neural spine and neural arch inclination is affected (Slijper 1936). Neural spine inclination only has been measured by Gillet et al. (2019). There are no systematic measurements of neural arch inclination available, and as such this characteristic must been judged through visual assessment.

In the thoracic region most taxa retain neural spines which are inclined caudally. However, in the Mysticeti the neural spines of the first few thoracic vertebrae are relatively short and are either vertical or inclined cranially (Slijper 1936: 422), allowing for differentiation of this group. However, the main changes to orientation have been further down the spine and allow for greater distinction between cetacean families.

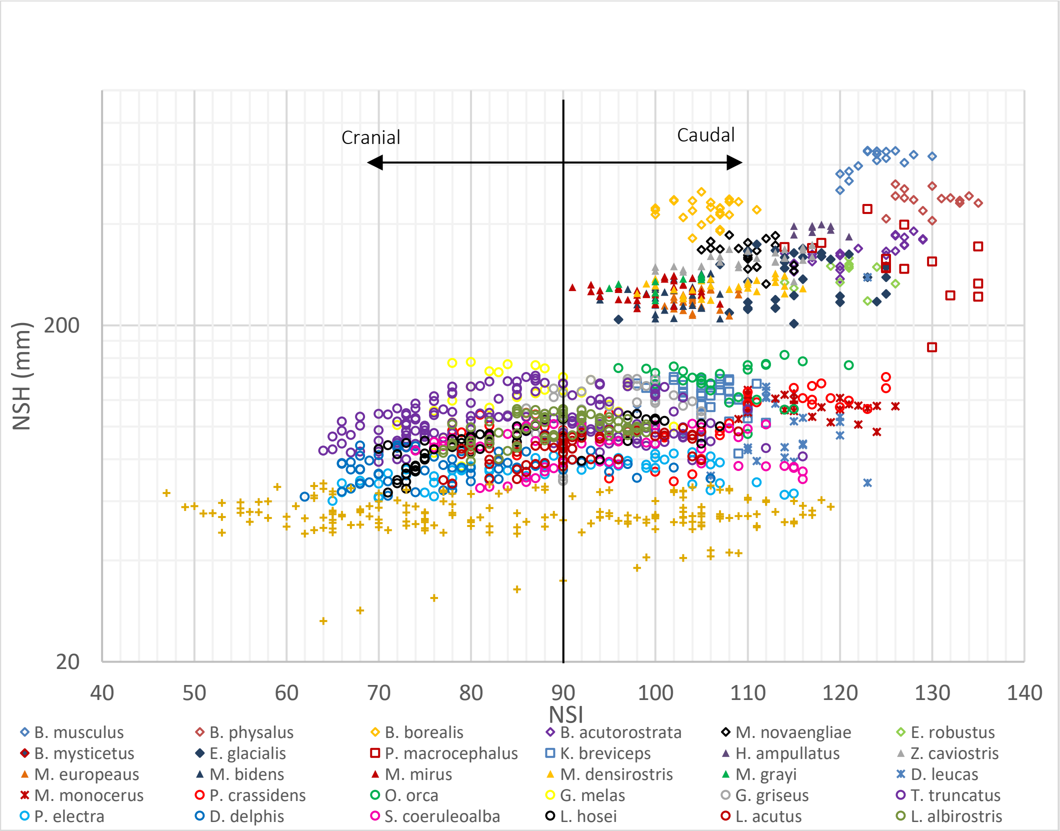

Figure 23 NSI and NSH in lumbar vertebrae of adult cetaceans. Y axis is depicted with a logarithmic scale

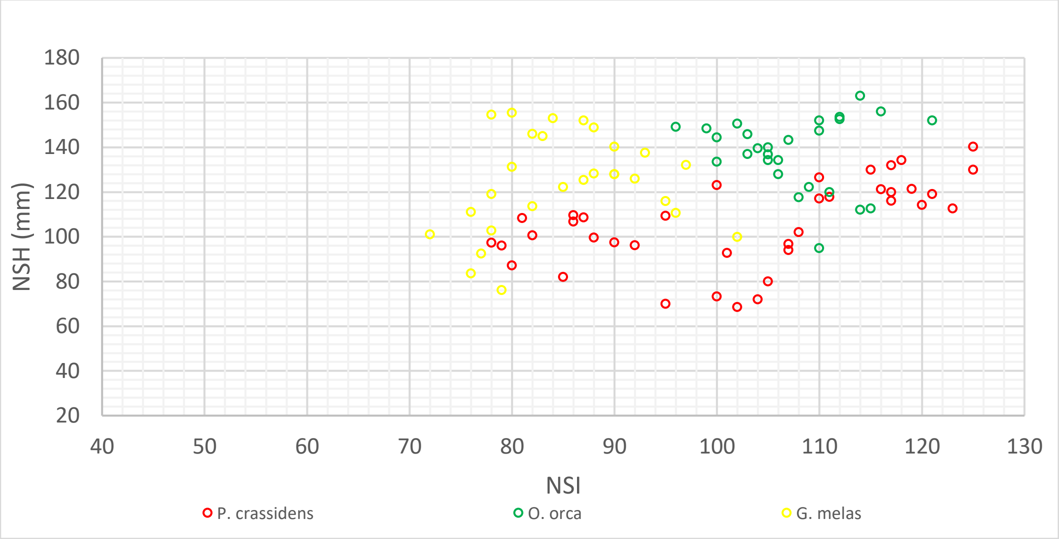

Figure 24 NSI and NSH in lumbar vertebrae of adult Orcininae.

Figure 23 depicts neural spine inclination and neural spine height in the lumbar region. The changes to neural spine inclination in this region are most extreme among the Delphininae and Phocoenidae. The presence of anticlinal vertebrae (with neural processes oriented in an anterior direction) typically in the lumbar and early caudal regions, and a synclinal point, reflecting the point at which process inclination switches back to a posterior direction (in the caudal region) is seen only among the delphinids (Buchholtz and Schur 2004: 392). This is evident within the dataset. Delphinids are the only taxa to have neural spines which are inclined at an angle of less than 90 degrees, with the exception of *P. phocoena*, which has characteristically curved neural spines which also cause the angle to be less than 90 degrees (Figure 25).

Figure 25 Lumbar region of *P. phocoena* showing curved neural processes (specimen held at Cardiff University)

While all Delphininae have neural spines which are inclined cranially, this trait is much less evident among Orcininae (Figure 24). Only the pilot whale and false killer whale show this trait among the Orcininae in the posterior lumbar vertebrae, and the degree of cranial inclination is much less than in the Delphininae. Neural spines of the killer whale are generally inclined caudally. However, neural arches of this species do show a cranial inclination (Slijper 1936: 426).

Neural spine inclination can also be used to differentiate between the sei whale and other Balaenopterinae (Figure 26). In this species the neural spines are oriented caudally, but to a lesser degree than other Balaenopterinae, giving the processes the appearance of being more upright. The humpback whale also has neural spines which are inclined further cranially, though to a lesser degree than the sei whale, and these species can be distinguished using other characteristics (e.g. relative centrum length).

Neural process characteristics are therefore important for differentiation to species, genus, subfamily and family level among both Mysticeti and Odontoceti.

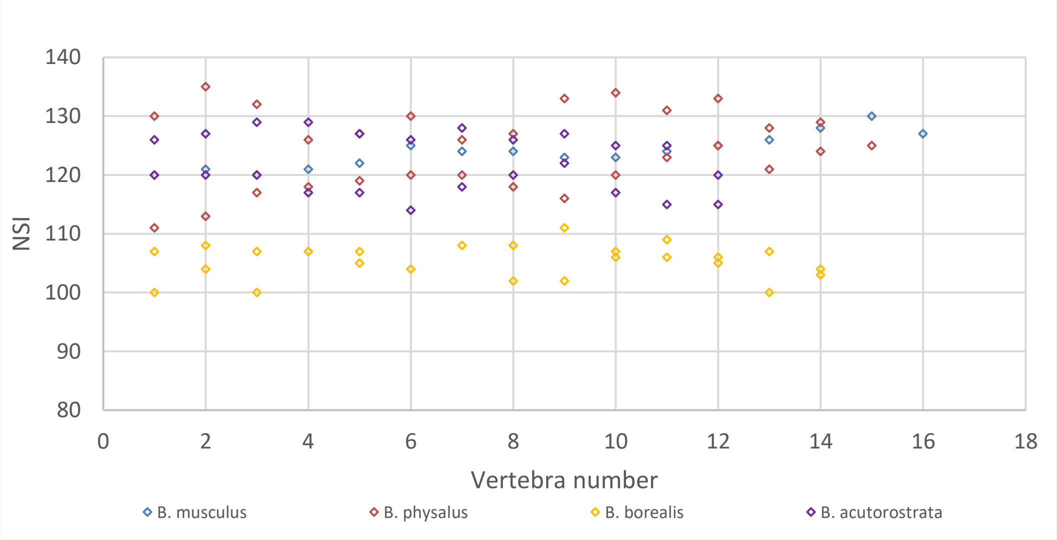

Figure 26 NSI in lumbar vertebrae of adult and young Balaenopterinae

4.2.6 TRANSVERSE PROCESSES

Transverse process dimensions have been shown to have a connection with flexibility and locomotion, while characteristics of the transverse processes in the thoracic region can also relate to breathing.

Slijper (1936) identified a connection between the size of the transverse processes (BPtr) and the relative development of the multifidus and longissimus muscles which varies between different cetacean families. This relationship is further considered here by a comparison of the overall height of the vertebra (H) (from the base of the centrum to the tip of the neural process) to the overall breadth (BPTr) (from the tip of each transverse process); characteristics also known to be connected to this musculature. While this data has been collected during the research undertaken as part of this thesis, many other studies do not include these measurements (e.g. Gillet et al. 2019). These dimensions are more likely to be affected by breakages causing the loss of the tips of the neural process or transverse processes. For these reasons the dataset for these measurements is smaller than for others collected. As such species-level discrimination would not be reliable, and the results have therefore been illustrated for families rather than species (Figure 27). As in earlier figures, data relates to adult specimens only.

Figure 27 demonstrates that there are clear differences between many of the cetacean families based on H/BPTr. The vertebrae of the Ziphiidae are easily distinguished by their great height relative to breadth (Slijper 1962), while Physeteriidae (represented only by the sperm whale) and Kogiidae (represented by the pygmy sperm whale) also have vertebrae which are generally up to 1.2 times higher than they are broad. The Mysticeti form a cluster, as do the Delphinidae and Delphinapteridae. Phocoenidae are only distinguishable due to their relatively smaller size.

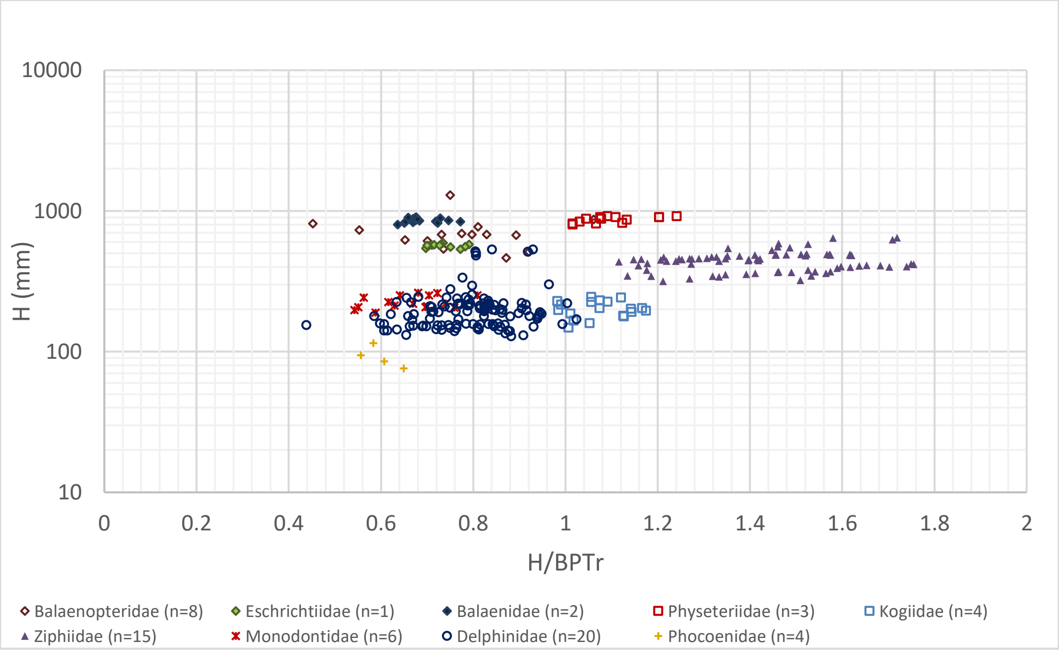

Figure 27 H and BPTr in lumbar vertebrae of adult cetaceans. Y axis is depicted with a logarithmic scale

The transverse processes are also influenced by the insertion of lateral musculature which varies between taxonomic groups. The greatest length of the tips of the transverse processes (GLPT), and general form of this area was observed to differ between families, genera and in some cases species. In some, the tips of the processes were found to be expanded in an anterior-posterior direction compared with the overall length of the vertebra, while in others the tips are narrowed. The greatest length of the transverse processes relative to centrum length was calculated and is shown in Figure 28- 29. Centrum length was chosen as it allows appreciation of the relative expansion of GLPT compared with the centrum. GLPT relative to centrum height was also calculated (Figure 30) as a more stable measurement than centrum length. As previously, only adult specimens are shown in the figures.

Several clear patterns are evident within the dataset. The Delphininae and *P. phocoena* are generally inseparable when considering GLPT and form a broad overlapping group. However, within the medium and large size groups several taxa can be differentiated. *K. breviceps* for example, is clearly separable when considering GLPT/CL, and the Delphinapterids largely form a distinct group with greater relative GLPT compared with other Delphinoids (Figure 29) reflecting their widely expanded transverse process tips. The beluga whale in particular achieves a high GLPT/CL ratio. There is minor overlap between the Delphinapterids and Ziphiidae, however, they can be easily separated from this group when considering centrum shape, neural process characteristics and transverse process shape.

While there is a high degree of overlap between Delphinoids generally, the killer whale can be clearly distinguished based on GLPT/CH (Figure 30).

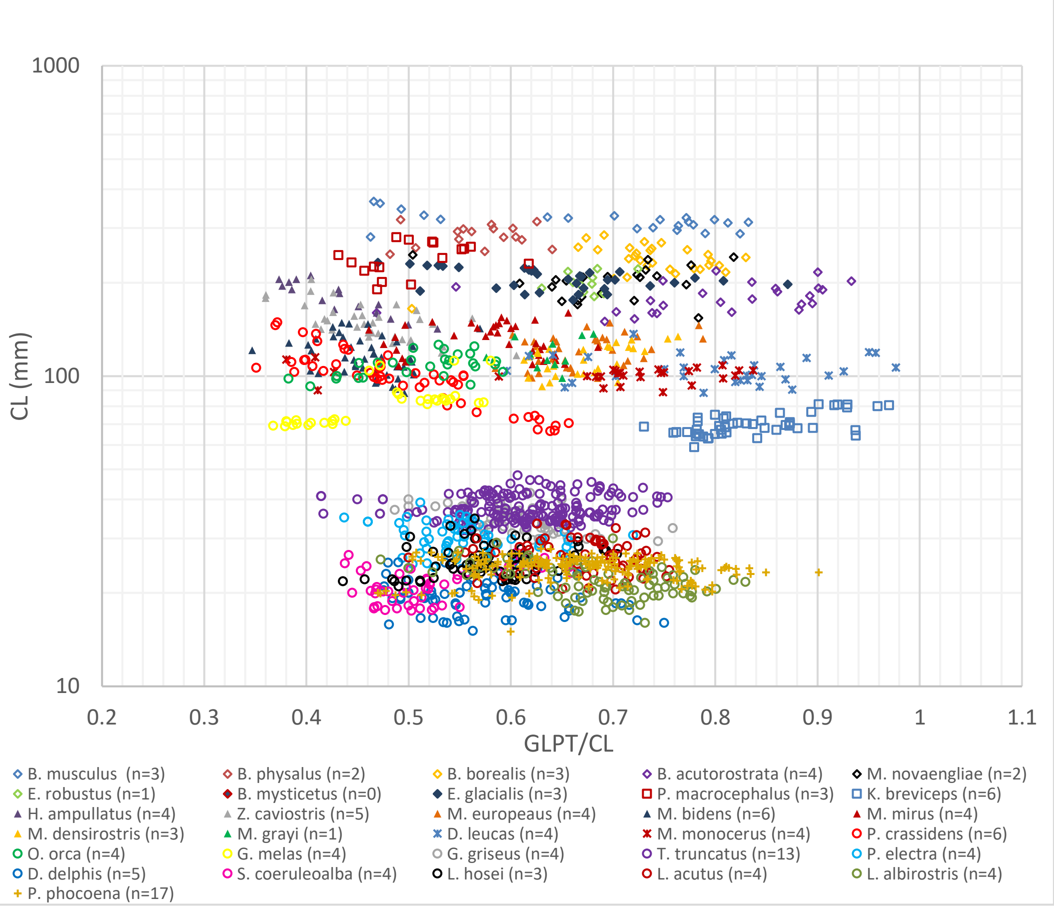

Figure 28 GLPT and CL in lumbar vertebrae of adult cetaceans. Y axis is depicted with a logarithmic scale

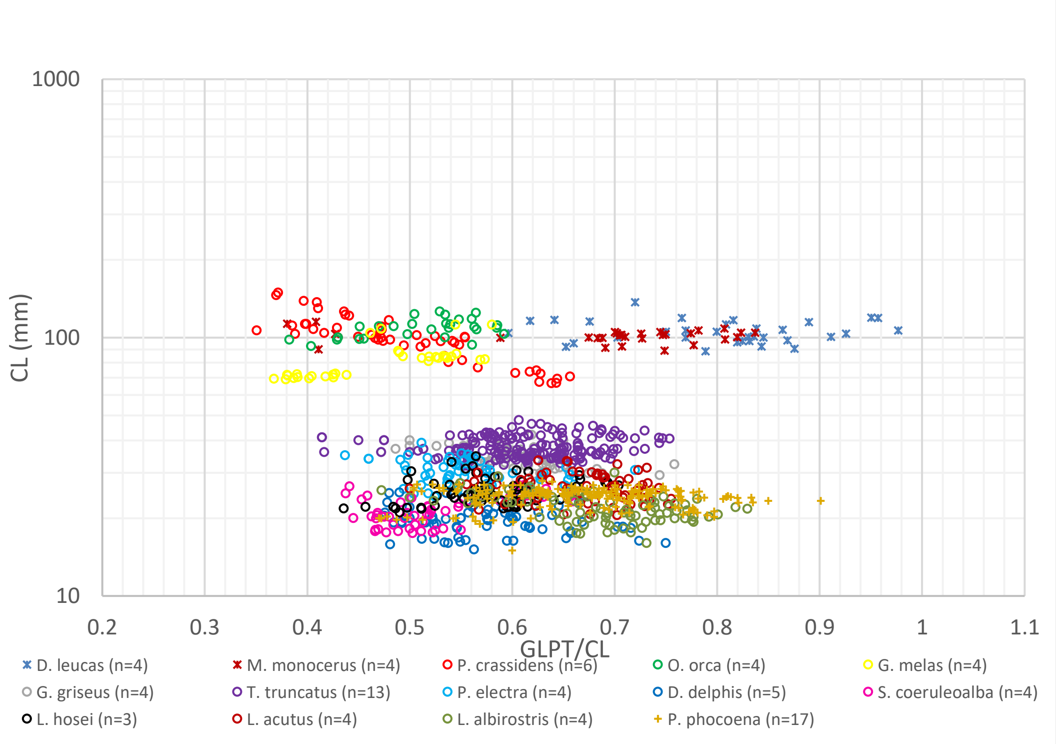

Figure 29 GLPT and CL in lumbar vertebrae of adult Delphinapterids and Delphinoids. Y axis is depicted with a logarithmic scale

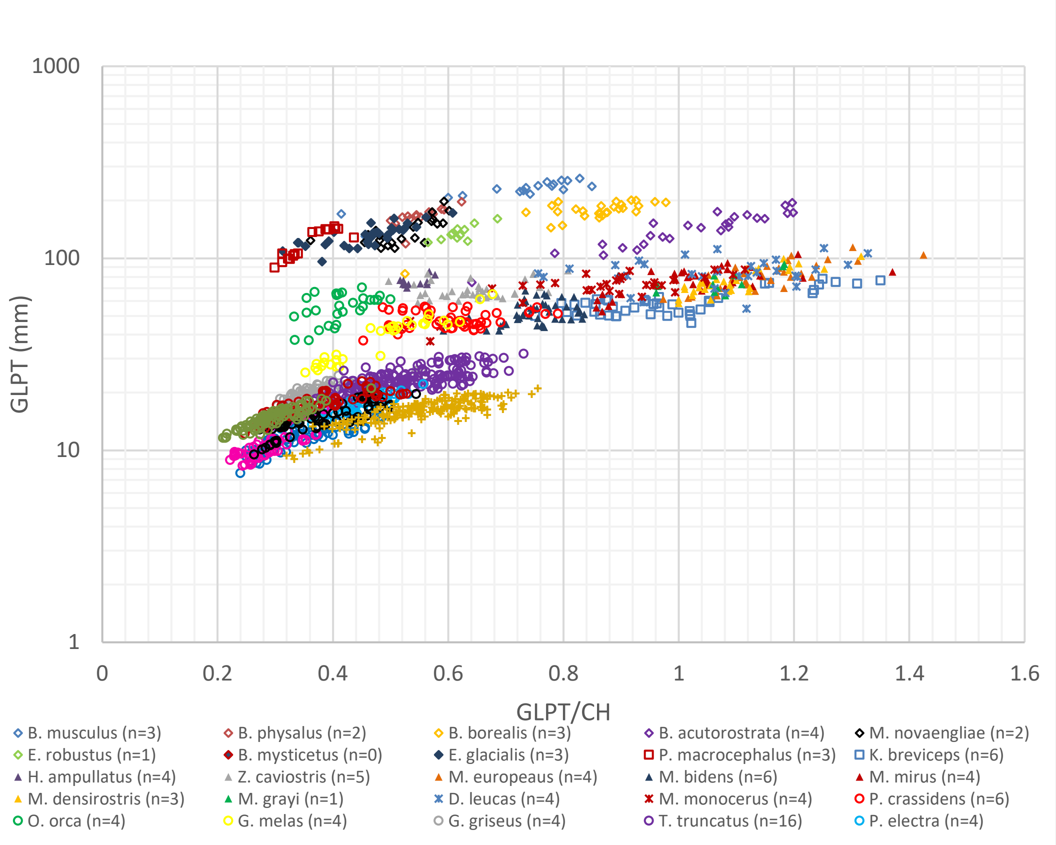

Figure 30 GLPT and CH in lumbar vertebrae of adult cetaceans. Y axis is depicted with a logarithmic scale

Figure 31 and Figure 32 demonstrate that GLPT can also be used to distinguish *M. bidens* from others in the same genus. While there is some overlap with *M. mirus*, on Figure 31, when vertebra number is taken into account (Figure 32) these species can be distinguished. *M. bidens* consistently demonstrates the lowest relative and absolute GLPT values, indicative of narrow transverse process tips (e.g. Figure 33) compared with the expanded tips of other Mesoplodont whales. This distinction is of particular importance when considering Scottish zooarchaeological assemblages as *M. bidens* is among the most common of the Mesoplodon species in UK waters (Clark et al. 2010: 57).

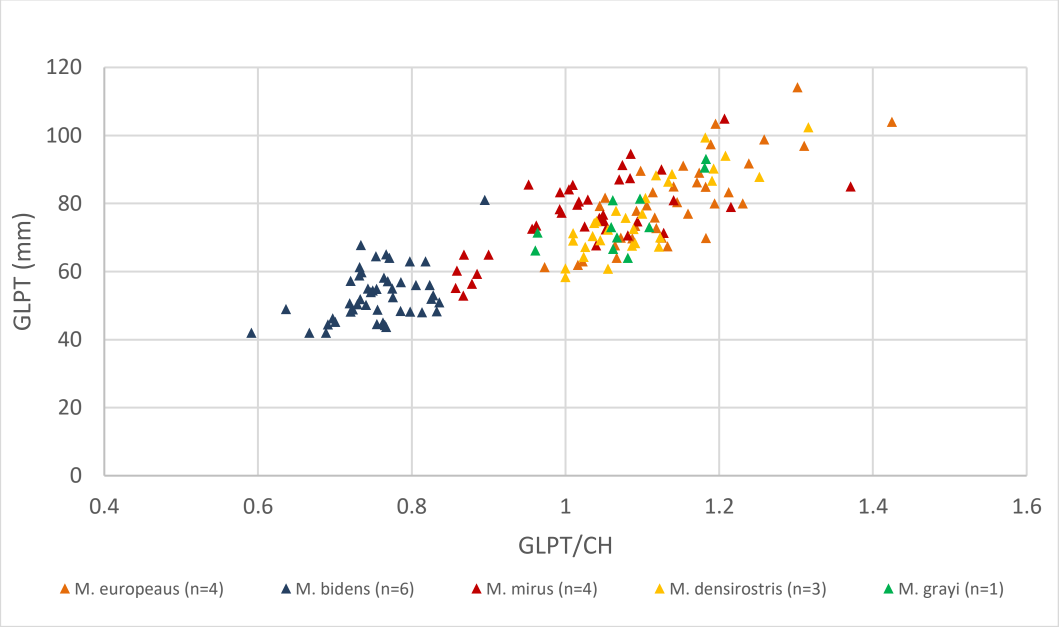

Figure 31 GLPT and CH in lumbar vertebrae of adult Mesoplodon sp.

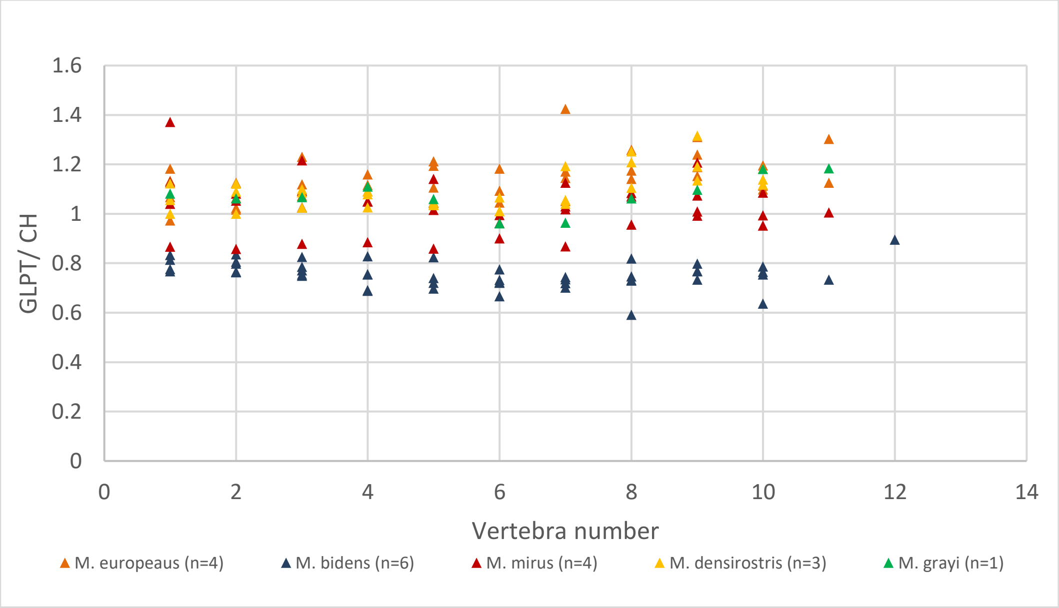

Figure 32 GLPT and CH in lumbar vertebrae of adult Mesoplodon sp.

Figure 33 Lumbar vertebrae of M. bidens showing GLPT (photo by author of specimen held by the Icelandic Natural History Museum)

Within the larger taxa, the sperm whale is characterised by lower relative GLPT compared with baleen whales, though there is minor overlap with the balaenids and the humpback whale, which have the lowest values for any baleen whales. The minke whale has the greatest relative GLPT followed by the sei whale (Figure 34 – 35). There also appears to be some separation between the blue and fin whales, with the former achieving greater absolute and relatives values. However, in general baleen whales have more variation in GLPT along the spine, giving a wider range of relative GLPT values. The lower ranges of the blue whale therefore overlap with the range for the fin whale.

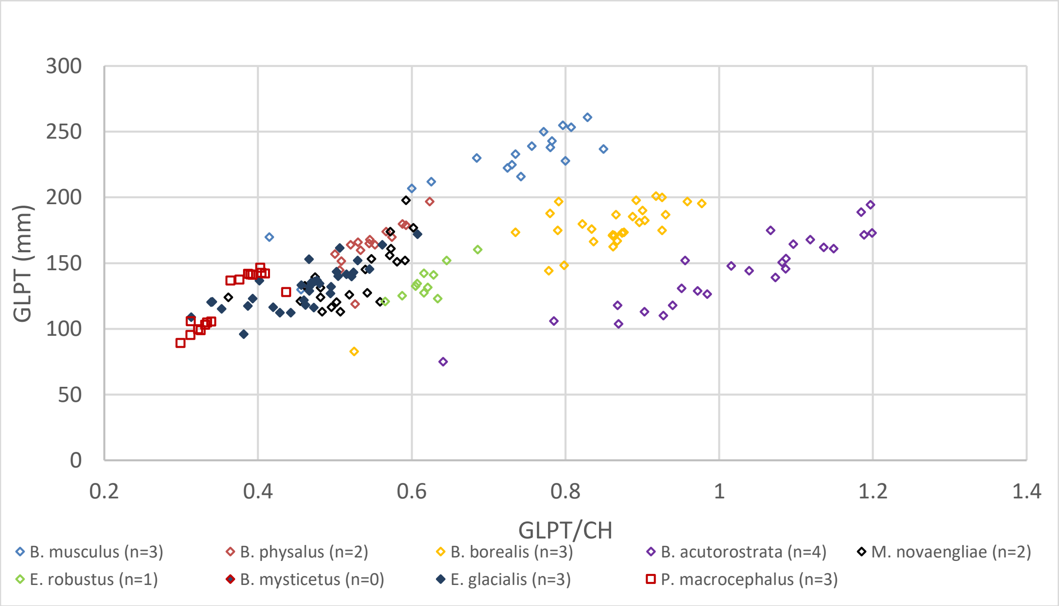

Figure 34 GLPT and CH in lumbar vertebrae of adult Mysticeti and P. macrocephalus

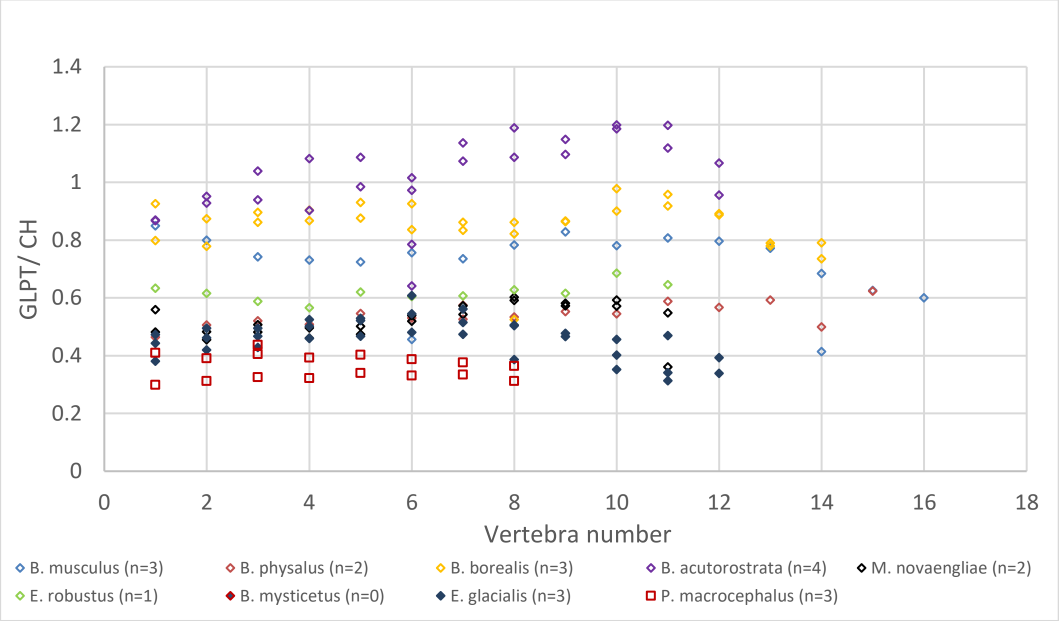

Figure 35 GLPT and CH in lumbar vertebrae of adult Mysticeti and P. macrocephalus

4.3 SUMMARY OF TAXONOMIC DIFFERENTIATION

The previous section demonstrated that morphometric variation between cetacean taxa (of use for identification) is present to varied extents when considering:

- Centrum length, height and width;
- Neural process and neural spine height;
- Elevation of metapophyses;
- Height and breadth of the neural arch;
- Neural spine inclination; and
- Transverse process breadth and length;

The list of osteological traits identified in Step 1 also indicated that neural arch inclination, the location of the transverse processes relative to the centrum, location of arterial foramen and number of ribs and the nature of rib articulations would also aid identification. Some of these characteristics and many other differences between cetacean bones cannot be accurately captured by simple measurements and assessment of morphology remains an important aspect in cetacean bone identification. In addition to the aforementioned characteristics, others which provide clues as to specific identities include the shape of the vertebral centrum (e.g. spool shape, as is common amongst some larger Delphinoids for example, compared with the barrel shape common amongst beaked whales (Buchholtz and Schur 2004)), metapophysis form and shape, and form of the neural spine and muscle attachment sites (Slijper 1936: 414). In addition, the location, form and size of arterial foramen and grooves also provides insight into taxonomic identity (Slijper 1936, chapter 12), as do the neural arch and laminae characteristics (e.g. van den Hurk 2020: 257), epiphyseal fusion patterns (see Appendix 6, Section 2.4) and trabeculae structure in some species. This list is not exhaustive and aspects of bone morphology which are relevant for taxonomic identification are cited in Appendix 6, where they are relevant to the archaeological material analysed.

The dataset presented demonstrates that differentiation between taxonomic groups occurs on a spectrum, affecting different taxa and areas of the spine in different ways. However, broad patterns are evident. A combination of factors including centrum length, neural process, metapophysis, neural arch and transverse process relative and absolute dimensions and form allow for family, sub-family, genus and species-level identifications.

Mysticeti can generally be differentiated by their CL/CH ratio, metapophysis form, and size. Transverse process characteristics are also important for identification of Mysticeti. Within this group, differentiation to family, genera and species level is possible in some cases. CL/CH allows for separation of Balaenopterinae and Eschrichtiidae, characterised by longer centrum lengths, from the Megapterinae and Balaenids, characterised by shorter centrum lengths. The latter group can then further be differentiated by the greater dimensions of the neural arch in the balaenids, allowing for species-level discrimination of *M. novaengliae*. Insufficient information was available to assess differences between the balaenids, and other studies have struggled to distinguish these species morphologically (Cumbaa 1986). Within the Balaenopterinae, *B. acutorostrata* is defined by its smaller absolute size and relatively long centrum lengths (and as such may be confused with larger species of Ziphiidae, though can be differentiated based on morphological characteristics) and GLPT, while *B. borealis* can be distinguished by the inclination of its neural spines and relative GLPT. *B. musculus* and *B. physalus* are very similar and no characteristics have been identified which allow for definitive discrimination between these species, though relative GLPT may allow for some differentiation. *E. robustus* shares many similarities with the balaenopterids. Generally, this species can be differentiated from other balaenopterids on the basis of centrum height, lower metapophyses and neural arch properties and from *B. borealis* on neural spine inclination.

P. macrocephalus is of a similar size to many of the Mysticeti, but can be differentiated on the basis of centrum length and width relative to height, metapophysis form and location, overall height compared with breadth and GLPT. *K. breviceps* can be identified on this basis also, though with the additional characteristic of the unusual ventral keel which occurs as a hypapophysis in the lumbar vertebrae of this species only (*K. sima*, not present within the study area, also shows this characteristic).

The Ziphiidae family can be identified based on a number of characteristics including relative centrum length, metapophysis position and neural process characteristics. Within this family beaked whales can generally be differentiated to genus level, particularly on the basis of CL/CH and MPH/NPH. As *Hyperoodon ampullatus* and *Ziphius caviostris* represent the only species within their respective genera within the study area, this effectively allows species-level identification for these two. Differentiation between species within the genus Mesoplodon is generally not possible, though *M. bidens* (the most common species of this genus within Scottish waters) can be differentiated from other Mesoplodont species on the basis of the lesser length of its transverse processes (GLPT).

Delphinoids are identifiable on numerous characteristics including centrum lengths and neural process and metapophysis height and transverse process length. Within this group Delphinapterids can be distinguished from most other taxa on the basis of the NPH/CL which is amongst the lowest of all taxa within the study, and the beluga in particular has low NPH/CL values. Although there is overlap with *G. melas* and *P. crassidens* the Delphinapterids can be distinguished from these species based on their well-developed metapophyses and transverse process form. The GLPT/CL ratio allows for differentiation of this group, and the beluga whale in particular achieves a high GLPT/CL ratio.

The three members of the Orcininae subfamily are morphologically very different, and species-level identification is possible for all. They form the clearest group when considering the HNA/NSH, though there is overlap with other taxa such as the Delphinapterids. They can be distinguished from one another on the basis of relative centrum length, metapophysis form and neural spine form.

The Delphininae subfamily can be clearly distinguished based on the relative centrum length to height, and by the neural process length relative to centrum length. Transverse process characteristics have not been found to be useful for discrimination within this group. However, based on other characteristics species-level identifications can also be achieved. *L. albirostris* can be identified on the basis of centrum length and neural process height. *P. electra* can be distinguished on the basis of its greater neural arch height compared with other Delphininae. There is greater overlap between *L. acutus, L. hosei, D. delphis* and *S. coeruleoalba,* but differences occur on a spectrum and through precise definition of the position along the spine discrimination may be possible in some cases, particularly within the lumbar and caudal regions. This is also the case for *G. griseus* and *T. truncatus*, which can be distinguished from other delphininae based on centrum height and neural process characteristics, and from one another through a combination of relative centrum length, absolute centrum height, and precise position along the spine.

Phocoenidae is represented by a single species within the study area. *P. phocoena* is similar to the Delphininae in many respects, but can be differentiated from this group on the basis of CL/CH, metapophysis height and other neural process characteristics. The curved form of the neural spine is also characteristic of this species.

The data set out here has demonstrated that many cetacean taxa can be reliably differentiated using vertebral morphology and that useful traits for identification can be recognised through an understanding of cetacean evolution and functional morphology. The work has also found that use of relative and absolute dimensions, and precise identification of location along the spine, is key to taxonomic identification when comparative datasets are available. Overall, the method developed here has proved a successful means by which reliable taxonomic differentiation between cetacean taxa can be achieved.

5 APPLICATION TO ARCHAEOLOGICAL SPECIMENS

A series of examples from Cladh Hallan and Bornais have been chosen to demonstrate identification of archaeological specimens through comparisons with the reference dataset. Additional identifications are discussed in Appendix 6. The method for identification follows the approach set out in Step 2 and the flowchart shown in Figure 7. The examples below are included as a guide to demonstrate how identifications can be achieved using the information set out within this thesis. Researchers using the reference dataset (Appendix 7) for identification of their own archaeological specimens should use as many metrics as possible to increase confidence in the identification. The reference dataset should be used as a guide to identifications, supported by assessment of other morphological features.

While adult specimens can be compared with the reference data directly, for sub adult specimens consideration must be given to changes in absolute size and (in the case of delphininae) relative dimensions. Relevant morphological features are also drawn on where relevant to support identifications. This is demonstrated below.

5.1 VERTEBRA (BORNAIS, CONTEXT 789)

The bone is identified as a lumbar vertebra (Figure 36). The narrow neural arch indicates that the bone is from the lower lumbar region. All complete measurements were recorded (following the list in Table 2). Table 3 provides details of the absolute and relative dimensions.

The centrum is present and both epiphyseal discs are fused to centrum indicating a physically mature specimen which can be directly compared with the reference datasets. The processes are absent though their bases remain.

Dimension	Measurement
Centrum Length	25 mm
Centrum Height	30 mm
Centrum Width	33 mm
Breadth of neural arch	8 mm
CL/CH	0.83

Table 3 Measurements for vertebra (789)

Figure 36 Thoracic vertebrae from 1795 on the left and lumbar vertebra from 789 on the right

The relative centrum length and height have been plotted against the reference dataset, shown by the black cross on Figure 37. The relative centrum length and absolute centrum height place the vertebra firmly within the range recorded for *P. phocoena* (Harbour porpoise) (Figure 37). This identification is supported by the form of the bone, including thin neural arch laminae, well-defined arterial grooves and spool shaped centrum, all of which are characteristics of the harbour porpoise. Thus through comparisons with the reference dataset the identification can be achieved, and is supported by morphological evidence, placing a high degree of certainty on the identification.

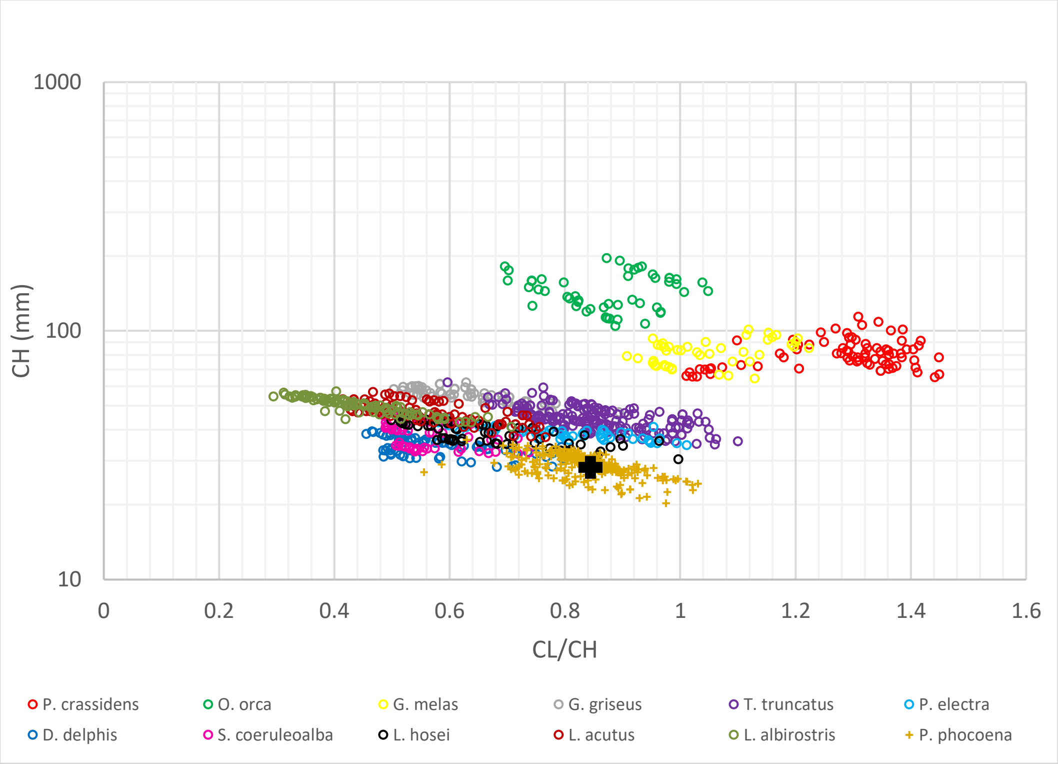

Figure 37 CL/CH and CH in lumbar vertebra of adult Delphinoidea. Y axis is depicted with a logarithmic scale

5.2 Vertebra (Cladh Hallan, context 1413; SF 3501)

The bone is identified as a lumbar vertebra (Figure 38) and is unfused on both faces. On the cranial face the bone has been hollowed out. Centrum length is therefore likely to be slightly shorter than in the original bone, however, the patterning of foramen around the centrum edge indicates that the CL is near complete (apart from the discs). Processes are missing and identification therefore focused on centrum characteristics. Table 4 provides details of the dimensions.

Dimension	Measurement
Centrum Length	87 mm
Centrum Height	88 mm
Centrum Width	95 mm
CL/CH	>0.98

Table 4 Measurements for vertebra (1413; SF 3501)

Figure 38 Lumbar vertebra (SF 3501)

The centrum height and relative centrum length are plotted on Figure 39 by the black cross. The centrum length is incomplete due to the absence of the epiphyseal discs and working indicating that centrum length was originally longer. Although the bone is from a sub-adult it is already too large to be from the smaller Delphininae subfamily or Phocoenidae. While increases in absolute and relative dimensions are to be expected as the bone is from a sub-adult, the general form of the bone is line with the mid-sized Odontoceti. The radial patterning on the non-hollowed out centrum face is also indicative of an Odontoceti, ruling out all of the Mysticeti. All possible candidates from within the mid-sized Odontoceti are considered below.

The absolute centrum height and relative centrum length place the vertebra within the values anticipated for Orcininae (in particular *G. melas*) or Monodontidae. Other mid-sized Odonteceti include the beaked whales. The centrum shape is of the archaeological specimen is very different from that of the beaked whales. Species within this family have barrel-shaped centra, not mirrored by the archaeological specimen. Additionally, although the epiphyseal discs are missing on the archaeological specimen their presence would not be expected to elongate the centrum sufficiently for values to fall within the range of those recorded for the beaked whales. Thus the beaked whales can be ruled out.

Differentiation between the Orcininae and Monodontidae is clearest when processes survive. However, in their absence centrum characteristics also hold clues. The centra of the latter are typified by a more exaggerated spool shaping of the ventral aspect of the centra, and with particular flaring at the caudal end of the vertebra. In contrast the archaeological specimen has a relatively rounded ventral aspect with little flaring or exaggeration to the spool shape.

This suggests a member of the sub-family Orcininae is likely, and the general CL/CH ratio and form of the bone is indicative of *G. melas* (Figure 39). This also corresponds with morphological features. The ventral aspect of the vertebra is gently concave, as seen in *G. melas* and muscle attachments at the base of the neural arch laminae are also generally more pronounced in *G. melas*, and are seen in the archaeological specimen. Thus, all data supports an identification of *G. melas.*

The identification was supported by ZooMS analysis, which confirmed the identification as Delphinidae, with possibilities for *G. griseus, G. melas* and *P. crassidens.*

In this case, while the morphometric data provides a guide for identification, because the bone is from a sub-adult and because it is worked and processes are absent, morphological features of the centra must be relied upon.

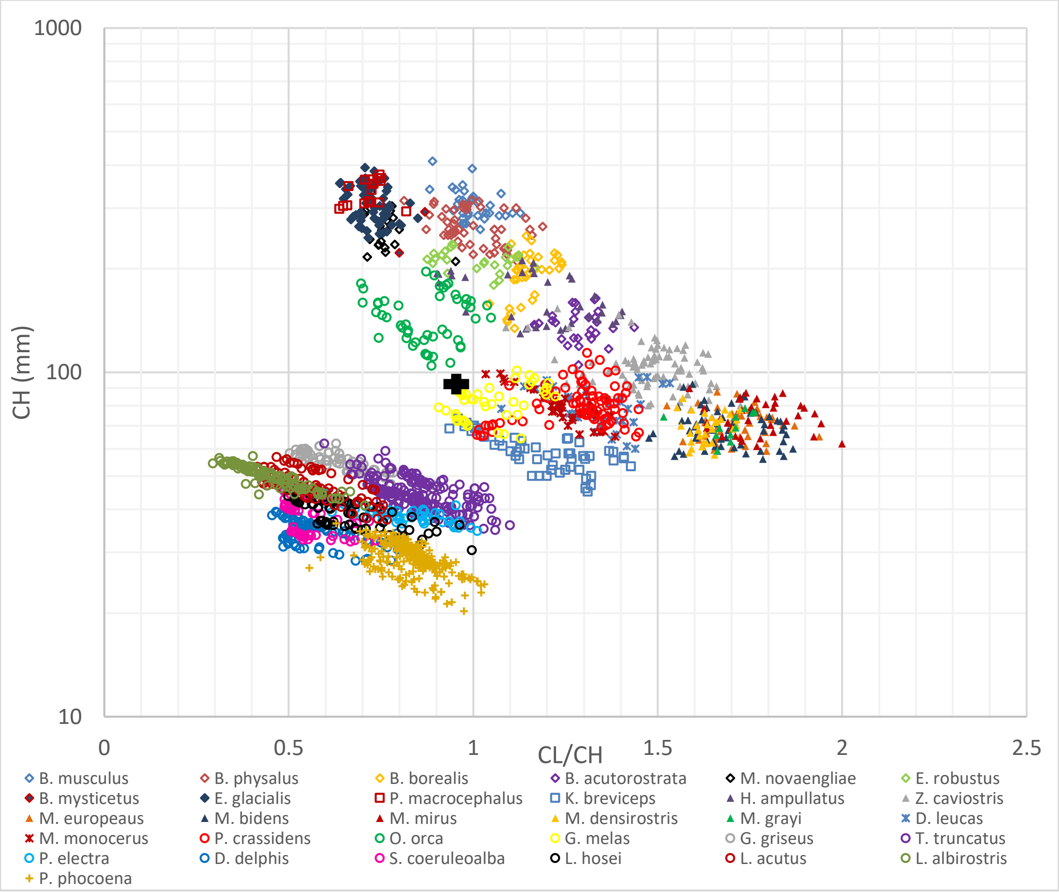

Figure 39 Comparison of lumbar vertebra (SF 3501) marked by the black cross, with the reference dataset showing relative centrum length and height. Y axis is depicted with a logarithmic scale

5.3 VERTEBRA (CLADH HALLAN, CONTEXT 2377; SF 4698)

The bone is identified as a lumbar vertebra with both faces unfused (Figure 40). The neural arch is present but broken off and part of the neural spine survives, but not to the full dorsal extent. The metapophyses are evident and elevated, but they are highly reduced and virtually absent, as seen in the mid to lower lumbar region amongst species of Delphinidae. Table 5 provides details of the dimensions. CL/CH has not been calculated as the bone is likely from a member of the delphininae subfamily (see discussion below), which are known to undergo ontogenetic change to relative dimensions.

Dimension	Measurement
Centrum Length	31 mm
Centrum Height	58 mm
Centrum Width	66 mm

Table 5 Measurements for vertebra (2377; SF 4698)

Figure 40 Lumbar vertebra SF 4698

Metapophysis elevation indicates that this vertebra is from a member of the Delphinidae family. This feature is particularly common amongst the Delphininae. Both centrum length and height are too small to be from any member of the subfamily Orcininae (Figure 41) and although the bone is from a juvenile specimen, which would allow for an increase in size, other features also support an identification from within the Delphininae subfamily. In particular the discoidal form of the centrum is in line with a member of the Delphininae subfamily. Although from a sub-adult specimen the centrum height is 58mm (marked by the approximate line on the figure below) and is therefore too large to be from the smaller Delphininae (or Phocoenidae), thus it is likely a larger Delphininae (*T. truncatus* or *G. griseus*). Species-level identification is not possible as the bone is missing its epiphyses and is a sub-adult delphininae, a subfamily known to undergo ontogenetic change to relative dimensions. ZooMS analysis of this bone led to the identification of superfamily Delphinoidea, supporting the morphometric identification of Delphininae, though with a lower level of precision.

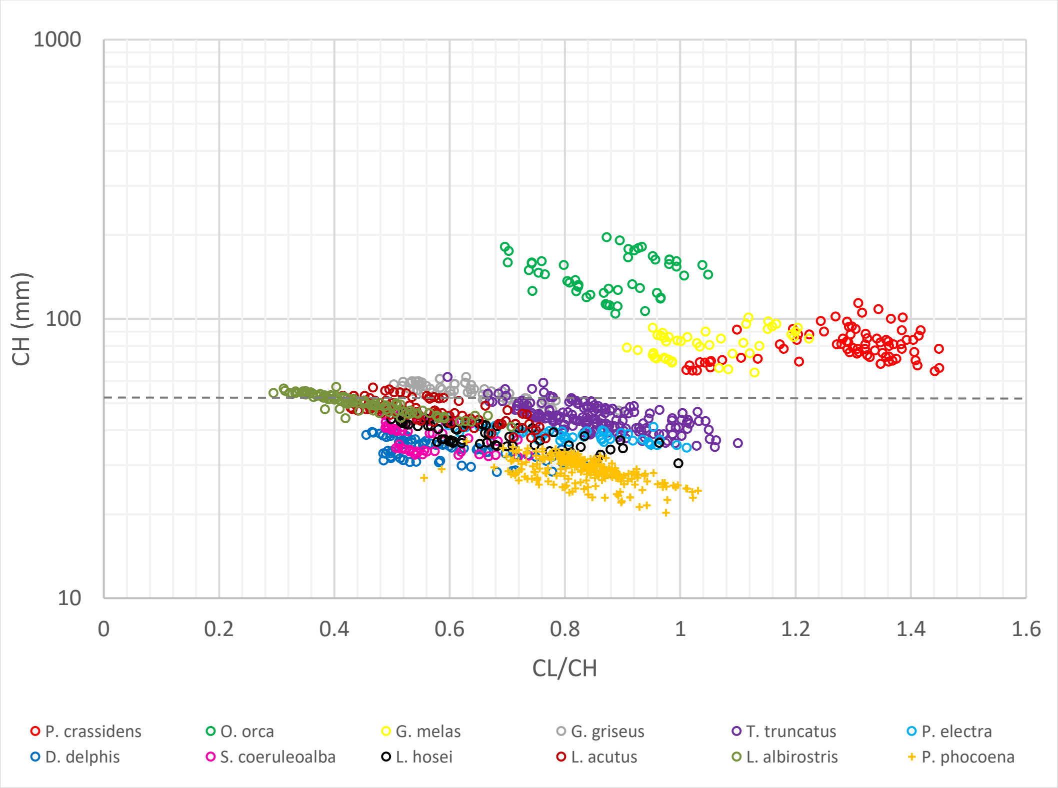

Figure 41 CL/CH and CH in lumbar vertebra of adult Delphinoidea. Dotted line marks CH of the lumbar vertebra SF 4698. Y axis is depicted with a logarithmic scale

5.4 VERTEBRA (BORNAIS, CONTEXT 374, SF 1321)

The bone is identified as a lumbar vertebra. Both centrum faces survive and are unfused. The epiphyseal discs are not present. One side of the bone is partly hollowed out, and both sides have chop marks. The bases of all processes are present, however, the neural spine is missing above the neural arch and the ends of transverse processes are missing. Metapophyses are not evident (likely due to degraded nature of bone on the neural arch). Table 6 provides details of the dimensions.

Dimension	Measurement
Centrum Length	120 mm
Centrum Height	109 mm
Centrum Width	136 mm
Breadth of the neural arch	34 mm
Greatest length of process transversii	77* mm
CL/CH	c. 1.1 (without discs)
CW/CH	1.24
GLPT/CH	c. 0.71

Table 6 Measurements for vertebra (374; SF 1321)

As the vertebral epiphyses are not present the CL/CH cannot be properly calculated, however, the ratio without the discs is 1.1, indicating that with the discs present this would be greater. Taxa with centrum length to height ratios of greater than 1.1, and with centrum heights of 109mm and greater include the smaller balaenopterids (*B. acutorostrata* and *B. borealis*), the larger Ziphiidae (*H. ampullatus* and *Z. caviostris*) and the largest specimens of *P. crassidens* (Figure 42).

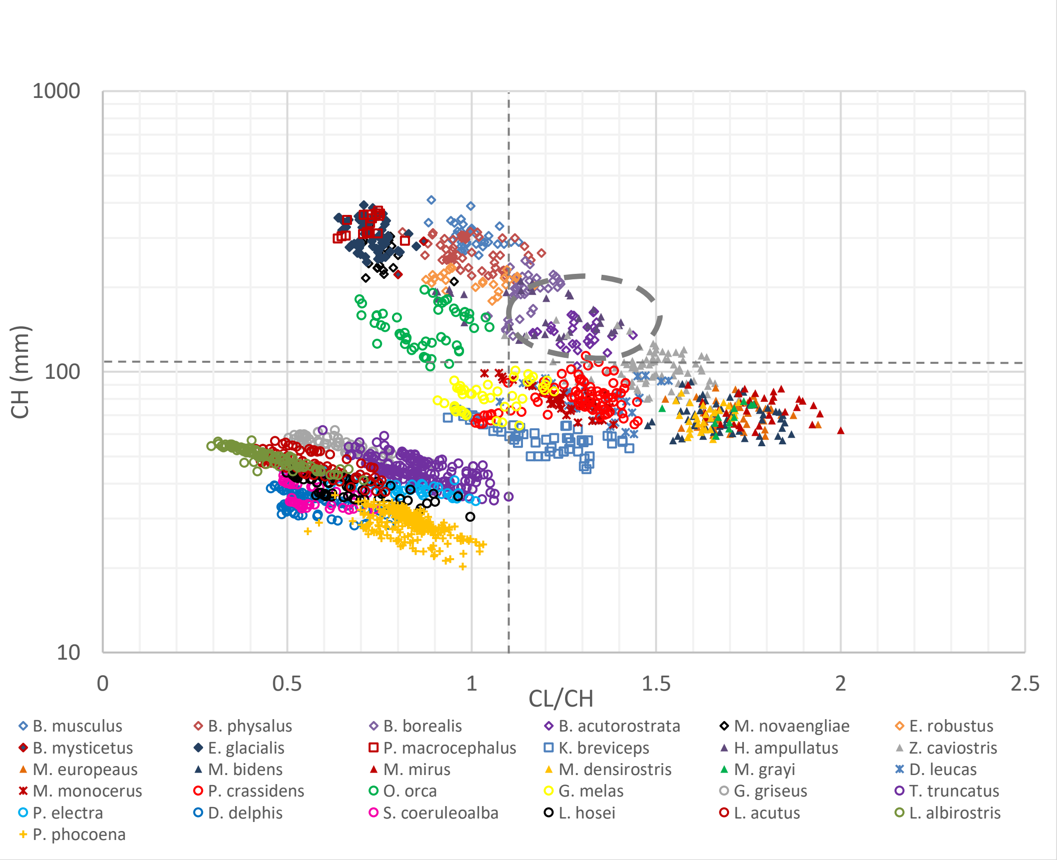

Figure 42 CL/CH and CH in lumbar vertebra of adult cetaceans showing general dimensions of SF 1321. Y axis is depicted with a logarithmic scale

Centrum width can be used to further distinguish between these taxa, and when this factor is taken into consideration the archaeological specimen can be determined to be from a smaller balaenopterids (*B. acutorostrata* and *B. borealis*) or *H. ampullatus* (Figure 43).

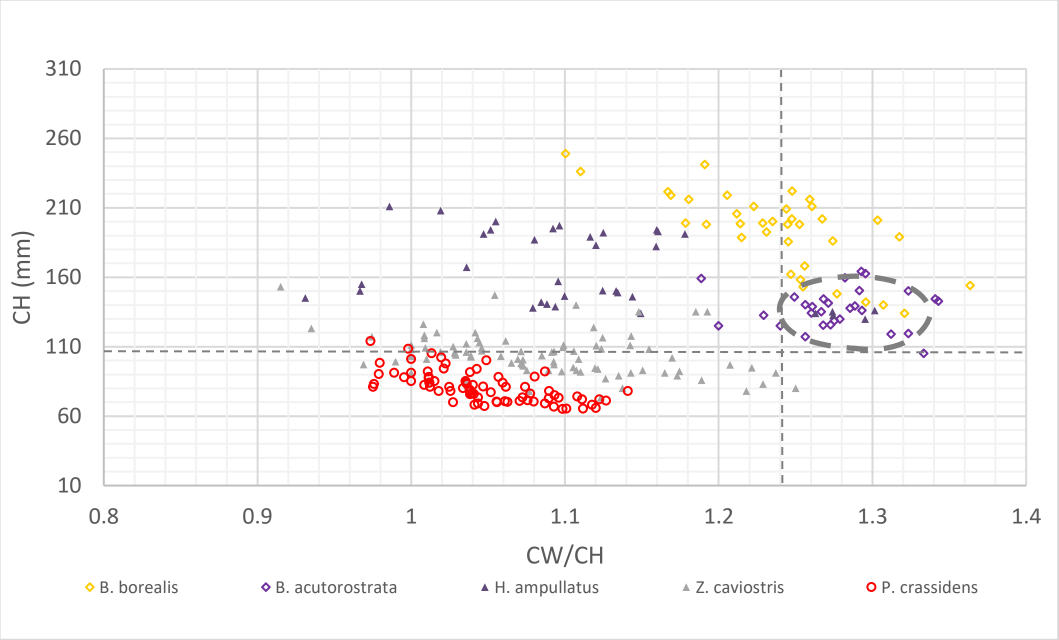

Figure 43 CW/CH and CH in lumbar vertebra of adult cetaceans showing general dimensions of SF 1321.

Transverse process characteristics can further be used distinguish between these taxa. While the full transverse processes are not present, the greatest length of the sections surviving can be used to gauge whether the archaeological specimen has measurements which are too large to be from any of the potential taxa. The GLPT/CH ratio is at least 0.71 (and may be greater if the broken portions of the transverse processes included areas of greater length) and GLPT is at least 77mm (Figure 44) demonstrating that the archaeological specimen has values greater than the recorded range of *H. ampullatus*, indicating that the bone is from a Balaenopterinae.

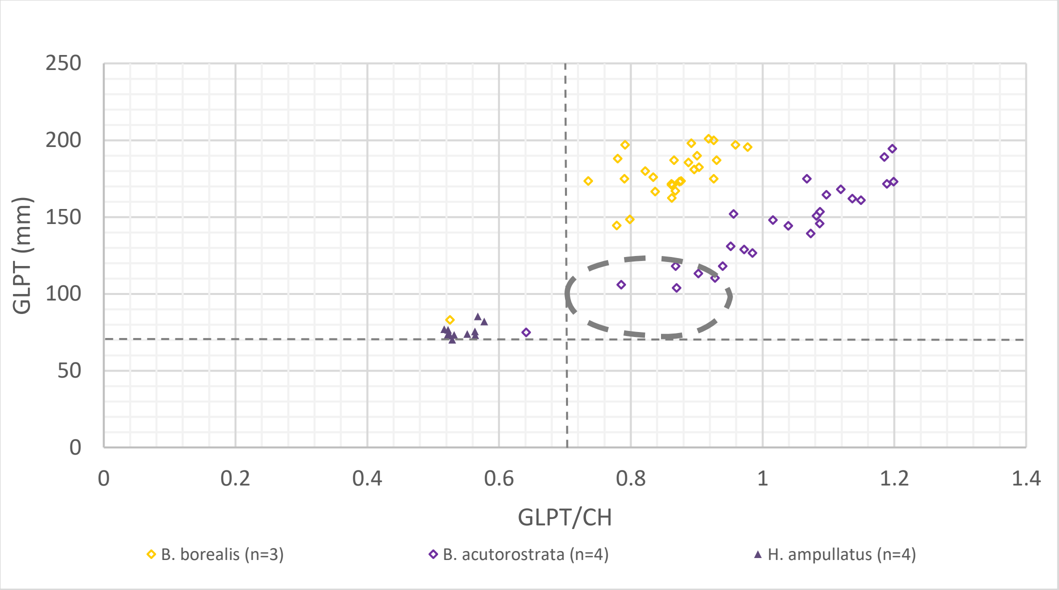

Figure 44 GLPT and CH in lumbar vertebra of adult cetaceans

Other features are of use in discrimination between these taxa and support this identification. The transverse processes in *H. ampullatus* have a strong ventral inclination. This is contrast to those of the balaenopterids which tend to extend horizontally from the centrum (see Figure 45). In addition, the fusion pattern on the centrum of the archaeological specimen is generally stippled, which is typically a feature of Mysticeti rather than Odontoceti vertebral centra (see Appendix 6, section 2.4). Both morphometric and morphological evidence therefore supports an identification of smaller balaenopterid.

While *B. acutorostrata* and *B. borealis* can be distinguished on the basis of neural process characteristics and size, the neural process is incomplete in the archaeological specimen and the crucial inclination of the neural process which allows for discrimination between these species cannot be gauged. Thus, the archaeological specimen is identified as Balaenopterinae.

Figure 45 Top left: Lumbar vertebra from H. ampullatus (NHM Wands 1860.12.2.2 L5), top right: archaeological specimen SF 1321; Bottom: Lumbar vertebra from B. acutorostrata in the collection of Neil Anderson, Shetland.

6 FURTHER WORK

The previous sections have demonstrated that the reference dataset and toolkit produced as part of this thesis can be used to guide the identification of cetacean vertebrae from archaeological sites. The toolkit and dataset are presented here in their first iteration, and ongoing work will seek to hone and improve these outputs. Through the collection of more data ongoing work will define more clearly where taxa can be differentiated and where they cannot, and which characteristics are of greatest use in different circumstances. At present the reference dataset can be used as a guide to identification which should be supported by a general understanding of cetacean vertebral morphology and comparison with reference collections.

The current dataset represents around one third of all cetacean species worldwide, covering those which are present in north-eastern Atlantic waters. However, many cetacean bone assemblages exist beyond this area and data collection should therefore be expanded to include all species. Likewise, the method and datasets should also be expanded to include other parts of the cetacean skeleton (research which is currently underway).

Further work could also hone the morphometric data relating to the vertebrae. The current study considered potential sources of variation between vertebrae (such as age), in addition to variation caused by taxonomic identity. Sexual dimorphism is known to affect cetaceans. Information about sex was not consistently available for specimens within the current dataset (see Appendix 3), and the effects of this potential source of variation on the dataset could be assessed in future work.

Statistical analysis could also be applied and the dataset reported on here shares similarities with the multivariate Iris Flower dataset, which Fisher (1936) used in his seminal paper on the use of multiple measurements in taxonomic problems. Linear Discriminant Analysis and Principal Component Analysis, amongst other methods, can be used to separate the data. Statistical methods such as this could be applied to the cetacean bone data to demonstrate in a quantitative manner which taxa can be reliably differentiated (here discussed qualitatively). Use of population standard deviations would also be desirable, in order to arrive at standard deviations for the range of dimensions for each vertebrae which would be representative of the population rather than a sub-set, such as the current dataset is based. However, use of these methods would require analysis of variation between each individual vertebra. Currently the dataset is small for each individual vertebra, and more data would be required to undertake reliable statistical analyses.

Chapter 6: Results on identification and analysis: Cetaceans at Cladh Hallan and Bornais from the Bronze Age to Norse periods

1 INTRODUCTION

This chapter sets out the results of the assessment and analysis of the cetacean bone assemblages from Cladh Hallan and Bornais. The discussion is led by taxonomic identification. It establishes:

- Results of identification using the method and toolkit for morphological assessment and ZooMS analysis, and comments on the success of the methods;
- Archaeological results including taxonomic identifications, elements and quantification of cetacean remains from Cladh Hallan and Bornais;
- An overview of modifications to the assemblages, and in particular taxonomic identification, element and quantification data relating to unmodified elements, modified elements, worked and unworked fragments and artefacts to frame discussions in the following chapter; and
- An overview of spatial distribution of the remains with a focus on species.

Results on the use of the identification methodologies are presented first. This is followed by the archaeological presentation of the results, concerned with highlighting key temporal and spatial patterns which are interpreted in Chapters 7 and 8. The cetacean bone registers which set out full results of recording, assessment and analysis are included within Appendix 4 and 5. Some of the results for Bornais have been published within the recent monograph on mounds 2 and 2A (Evans 2021; Sharples 2021). However, the data set out here includes additional identifications obtained following the publication of that work. Mound 1 is also reported on in detail, updating previous work (Mulville and Powell 2012).

2 IDENTIFICATION RESULTS

The following section gives an overview of the success of the morphological method of identification, ZooMS analysis and a combination of the two techniques.

The Cladh Hallan and Bornais assemblages were identified to the Order Cetacea using initial morphological analysis with higher level taxonomic identifications achieved morphologically or morphometrically for more complete or diagnostic elements, or using ZooMS.

The Cladh Hallan and Bornais assemblages were found to comprise of 1285 and 1560 pieces of bone respectively. Of these, 462 pieces of bone from Cladh Hallan (36% of the assemblage), and 261 pieces of cetacean bone from Bornais (17% of the assemblage) were directly identified to a taxonomic level higher than the Order Cetacea using a combination of morphological analysis and ZooMS. The level of success was lower at Bornais primarily due to the high degree of burning seen on a large proportion of the assemblage (principally from mound 1), which hampered both morphological and biomolecular identification. The results from each method are discussed separately below.

The NISP for each taxonomic rank and identification is set out in Tables 7 and 8 below, alongside the results from the biomolecular and combined methods.

		NISP		
Taxonomic rank and identification	Morphology	ZooMS	Combination	Total
Species	330	74	2	406
B. musculus		21		21
B. physalus		3		3
M. novaeangliae		9		9
P. macrocephalus	327	41		368
O. orca	1		1	2
G. melas	1		1	2
P. phocoena	1			1
Genus	1			1
Lagenorhynchus sp.	1			1
Subfamily	5	1	1	7
Balaenopterinae		1		1
Delphininae	1			1
Large delphininae	4		1	5
Family	2	12	2	16
Balaenidae		10		10
Delphinidae	2	2	2	6
Superfamily	2	2	1	5
Delphinoidea	2	2		4
Small delphinoid			1	1
Parvorder	18	6		24
Medium to large Odontoceti	1			1
Mysticeti	6	6		12
Odontoceti	11			11
Order	823			823
Cetacea	823			823
Size groups	3			3
Large cetacean	1			1
Medium to large cetacean	2			2
Grand Total	1184	95	6	1285

Table 7 Identifications derived from different identification methods at Cladh Hallan

	NISP			
Taxonomic rank and identification	Morphology	ZooMS	Combination	Total
Species	**7**	**94**	**3**	**104**
B. musculus		3		3
B. physalus		9		9
B. acutorostrata		1		1
M. novaeangliae		5		5
E. robustus		9		9
P. macrocephalus	5	66		71
O. orca		1	2	3
P. phocoena	2		1	3
Subfamily	**5**		**1**	**6**
Balaenopterinae	1			1
Delphininae	2		1	3
Small Delphininae	2			2
Family	**12**	**32**	**3**	**47**
Balaenopteridae		3		3
Balaenidae		19	1	20
Delphinidae	9	8	2	19
Ziphiidae	3	2		5
Superfamily	**3**	**10**		**13**
Delphinoidea	1	10		11
Small delphinoid	2			2
Parvorder	**6**	**15**		**21**
Mysticeti	1	15		16
Odontoceti	5			5
Order	**1295**	**4**		**1299**
Cetacea	1295	4		1299
Size groups	**68**		**2**	**70**
Large cetacean	61		2	63
Large to Medium cetacean	4			4
Medium cetacean	1			1
Small cetacean	2			2
Grand Total	**1396**	**155**	**9**	**1560**

Table 8 Identifications derived from different identification methods at Bornais

2.1 MORPHOLOGICAL IDENTIFICATION

A total of 361 pieces of bone from Cladh Hallan (28% of the assemblage) could be identified to taxonomic ranks higher than Order using morphological methods, with species-level identifications achieved in 330 cases.

The high number of morphological identifications was largely due to the number of fragments of sperm whale skull which can be recognised by its unusual trabeculae structure (e.g. Figure 46) which accounted for 327 of the species-level identifications. However, identifications of vertebrae were also achieved using the method and toolkit for morphometrical identification set out in Chapter 5. Detailed discussion of the results of the application of the methodology to the Cladh Hallan assemblage is set out within the previous chapter and Appendix 6. In total 17 vertebrae and 29 vertebral epiphyses were identified to above Order level using morphological assessment. Species-level identifications were only possible on three of the vertebrae.

Figure 46 Unusual sperm whale skull structure seen in an artefact from Cladh Hallan (SF 3811)

The majority of the bone from Bornais could only be identified as cetacean (Table 8). However, morphological analysis led to the identification of a further 101 bones (6% of the assemblage) to taxonomic ranks higher than the Order Cetacea, or to size groups. Most of the morphological identifications come from a large number (59 in total) of mandible fragments from a large cetacean found on mound 1. These were burnt and highly fragmented and could represent the same bone. Vertebral elements were also identified morphologically following the method in Chapter 5. In total 27 vertebrae and 12 vertebral epiphyses were identified to above Order level by morphological assessment (some using a combination of ZooMS and morphological identification, but where morphological identification alone would have led to identifications above the Order level; full details in Appendix 6). As at Cladh Hallan only a limited number could be identified to species level (2 vertebrae in this case).

Morphological identification on both sites was hampered by the predominance of unfused vertebrae and loss of identifiable features such as processes (see Figure 47). The presence of a number of specimens from the sub-family Delphininae further inhibited species-level identifications, as many species within this subfamily are morphologically similar (see Chapter 5). Size groupings within the subfamily were used to partially address this issue, and the 'large delphininae' identified represent either the bottlenose dolphin or Risso's dolphin, while 'small delphininae' represent either Lagenorhynchus sp., the common dolphin, striped dolphin or melon headed whale.

Although breakages and loss of epiphyses reduced the efficacy of the method for morphological identification, the assessment still resulted in identifications to species, subfamily, family, superfamily and parvorder level on both sites. This data primarily demonstrated the presence of a range of delphinoids (dolphins and porpoises) on both sites largely owing to the relative completeness of vertebral elements of these taxa compared with others, though other groups such as the balaenopterids and beaked whales were also recorded. While species-level identifications provide the best basis for interpretations, identifications to higher taxonomic levels can also result in data suitable for archaeological interpretation.

Figure 47 Examples of cetacean vertebrae from Bornais showing unfused state and loss of processes in many cases

2.2 ZOOMS ANALYSIS

Further detailed taxonomic identifications were also achieved using ZooMS analysis. At Cladh Hallan ZooMS analysis led to the direct identification of 101 bones (8% of the assemblage) (see counts for ZooMS and Combination in Table 7). The results of an earlier study which included an additional three identifications by ZooMS have also been included within this table (Buckley et al. 2014). In total ZooMS led to 74 species-level identifications and 21 identifications to subfamily, family, super family and parvorder level. Additional identifications were made using a combination of ZooMS and morphology (see below).

ZooMS analysis of the Bornais material was undertaken on 164 bones, including 5 samples analysed by Buckley (et al. 2014)[10]. This resulted in 160 identifications above the taxonomic rank of Order (see 'ZooMS' and 'Combination' counts in Table 8). The analysis led to 94 species-level identifications and a further 57 bones were identified to family, superfamily or parvorder level by ZooMS.

2.3 COMBINATION

Following the initial morphological assessment and ZooMS analysis the assemblage was reassessed morphologically to determine whether a more precise identification could be gained by a combination of the two methods. At Cladh Hallan combined methods resulted in the identification of 6 bones to above Order level, and at Bornais a further 9 bones were identified to above Order level. At both sites the combined identifications were primarily possible on delphinoid bones, reflecting the fact that ZooMS can be helpful to distinguish between morphologically similar species within this superfamily. Further details on the precise identifications are set out within Appendix 6.

3 ARCHAEOLOGICAL RESULTS

The following section sets out the results of the assessment and analysis of the Cladh Hallan and Bornais assemblages, including a breakdown of taxa, elements and quantification of cetacean bone at both sites. The characteristics of the assemblages are discussed chronologically to enable later discussion of temporal patterns in use and procurement, with the overall goal of addressing archaeological research aims set out in Chapter 2.

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[10] Note, a sixth sample analysed by Buckley et al. (2014) was identified as from seal, and is therefore not included here.

3.1 CLADH HALLAN: TAXA, ELEMENTS AND QUANTIFICATION

3.1.1 OVERVIEW

The majority of the cetacean bone from Cladh Hallan came from the Late Bronze Age phases (Table 9), with a much smaller assemblage from the Early Iron Age phase, and a few fragments from the Early Bronze Age. Phase 9 produced the highest overall counts.

Period and Phase	Cetacean bone counts
Early Bronze Age	**7**
3	7
Late Bronze Age	**1164**
4	5
5	1
6	16
7	10
8	205
9	481
10	178
11	161
12	107
Early Iron Age	**94**
13	25
14	25
15	9
16	35
Uncertain	**20**
0	2
U/S	18
Grand Total	**1285**

Table 9 Overview of cetacean bone quantities within the Cladh Hallan assemblage

3.1.2 TAXA

A range of taxa were identified at Cladh Hallan, with some major differences observed between periods. Figure 48 shows a breakdown of the percentage of Number of Identified Specimens (NISP) for each phase. Only phases in which identifications above Order level were achieved are shown.

A single identification of Odontoceti was made in Early Bronze Age deposits. No other remains from the Early Bronze Age could be identified and the assemblage from this period was very small.

The larger Late Bronze Age assemblage produced evidence of at least 10 different species. Sperm whale represent the most frequently identified species throughout the Late Bronze

Age phases (NISP 368), followed by Balaenidae (NISP 10) and humpback whale (NSIP 9) (Figure 48). All other species, which include blue whale, fin whale, and a smaller Balaenopterinae (either sei or minke whale), killer whale, pilot whale, and smaller dolphins including Lagenorhynchus sp. (either white beaked or white sided dolphins) and large delphininae (either bottlenose dolphin or Risso's dolphin) were represented by fewer than 5 pieces of bone each.

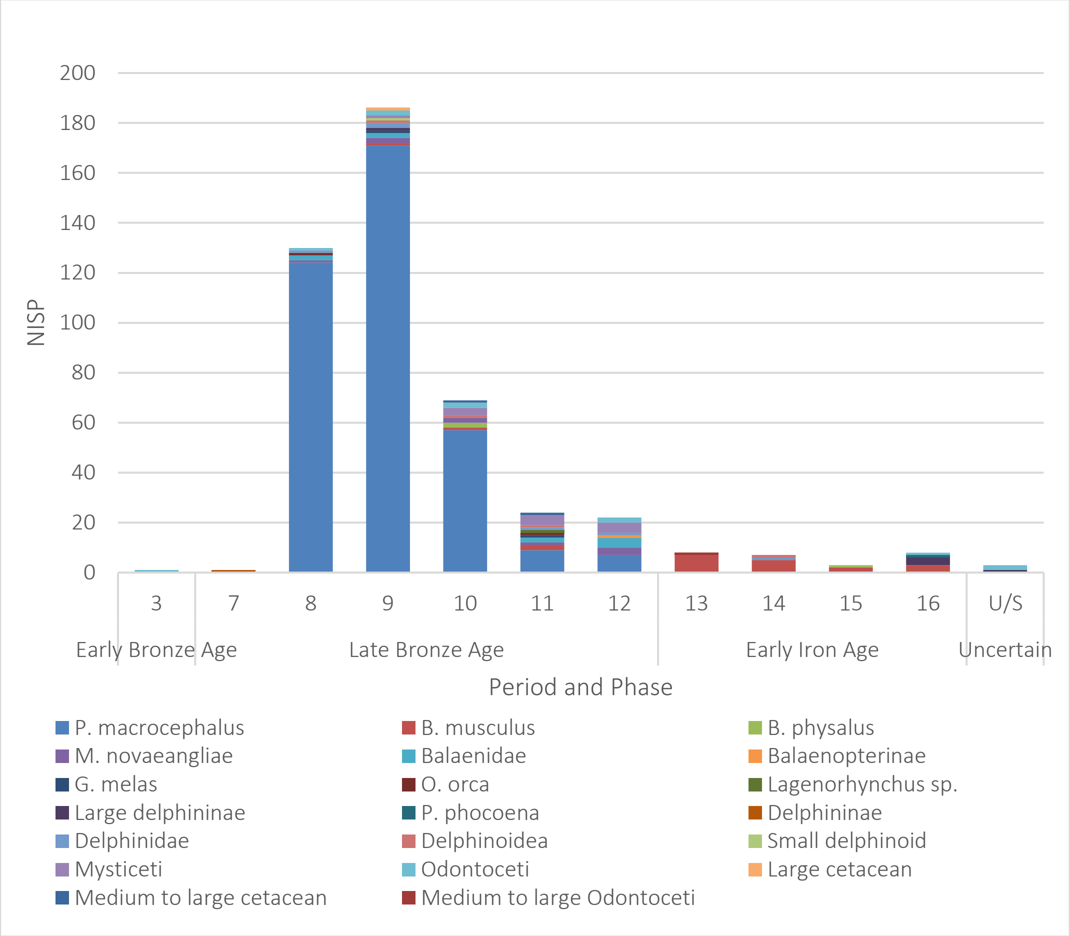

Figure 48 Taxa identified at Cladh Hallan

Balaenidae is made up of two species. While ZooMS sequencing has been undertaken for the right whale, there is no published sequence for the bowhead whale though Buckley et al. (2014: 636) indicate that it cannot be distinguished from the right whale by peptide analysis. Bowhead whales are an ice-edge species and as such it is very unlikely that they would have inhabited Hebridean waters during the Holocene and it is probable that the bone identified as Balaenidae represents right whale, as asserted by previous studies (Buckley et al. 2014: 639).

The remains from the early Iron Age phases (13 -16) are less varied, with evidence of 4 different species, though this may be a function of the smaller sample size (which totalled

94 fragments of cetacean bone, compared with over 1000 in the Late Bronze Age period) (see Table 9). The species composition of the assemblage is also very different with blue whale dominating the identified samples (NISP 17) and sperm whale absent. Fin whale was identified (NISP 1) as were smaller species including large delphininae (either bottlenose dolphin or Risso's dolphin) (NISP 3) and harbour porpoise (NISP 1).

3.1.3 ELEMENTS

Elements could be identified for 415 bones. A range of elements were present, representing the head, spine, ribs and appendicular skeletons of a variety of species (Tables 10 and 11). Some elements were present in an unmodified form, while others had been worked into artefacts or reduced to smaller fragments but retained sufficient characteristics for identification. Modifications are discussed in more detail later.

The most numerous element(s) were from the maxilla, found in Late Bronze Age phases 8-12 all identifiable by the unusual trabeculae structure. All belonged to sperm whale(s). No complete skulls are present and instead this body part is represented by large numbers of mostly small fragments. Sperm whale was additionally represented by a tooth, rib and vertebral epiphysis.

Five teeth were recorded of which three could be identified. In addition to the sperm whale tooth, teeth from a killer whale and Delphinoidea were also identified. The sperm whale tooth and killer whale tooth were both from Late Bronze Age deposits (phases 9 and 11 respectively).

With the exception of head elements, the majority of the material derives from vertebrae reflecting both the predominance of these elements within the cetacean body and the common pattern seen on Hebridean sites (Mulville 2002). The appendicular skeletons of a small number of cetaceans were also present. Vertebral remains represented a range of species. Most vertebrae were from delphinoids though a vertebra and process from a blue whale were also identified. Thoracic vertebrae of a killer whale, and one from a pilot whale were identified, in addition to a lumbar vertebra from the same species, a caudal vertebra from Lagenorhynchus sp. (either white sided or white beaked dolphin), and three lumbar vertebrae and a caudal vertebra from a large delphininae (either bottlenose dolphin or Risso's dolphin) and other more generic identifications. Two of the lumbar vertebrae from the bottlenose dolphin/Risso's dolphin were from the same phase and may represent an articulated portion. Thoracic, lumbar and caudal vertebrae are each represented between three and four times within the assemblage, demonstrating no preference for particular regions of the spine.

A wider range of taxa were represented by vertebral epiphyses, including blue whale, humpback whale, sperm whale and delphinoids. The presence of vertebral epiphyses in relatively high numbers (37 were identified on the site), indicates the exploitation of individuals who have not reached full physical maturity[11]. Most species were represented by single identifications, except for blue whale and sperm whale. Blue whale epiphyses (which account for 5 of the epiphyses identified) derive solely from Early Iron Age deposits. The range of sizes present suggests that they derive from different locations along the spine (Figure 49).

	Periods and Phases													
	EBA				LBA					EIA				
Elements	**3**	**5**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**U/S**	**Total**
Skull fragment				123	164	48	5	2						342
Tympanic bulla		1												1
Tooth	1				1		2	1						5
Thoracic vertebra				2	1									3
Lumbar vertebra							1					2		3
Lumbar vertebra (lower lumbar)					1									1
Caudal vertebra					1	1	1						1	4
Vertebra				1	3	3	1	1						9
Vertebral process			1								1			2
Vertebral epiphysis			1	1	5	3	4	11	1	4		5	2	37
Rib					2			1					1	4
Scapula												1		1
Phalange						1				1				2
Long bone epiphysis					1									1
Total	**1**	**1**	**2**	**127**	**179**	**56**	**14**	**16**	**1**	**5**	**1**	**8**	**4**	**415**

Table 10 Cetacean bone elements identified in each phase at Cladh Hallan

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[11] Age profiles have not been discussed in detail as rates of fusion of vertebral epiphyses for cetaceans are not fully known, and in some very old individuals fusion may not be fully complete (R. Sabin pers. comm. 2019). Studies have also indicated differences between species. Complete fusion along the entire spine has been found to be rare in the harbour porpoise and many specimens retain unfused epiphyses long after sexual maturity. Complete fusion is more common in delphinids (Galatius 2005).

	Identification																		
Elements	B. musculus	Balaenopterinae	M. novaeangliae	P. macrocephalus	O. orca	G. melas	Lagenorhynchus sp.	Large delphininae	P. phocoena	Delphininae	Delphinidae	Delphinoidea	Small delphinoid	Odontoceti	Medium to large Odontoceti	Mysticeti	Cetacea	Large cetacean	Medium to large cetacean	Total
Skull fragment				342																342
Tympanic bulla																	1			1
Tooth				1	1							1		2						5
Thoracic vertebra					1	1					1									3
Lumbar vertebra						1		2												3
Lumbar vertebra (lower lumbar)								1												1
Caudal vertebra							1	1			1								1	4
Vertebra	1											1	1			1	4		1	9
Vertebral process	1									1										2
Vertebral epiphysis	5	1	1	4				1			3	1		9	1	5	6			37
Rib			1														2	1		4
Scapula									1											1
Phalange			1								1									2
Long bone epiphysis			1																	1
Total	7	1	4	347	2	2	1	5	1	1	6	3	1	11	1	6	13	1	2	415

Table 11 Taxonomic identification of elements at Cladh Hallan

Figure 49 Blue whale vertebral epiphyses from Early Iron Age deposits. From left to right SF 2074, 2073, 3171. Farthest right is from context 462 but has no SF number.

Four fragments of vertebral epiphyses were also identified as sperm whale, one from phase 9 and three from Phase 12. Two of the latter were derived from a single context (1315) and although two separate finds numbers have been given to the pieces (SF3453 and SF 4826) they were found to refit (Figure 50).

Figure 50 Sperm whale vertebral epiphysis SF3453 and SF 4826 (left and right), refitted

Other elements include the rib of a humpback whale and rib fragments identified as large cetacean. Flipper bones including a phalange and the epiphyseal end of a long bone, both from a humpback whale, were identified in Late Bronze Age deposits (phases 10 and 9 respectively). A humpback whale rib and vertebral epiphysis were also present in Late Bronze Age deposits (phase 12).

3.1.4 QUANTIFICATION

Although the majority of the fragments identified were from sperm whales, other species may also be represented by fragments identified to higher taxonomic levels. The ability to identify fragments of sperm whale skull based on their morphology is likely to have led to a skew in the dataset toward that species, and at the expense of other species which have a less distinct bone structure.

The uncertainty regarding quantification hampers interpretation. The longevity of the activity at Cladh Hallan (which spanned over a thousand years), may render it likely that multiple individuals are represented and the bones represented on site are likely to be only a small fraction of the whales exploited (owing to selective transport which is likely to have affected the remains of larger species in particular). The MNI is therefore likely to be higher than one for each species. However, there is nothing within the dataset which proves the presence of more than one individual of each species. Additionally, the deposition of multiple elements from the same species within successive phases, e.g. sperm whale and humpback whale within Late Bronze Age deposits and blue whale within Early Iron Age deposits may support the argument for these remains representing the same individuals. A conservative approach is applied here and an MNI of one assigned for each species. Analysis of aDNA to identify individual specimens would shed further light on quantification (e.g. Evans et al. 2016; UHI 2019).

3.2 BORNAIS: TAXA, ELEMENTS AND QUANTIFICATION

3.2.1 OVERVIEW

The Late Iron Age and Norse phases at Bornais produced sizeable assemblages (Table 12). The Late Iron Age I assemblage was by far the largest[12], however, much of the material from this phase was highly fragmented and burnt.

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[12] Mound 1 material including Late Iron Age and Norse remains was previously reported on by Mulville (2012). Mulville (2012: 194) recorded 993 fragments from Mound 1, a higher total than reported on here. It is thought that a bag of bone may have been missing by the time the current analysis took place and the additional fragments reported by Mulville (2012) are not discussed further here.

Period	NISP
Late Iron Age I	700
Late Iron Age II	18
Early Norse	155
Middle Norse	253
Late Norse	173
Final occupation	24
Norse	216
Unphased and U/S	21
Total	**1560**

Table 12 Overview of cetacean bone quantities within the Bornais assemblage

3.2.2 TAXA

A range of taxa were identified on the Bornais mounds (Figure 51). Due to the very small size of the Late Iron Age II assemblage no distinction between the LIA I and LIA II period is made. In Iron Age deposits taxonomic identification was hampered by the degree of burning on the large mound 1 assemblage, though Balaenidae (NISP 4) (likely right whale, see discussion in Chapter 6), gray whale (NISP 3), sperm whale (NISP 2) and fin whale (NISP 1), were all identified. Other fragments were identified to higher taxonomic levels including Ziphiidae (beaked whales) (NISP 1), super family Delphinoidea (dolphins and porpoises) (NISP 1), and suborders Mysticeti (baleen whales) (NISP 3) and Odontoceti (toothed whales) (NISP 1) and to size groups, including large cetaceans. The latter was the most numerous identification (NISP 59), though this is owing to a large number of burnt fragments from large species. The remains indicate the presence of at least 6 different species.

A range of taxa were also identified in Norse deposits. Sperm whale fragments dominated the Norse deposits (NISP 67), and delphinoids (including dolphins and porpoises) were represented in relatively high numbers (NISP 44). Other species with high NISPs included balaenid (NISP 16 in Norse deposits), fin whale (NISP 8) and gray whale (NISP 6). Other taxa including blue whale, minke whale, humpback whale, beaked whale, were represented by NISPs of lower than 5 each.

In addition to having the highest NISP in Norse deposits, sperm whale identifications also increased through time, with 14 fragments identified in Early Norse deposits, 19 in Middle Norse deposits and 34 in Late Norse deposits. The number of species also increased through time: a minimum of 7 species were identified in the Early Norse period, 8 in the Middle Norse period, and 9 in the Late Norse period. Norse deposits therefore included a wider range of species than the Late Iron Age deposits, following the pattern first identified by Mulville

(2002).

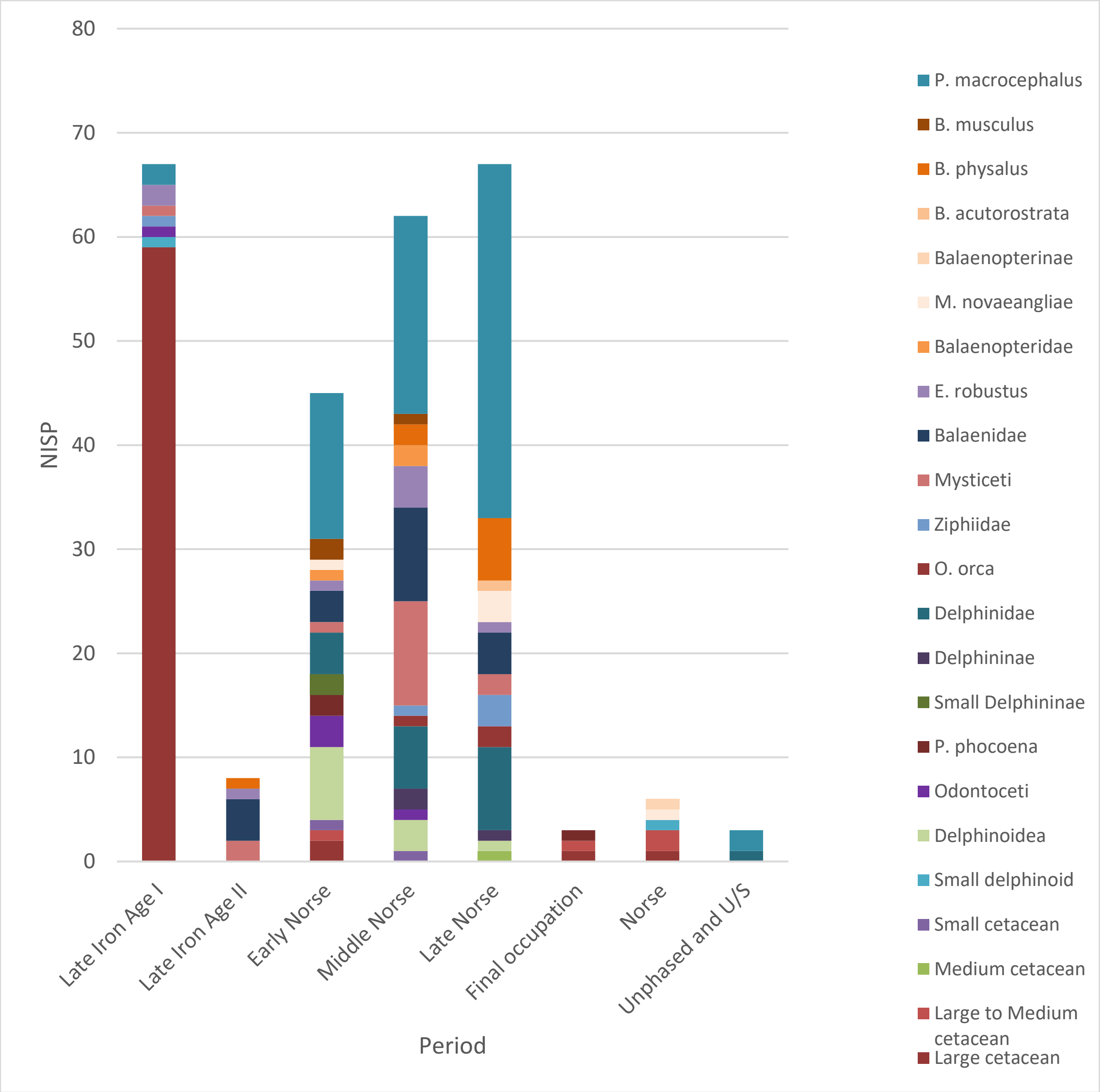

Figure 51 Taxa identified at Bornais (NISP) for mounds 1, 2 and 2A

3.2.3 ELEMENTS

The elements present at Bornais represent the axial and appendicular skeleton. A total of 237 elements were identified from across the phases (Table 13). The large number of mandible fragments from Late Iron Age deposits on mound 1 make up the majority (61%) of the elements identified, with skull, mandible, tooth and ear fragments making up 71% in total. Head elements represent the remains of both large and small taxa (Table 14), though skull fragments solely represent the larger species.

	Period								
Elements	Late Iron Age I	Late Iron Age II	Early Norse	Middle Norse	Late Norse	Final occupation	Norse	Unphased and U/S	Grand Total
Skull			4	4	3				11
Mandible	142				3		1	1	147
Ear bone	1								1
Tooth					11			1	12
Cervical vertebra			1						1
Thoracic vertebra			3	1			1		5
Lumbar vertebra				1		1			2
Caudal vertebra			2		2	1			5
Caudal fluke vertebra					1				1
Vertebra	1		3	1	4				9
Vertebral centrum			1	2			1		4
Vertebral process		1		1	1				3
Vertebral epiphysis	5		5	8	1			2	21
Rib	1		1	3			3		8
Metacarpal			2						2
Phalange or metacarpal			1	2					3
Phalange			1				1		2
Grand Total	150	1	24	23	26	2	7	4	237

Table 13 Elements identified on mounds 1, 2 and 2A

As with many sites (Mulville 2002) vertebrae and vertebral epiphyses are an important part of the assemblage, constituting 21% of the identifiable elements. A range of taxa are represented by vertebrae and vertebral epiphyses. The former represent blue whale, fin whale, Balaenidae, sperm whale, killer whale, small dolphins and harbour porpoise, while the epiphyses represent gray whale, sperm whale and Delphinoidea. Vertebral region could only generally be characterised for smaller taxa. This is primarily due to the higher degree of modification the vertebrae of larger species and the associated loss of identifiable traits (discussed further below). All regions of the spine were represented by Delphinoids. The caudal and thoracic regions were most common, followed by the lumbar region. A single cervical vertebra was also recorded.

Ribs and elements representing the appendicular skeleton were also identified. Ribs tended to be from larger species while flipper portions were generally represented by smaller taxa (Delphinidae).

Temporal patterns are evident. The Late Iron Age assemblage mainly includes elements of large species including the fragmented mandible, epiphyses from a sperm whale, beaked whale and gray whale, and a vertebral process from a fin whale. A gray whale rib is also represented within the LIA deposits. Only a single vertebra from a small delphinoid is present, identified in LIA I deposits, no small species were identified in LIA II deposits. This contrasts with the Early, Middle and Late Norse remains which have high numbers of Delphinoid bones, and in particular vertebrae though flipper elements, mandibles and teeth are also present. Three sets of articulating delphinoid elements were also identified within Early and Middle Norse deposits including the metacarpals of a delphinid (1193); two probable articulating caudal vertebrae from a harbour porpoise (2356); and two mid thoracic vertebrae from a small delphininae (1795). Late Norse deposits have fewer delphinoid vertebrae.

Teeth and mandibles are more frequent in Late Norse deposits. These included fragments of sperm whale ivory (from contexts 886, 879 and 1713), beaked whale teeth (1427 and 1395), and a killer whale tooth (1687). Three fragments of mandible and three teeth were from Delphinidae were also recovered from Late Norse deposits (52 and 1072).

Skull fragments, which represent some of the of the largest piece of bone present within the assemblage, were also principally from Norse deposits and tended to be from larger taxa. Fragments of gray whale (1592) and sperm whale (2381) skull were recovered from Early Norse deposits. Two balaenid skull fragments were also recovered; one from a Middle Norse deposit (1044), and another from a Middle Norse transitional phase deposit (519). A fin whale skull fragment (1624) and sperm whale (962, 1101) skull fragments were also recovered from Late Norse deposits.

	Identification																						
Element	B. musculus	B. physalus	Balaenopterinae	Balaenopteridae	E. robustus	Balaenidae	P. macrocephalus	Ziphiidae	O. orca	Delphininae	Small Delphininae	Delphinidae	P. phocoena	Delphinoidea	Small delphinoid	Mysticeti	Odontoceti	Cetacea	Large cetacean	Large to Medium cetacean	Medium cetacean	Small cetacean	Grand Total
Skull		1			1	2	5											2					11
Mandible												4						83	59	1			147
Tympanic bulla																		1					1
Tooth							4	3	1			4											12
Cervical vertebra														1									1
Thoracic vertebra											2	1		1	1								5
Lumbar vertebra										1			1										2
Caudal vertebra										1		1	2							1			5
Caudal fluke vertebra									1														1
Vertebra	1	1		1		1	1								1		1	1			1		9
Vertebral centrum			1														2	1					4
Vertebral process		2								1													3
Vertebral epiphysis					2		1	1				3		6		1	2	2		1		2	21
Rib					2		2							1				2		1			8
Metacarpal												2											2
Phalange or metacarpal												3											3
Phalange												1							1				2
Grand Total	**1**	**4**	**1**	**1**	**5**	**3**	**13**	**4**	**2**	**3**	**2**	**19**	**3**	**9**	**2**	**1**	**5**	**92**	**60**	**4**	**1**	**2**	**237**

Table 14 Taxonomic identification of elements at Bornais

3.2.4 QUANTIFICATION

Although NISP has been calculated for all mounds, the nature of the assemblage meant that it was generally not possible to identify any species with an MNI of greater than one for each species due to the same issues of fragmentation seen in the Cladh Hallan assemblage.

3.3 MODIFICATION: ELEMENTS, FRAGMENTS AND ARTEFACTS

Modifications were recorded within both assemblages, and unworked elements, modified elements, unworked and worked fragments and artefacts were recorded at both Cladh Hallan and Bornais and are reported on here. The following section investigates the taxonomic profiles of each of these categories and forms the basis for the discussions on selective utility set out in the following chapter.

Prior to the development of the method for morphological identification (see Chapter 5), and before the advent of biomolecular techniques of analysis it was not possible to undertake detailed taxonomic analysis on most cetacean bone assemblages (e.g. Mulville 2002). Identifications were particularly difficult to establish for fragmented or worked bone. The methods applied by the current research have enabled closer characterisation of taxonomic profiles than was previously possible. Tables 15 and 16 demonstrate the level of identifications achieved by the different methods for the different categories of modified bone.

When analysing the assemblages and assigning modification categories it was in some cases difficult to distinguish between categories and there may therefore be some overlap. Unworked and worked fragments were at times difficult to distinguish and fragmentation itself may be the product of working, though pieces recorded as unworked fragments showed no obvious signs of modification such as chop marks. Additionally, modified elements may also have some overlap with the worked fragment category. The latter only being distinguished as a separate category because modification had been undertaken to such a degree that the element is no longer discernible. However, use of the defined categories essentially provided a way to investigate the extent of modification, ranging from no modification at all (unmodified element) to fragmented bone and artefacts.

The identifications and modifications from both sites are discussed together within the following sections, due to the similarities in modifications seen between the assemblages.

	Method and no. of identifications			
Modification and identification level	Morphology	ZooMS	Combination	Total
Unworked element	**27**	**8**	**2**	**37**
Species	2	5		7
Family	2	1		3
Genus	1			1
Subfamily	3	1	1	5
Superfamily	1	1	1	3
Parvorder	10			10
Order	8			8
Modified element	**11**	**1**	**1**	**13**
Species	2	1	1	4
Subfamily	2			2
Superfamily	1			1
Parvorder	1			1
Order	3			3
Size groups	2			2
Unworked fragment	**1028**	**55**		**1083**
Species	322	43		365
Family		8		8
Parvorder	1	4		5
Order	705			705
Worked fragment	**88**	**9**		**97**
Species	3	8		11
Family		1		1
Order	85			85
Artefact	**30**	**22**	**3**	**55**
Species	1	17	1	19
Family		2	2	4
Superfamily		1		1
Parvorder	6	2		8
Order	22			22
Size groups	1			1
Total	**1184**	**95**	**6**	**1285**

Table 15 Method and number of identifications achieved for different categories of modification seen within the Cladh Hallan assemblage

	Method and no. of identifications			
Modification and identification level	Morphology	ZooMS	Combination	Total
Unworked element	**23**	**13**		**36**
Species		1		1
Subfamily	2			2
Family	10	4		14
Superfamily		8		8
Parvorder	2			2
Order	6			6
Size groups	3			3
Modified element	**14**	**6**	**4**	**24**
Species	2	3	2	7
Subfamily	3		1	4
Family	2	3	1	6
Superfamily	3			3
Parvorder	2			2
Order	1			1
Size groups	1			1
Unworked fragment	**1209**	**52**		**1261**
Species	2	34		36
Family		9		9
Parvorder	1	9		10
Order	1144			1144
Size groups	62			62
Worked fragment	**129**	**58**		**187**
Species	3	37		40
Family		11		11
Superfamily		1		1
Parvorder		6		6
Order	125	3		128
Size groups	1			1
Artefact	**21**	**26**	**5**	**52**
Species		19	1	20
Family		5	2	7
Superfamily		1		1
Parvorder	1			1
Order	19	1		20
Size groups	1		2	3
Total	**1396**	**155**	**9**	**1560**

Table 16 Method and number of identifications achieved for different categories of modification seen within the Bornais assemblage

3.3.1 OVERVIEW OF MODIFICATIONS

Unworked fragments dominate the assemblages from both sites in all phases, constituting over 80% of the material from both Cladh Hallan and Bornais. Worked fragments are the second most numerous type of modified bone at both sites, followed by artefacts, unmodified and modified elements (Table 17 and 18). Clear differences between the species represented within these different categories were evident and are discussed further below.

			Modifications			
Phase	Unmodified element	Modified element	Unworked fragment	Worked fragment	Artefact	Total
Early Bronze Age	**1**		**6**			**7**
3	1		6			7
Late Bronze Age	**23**	**11**	**1016**	**69**	**45**	**1164**
4			4		1	5
5			1			1
6			16			16
7	1	1	8			10
8	3	1	196	1	4	205
9	9	4	426	33	9	481
10	4	2	153	13	6	178
11	3	2	139	9	8	161
12	3	1	73	13	17	107
Early Iron Age	**11**	**2**	**48**	**27**	**6**	**94**
13	1		10	11	3	25
14	4	1	16	1	3	25
15			4	5		9
16	6	1	18	10		35
Uncertain	**2**		**13**	**1**	**4**	**20**
0			1	1		2
U/S	2		12		4	18
Total	37	14	1083	97	54	1285

Table 17 Modifications to cetacean bone assemblage at Cladh Hallan

			Modifications			
Period	Unworked element	Modified element	Unworked fragment	Worked fragment	Artefact	Total
Late Iron Age I	1	3	679	5	12	700
Late Iron Age II			14	4		18
Early Norse	10	8	97	33	7	155
Middle Norse	6	6	175	44	22	253
Late Norse	12	4	72	78	7	173
Final occupation		1	10	12	1	24
Norse	3	2	207	3	1	216
Unphased and U/S	4		7	8	2	21
Total	36	24	1261	187	52	1560

Table 18 Modifications to cetacean bone assemblage at Bornais

3.3.2 Unmodified and modified elements

At both Cladh Hallan and Bornais the unmodified elements are dominated by the remains of Delphinoidea though larger species were also present in small numbers (Table 19 and 20). The modified element category at Bornais is likewise dominated by smaller species (Delphinoids) though larger species are also present and at Cladh Hallan there is a relatively even split between large and small species within the modified element category. However, the nature of modifications differs and is discussed further below.

			Modification			
Identification	**Unworked element**	**Modified element**	**Unworked fragment**	**Worked fragment**	**Artefact**	**Total**
B. musculus	3	1	5	6	6	21
B. physalus			2		1	3
Balaenopterinae	1					1
M. novaeangliae	1		4		4	9
Balaenidae			8	1	1	10
Mysticeti		1	5		6	12
P. macrocephalus	1	1	354	5	7	368
O. orca	1	1				2
G. melas		1			1	2
Lagenorhynchus sp.	1					1
Large delphininae	4	1				5
Delphininae		1				1
Delphinidae	3				3	6
P. phocoena	1					1
Small delphinoid	1					1
Delphinoidea	2	1			1	4
Odontoceti	9				2	11
Cetacea	8	3	705	85	22	823
Medium to large cetacean		2				2
Medium to large Odontoceti	1					1
Large cetacean					1	1
Grand Total	**37**	**13**	**1083**	**97**	**55**	**1285**

Table 19 Modifications to the bones of different taxa at Cladh Hallan

	Modifications					
Identification	Unmodified element	Modified element	Unworked fragment	Worked fragment	Artefact	Total
B. musculus		1	2			3
B. physalus				5	4	9
B. acutorostrata			1			1
Balaenopterinae		1				1
M. novaeangliae			3		2	5
Balaenopteridae		1	1	1		3
E. robustus			2	3	4	9
Balaenidae			8	9	3	20
Mysticeti		1	9	6		16
P. macrocephalus	1	1	28	32	9	71
Ziphiidae	3				2	5
O. orca		2			1	3
Small Delphininae		2				2
Delphininae	2	1				3
Delphinidae	11	5		1	2	19
P. phocoena		3				3
Delphinoidea	8	1		1	1	11
Small delphinoid		2				2
Odontoceti	2	1	1		1	5
Cetacea	6	1	1144	128	20	1299
Large cetacean	1		59	1	2	63
Large to Medium cetacean	1		2		1	4
Medium cetacean		1				1
Small cetacean	1		1			2
Grand Total	**36**	**24**	**1261**	**187**	**52**	**1560**

Table 20 Modifications to the bones of different taxa at Bornais

Delphinoidea

Where smaller taxa are represented, modification tends to be in the form of butchery marks indicative of meat removal or processing at both sites. Examples from Cladh Hallan include cuts on the neural process of a small cetacean (Phase 7, context 2476, SF 5024) (Figure 52) and chop marks at the base of the transverse processes of articulating lumbar vertebrae from the bottlenose dolphin/ Risso's dolphin (Phase 16, context 407). Examples from Bornais include a caudal vertebra from a killer whale with a chop mark which may be related to meat removal (context 9).

A greater level of modification is also evident on many of the small cetacean bones from Bornais, and several of the vertebrae were chopped to a higher degree than would be necessary for meat removal alone. Many had their processes and parts of their centra removed. Chopped vertebrae appeared in Early Norse contexts (1257, 2356, 1795) Middle Norse contexts (1474; see Figure 53) and Late Norse contexts (9, 789).

Figure 52 Vertebral process from a small delphininae exhibiting cut marks consistent with meat removal from Cladh Hallan (2476)

Figure 53 Chopped delphinid thoracic vertebra from Bornais (Middle Norse transitional, 1474)

Larger taxa

Modified elements were also evident among some of the bones of larger taxa. Chopped vertebrae were present in both the Cladh Hallan and Bornais assemblage and modifications ranged in extent. Some were near complete vertebrae with processes missing (e.g. Bornais, context 374) others had portions of the centrum missing (e.g. Cladh Hallan context 3181) and some had large modifications resulting in the survival of only small portions of the vertebrae (e.g. Cladh Hallan 412, 1512; Bornais 2210, 863, 9, 576). The taxa represented by these chopped vertebrae varied, and included blue whale, Balaenopterinae (either minke or sei whale) and other generic identifications at Bornais, and Mysteceti as well as generic identifications at Cladh Hallan. These chopped pieces occurred in Late Bronze Age phases at Cladh Hallan, and in all Norse phases at Bornais. Modified vertebral epiphyses were also identified in Late Iron Age deposits at Bornais, from sperm whale and Mysticeti (337 and 454 respectively).

The tooth of a sperm whale with chop marks toward the root was also represented at Cladh Hallan (context 2210, SF 4564, Figure 54).

Figure 54 Chop or cut marks toward the root of the sperm whale tooth from Cladh Hallan

3.3.3 UNWORKED AND WORKED FRAGMENTS

At both sites the unworked and worked fragment categories show very different taxonomic profiles to the element categories and are dominated by the remains of large species. Only two pieces of worked delphinoid bone and one fragment of small cetacean bone were identified at Bornais, and the remainder of the fragments from both sites were all from large species (where taxonomic identifications could be assigned), accounting for hundreds of pieces of bone (see Table 19 and 20).

Sperm whale and balaenids were most frequently recorded on both sites, though a range of other Mysticeti were also identified, and most occurred repeatedly throughout the different phases of Cladh Hallan and Bornais. At Cladh Hallan in Late Bronze Age deposits fragments from sperm whale, balaenid, humpback whale and in one case fin whale were identified. Whilst in Early Iron Age deposits identified fragments were all from blue whale and fin whale.

At Bornais Late Iron Age deposits held fragmented remains of fin whale, gray whale and balaenid, while Norse deposits contained a greater range of taxa including blue whale, fin whale, minke whale, humpback whale, gray whale, sperm whale, delphinoids and more generic identification of Odontoceti and Mysticeti. Sperm whale fragments occur in their highest numbers in the Late Norse phase. Fragments from other taxa occur in much smaller numbers and general patterns cannot be established.

3.3.4 ARTEFACTS

The Late Bronze Age Phase 9 and 12 produced the largest artefact assemblages from Cladh Hallan, while the Late Iron Age and Middle Norse period produced the largest assemblages at Bornais. While artefacts are fewer in number than the bone fragments, the taxa identified generally reflect those present in the unworked and worked fragment categories. Larger species predominate, though smaller species are also evident on both sites. Some patterns are also evident through time (Tables 21 and 22). Late Bronze Age deposits at Cladh Hallan contained artefacts from a variety of species, with the highest numbers made from sperm whale bone reflecting the predominance of this species on the site, though large baleen whales were also used frequently. This pattern altered during the Early Iron Age and blue whale was the only species used for artefact manufacture. This may reflect the smaller assemblage from Iron Age deposits, and the preference for blue whale bone seen throughout deposits of this period.

There are a variety of taxa used for artefact manufacture in each phase at Bornais (Table 22), though typically one species occurs in higher numbers than others during each phase. In the Late Iron Age gray whale is most frequent, while in the Middle Norse period sperm whale predominated and in the Late Norse period fin whale is most common.

	Identification												
Period and Phase	B. musculus	B. physalus	M. novaeangliae	Balaenidae	Mysticeti	P. macrocephalus	G. melas	Delphinidae	Delphinoidea	Odontoceti	Cetacea	Large cetacean	Total
Late Bronze Age	**4**	**1**	**4**	**1**	**5**	**7**	**1**	**3**	**1**	**1**	**14**	**1**	**43**
4											1		1
8				1		1					1		3
9	1					1		1	1		4	1	9
10	1	1	2		1	1							6
11	2				2		1	1			2		8
12			2		2	4		1		1	6		16
Early Iron Age	**2**										**4**		**6**
13	1										2		3
14	1										2		3
U/S										**1**	**3**		**4**
Total	**6**	**1**	**4**	**1**	**5**	**7**	**1**	**3**	**1**	**2**	**21**	**1**	**53**

Table 21 Taxonomic patterns in artefact production through time at Cladh Hallan

	Identification													
Period	B. physalus	M. novaeangliae	Balaenidae	E. robustus	P. macrocephalus	Ziphiidae	O. orca	Delphinidae	Delphinoidea	Odontoceti	Cetacea	Large cetacean	Large to Medium cetacean	Total
Late Iron Age I				2	1	1				1	7			12
Early Norse				1					1		3	2		7
Middle Norse	1		2	1	7	1	1	1			8			22
Late Norse	3	1	1		1			1						7
Final occupation													1	1
Norse		1												1
Unphased and U/S											2			2
Total	**4**	**2**	**3**	**4**	**9**	**2**	**1**	**2**	**1**	**1**	**20**	**2**	**1**	**52**

Table 22 Taxonomic patterns in artefact production through time at Bornais

3.4 SPATIAL AND TEMPORAL DISTRIBUTIONS

The following section sets out patterns in the spatial distributions of cetacean bone and taxa at Cladh Hallan and Bornais through time. Taxa present across the different areas of each site in different periods are considered, as are the results of intensive sampling undertaken on a restricted number of contexts. As with the information set out in previous sections, data relating to spatial and temporal distributions aid understanding of use and procurement which are discussed in the following chapters. Tables 23 - 25 demonstrate taxa identified through space and time. Table 23 shows data from Cladh Hallan (phase 3, 7 – 16 only are shown as no identifications above Order level were achieved from other phases). Clear patterns are evident at both Cladh Hallan and Bornais relating to the distribution of individual taxa, and variations in biodiversity on the sites. These patterns are investigated further below.

3.4.1 DISTRIBUTIONS OF INDIVIDUAL TAXA

At both sites there is evidence of the contemporary use of the same species within different areas.

Late Bronze Age

Sperm whale occurs across the site at Cladh Hallan during Late Bronze Age phases, occurring within the majority of houses and other areas of the site (Table 23).

This pattern was investigated further and Table 24 demonstrates that it is primarily fragments of sperm whale skull which were scattered across the site in relatively high numbers. In addition to many small fragments, large pieces of sperm whale skull were found within Phase 8 and 9 deposits. These included large pieces of skull found at the entrance to House 1370 (SF 5018). The largest, measured 420mm x 370mm x 125mm (Figure 73). Additionally, a large fragment was incorporated within the capping of an otherwise stone-lined cist associated with house 401 (context 2105; SF 4560). The majority of the fragments of sperm whale skull in phase 9 originated from house 801. However, the tooth of a sperm whale was also found set vertically into the floor of house 1370, (SF 4564; Figure 54) during this phase, and a piece of sperm whale skull artefact was recovered from the forecourt of this structure (context 1765, SF3811). In contrast, although a sperm whale vertebral epiphysis was recovered from house 401 in phase 9, no skull fragments were identified from this house during this phase though a small number were recovered from the forecourt (context 1132). However, many unidentifiable fragments were recorded from this house which could represent this species, though sampling led to the identification of some of these fragments as from balaenid and humpback whale. These patterns are interpreted in the following Chapter (Section 8).

Period, Phase and Area	B. musculus	B. physalus	Balaenopterinae	M. novaeangliae	Balaenidae	Mysticeti	P. macrocephalus	O. orca	G. melas	Large delphininae	Lagenorhynchus sp.	Delphininae	Delphinidae	P. phocoena	Small delphinoid	Delphinoidea	Odontoceti	Medium to large cetacean	Medium to large Odontoceti	Large cetacean	Total
Early Bronze Age																	1				1
3																	1				1
House 1370																	1				1
Late Bronze Age	4	2	1	9	10	12	368	2	2	1	1	1	5		1	3	7	2		1	432
7												1									1
House 2476												1									1
8				1	2		124	1					1				1				130
House 1370				1	1		1														3
House 401					1		58	1													60
House 801							65						1								66
NE Area																	1				1
9	1			2	2	1	171		1	1			2		1	1	2			1	186
Entrance to House 1370							1														1
Forecourt							3													1	4
Forecourt of 1370							1														1
House 1370				1		1	11			1			1								15
House 401				1	2		1						1		1	1	1				8
House 801	1						142														143
NE Area							7		1												8
SE Area							5										1				6
10	1	2		2		3	57									1	2	1			69
Area C	1																				1
Forecourt				1			3														4
House 1370		1		1		2	6										1				11
House 2190							3											1			4
House 401		1				1	41														43
S Area							3										1				4
SE Area																1					1
W Area							1														1
11	2			1	2	4	9	1	1		1		1			1		1			24
Forecourt							1				1					1					3
House 1370	1			1		1	2														5
House 401	1				2	2	2	1	1				1								10
S Area						1												1			2
W Area							4														4
12			1	3	4	4	7						1				2				22
House 1370						3															3
House 401			1	3	4	1	7						1								17
NE Area																	2				2

Early Iron Age	17	1								3			1	1		1	1		1		26
13	7																		1		8
House 150	5																				5
House 401	2																				2
NE Area																			1		1
14	5												1			1					7
House 1500	2												1								3
House 401	3															1					4
15	2	1																			3
House 401	2	1																			3
16	3									3				1			1				8
House 150	1																				1
House 401										3				1			1				5
House 640	2																				2
Grand Total	21	3	1	9	10	12	368	2	2	4	1	1	6	1	1	4	9	2	1	1	459

Table 23 Spatial and temporal distribution of cetacean taxa at Cladh Hallan

	Sperm whale (NISP)			
Period, Phase and Area	Skull fragment	Tooth	Vertebral epiphysis	Total
Late Bronze Age	342	1	4	347
8	123			123
House 401	58			58
House 801	65			65
9	164	1	1	166
Entrance to House 1370	1			1
Forecourt	2			2
Forecourt of 1370	1			1
House 1370	7	1		8
House 401			1	1
House 801	141			141
NE Area	7			7
SE Area	5			5
10	48			48
House 1370	4			4
House 2190	3			3
House 401	37			37
S Area	3			3
W Area	1			1
11	5			5
House 1370	1			1
W Area	4			4
12	2		3	5
House 401	2		3	5
Total	342	1	4	347

Table 24 Spatial distribution of sperm whale elements in Late Bronze Age deposits at Cladh Hallan

All houses also produced sperm whale skull fragments in phases 10, 11 and 12 (with the exception of house 1370 during the phase 12, though sperm whale fragments were generally fewer in this phase from all areas). As discussed earlier, although large numbers of sperm whale fragments were identified they could all derive from a single individual.

Many other species were also found in different areas of the site during the Late Bronze Age, including humpback whale, which was represented by different elements found in different parts of the site. During phase 9 house 401 (context 1698), produced fragments from the bone of this species and house 1370 (context 2211) produced the epiphyseal end of a long bone. The phalange of a humpback whale was also recovered from the forecourt of house 401 (context 840) in phase 10 deposits and an artefact made of humpback whale bone was found in house 1370 (context 1644, SF3866). Although present in different phases the epiphyseal end of the long bone from phase 9 and the phalange from phase 10 may reflect different parts of the humpback whale flipper, possibly indicating a single individual deposited in different houses. The rib and vertebral epiphysis of a humpback whale were recovered from Late Bronze Age deposits (phase 12, house 401 context 595 and 1226 respectively). Fragments of balaenid, fin whale and blue whale bone were also found in different parts of the site during the Late Bronze Age, and smaller numbers of delphinoid bones were also found, both within the houses and adjacent external areas.

Early Iron Age

Distributions are more difficult to assess in the Early Iron Age as excavation generally focused on a single house per phase. However, when the Early Iron Age phases are considered together patterns are evident and presence of the same species in different houses is noted in this period as in the Late Bronze Age. Blue whale was the dominant species identified in Early Iron Age deposits and several vertebral epiphyses from this species were found in house 401 (phase 14). The epiphyses were recovered from a single context within this structure (462, SF 2073 and 2074). A further fragment of blue whale epiphysis was found in house 640 (phase 16, context 632, SF3171). The process of a blue whale vertebra was recorded from the house 401 in Phase 15 (context 469).

Late Iron Age

Late Iron Age material is found on mound 1 and 2 at Bornais, however the former dates from LIA I and the latter from LIA II (Sharples 2012, 2020), thus contemporary comparisons are not possible for this period though multiple species were identified in the same areas, as in other phases.

Norse

Norse deposits are found on mounds 2 and 2A and comparison of these different areas is therefore possible.

Early Norse deposits on mounds 2 and 2A both produced evidence of blue whale, sperm whale, balaenid and Delphinoid bones. The majority of these species were represented within the ploughsoils on mound 2A (GAA) and grey sands covering the hearth associated with the cultivation soils (GAD). On mound 2 the large species were found within the truncated Viking structure (BBE), house 1 deposits (BBC) and abandonment deposits (BBE). Delphinoid bones were found within foundation deposits (BBA), house 1 (BBB) and abandonment deposits (BBD).

Period, Mound and Area	B. musculus	B. physalus	B. acutorostrata	Balaenopterinae	M. novaeangliae	Balaenopteridae	E. robustus	Balaenidae	Mysticeti	P. macrocephalus	Ziphiidae	O. orca	Small Delphininae	Delphininae	Delphinidae	P. phocoena	Small delphinoid	Delphinoidea	Odontoceti	Large cetacean	Large to Medium cetacean	Medium cetacean	Small cetacean	Total
Late Iron Age I							2		1	2	1						1		1	59				67
1							2		1	2	1						1		1	59				67
CC							2			1							1			59				63
CC										1														1
CG									1		1								1					3
Late Iron Age II		1					1	4	2															8
2		1					1	4	2															8
BAB								1																1
BAC								1																1
BAE		1																						1
BAF								1	1															2
BAG							1	1	1															3
Early Norse	2				1	1	1	3	1	14			2		4	2		7	3	2	1		1	45
2	1					1	1	2	1	1								5						12
BBA							1		1									1						3
BBB																		1						1
BBC	1																							1
BBD										1								3						4
BBE								2																2
HB						1																		1
2A	1				1			1		13			2		4	2		2	3	2	1		1	33
GAA					1			1		7			2			2		1	3	2	1		1	21
GAB																		1						1
GAD	1									6					4									11
Middle Norse	1	2				2	4	9	10	19	1	1		2	6			3	1				1	62
2	1	2					4	8	10	12	1	1		2	6			3	1				1	52
AE														1										1
BCA																							1	1
BCB							1	1		1														3
BCC		2					1	2	7	7	1	1		1	3			1						26
BDA									1															1
BDB								1	1															2
BDD															1				1					2
BDE							1			1														2
BDF							1		1	1								1						4
BDG								1																1
BDH								1																1
BDI	1							1		2					2									6

BDJ																		1						1
HD								1																1
2A						2		1		7														10
GBA										2														2
GBF								1		2														3
GBG						2				3														5
Late Norse		6	1		3		1	4	2	34	3	2		1	8			1				1		67
2		2			1		1	2	2	7	3	1			6			1				1		27
AG															6									6
BEA								1		1														2
BEB										1														1
BEC		2					1	1			1													5
BEE									2	3	2													7
BEF					1																			1
BEH																		1						1
BEI												1										1		2
HH										1														1
IA										1														1
2A		4	1		2			2		27		1		1	2									40
GCA										1														1
GCB															1									1
GCD								1		9		1												11
GCD/GCC														1										1
GCE										3														3
GCF		1																						1
GDA										2														2
GDA/C															1									1
GDB			1																					1
GDC		2			1					9														12
GEC										3														3
GED					1																			1
GEI		1																						1
GGC								1																1
Final occupation																1				1	1			3
2A																1				1	1			3
GFB																1				1	1			3
Norse				1	1												1			1	2			6
1				1	1												1			1	2			6
CE				1	1															1				3
CF																	1				2			3
Total	3	9	1	1	5	3	9	20	16	69	5	3	2	3	18	3	2	11	5	63	4	1	2	258

Table 25 Spatial and temporal distribution of cetacean taxa at Bornais

Middle Norse deposits on mounds 2 and 2A also produced evidence of many of the same taxa, including sperm whale and balaenid bones. Both were found within house 2 construction (BCB) and house 2 occupation (BCC) deposits on mound 2. While on mound 2A both were found within deposits associated kilns within the central area (GBF). In addition sperm whale remains were also found within the central structures representing the early occupation and building 1 (GBA), and in middens associated with the kilns on the edge of the mound (GBG). Delphinid bones were found solely on mound 2 during this period, including from occupation deposits (BCC).

Taxa present on both mounds were more numerous in the Late Norse period, including fin whale, humpback whale, balaenid, sperm whale, killer whale and delphinids. These were found within a variety of deposits, though many were associated with deposits representing the early (BEC) and late (BEE) occupation of house 3 and its construction (BEA) and abandonment (BEF). Sperm whale was also found within the midden (HH) and badly damaged Late Norse house (IA). It is of note that in contrast to earlier periods delphinoids were rarer and none were identified within the house occupation or midden deposits in Late Norse deposits.

Groups containing fin whale, humpback whale, balaenid, sperm whale, killer whale and delphinids were more numerous on mound 2A during the Late Norse period but most were represented within deposits associated with the use of ancillary building 3 (GCD) and the middens to the south-east of the mound (GDC). The majority of the cetacean bone from GDC (and in particular sperm whale bone) was found in contexts associated with comb working waste (contexts 790, 862, 863), and these contexts may represent dumps of material from GCD.

3.4.2 SPATIAL PATTERNS IN CETACEAN BIODIVERSITY

While the same species were found in different houses at Cladh Hallan and different parts of the site at Bornais, a range of species were also found in each individual area of the sites, with the majority of areas producing evidence of one or more species per phase. Figures 55 and 56 set out the minimum number of species (MNS) per area for Cladh Hallan and Bornais respectively.

At Cladh Hallan this data demonstrates that some areas held evidence of to up seven different species in an individual phase (phase 11; Figure 55) and five of those from within one house (401), though most houses demonstrated the presence of multiple species. This is particularly the case in Late Bronze Age deposits, from which higher proportions of cetacean bone were recovered.

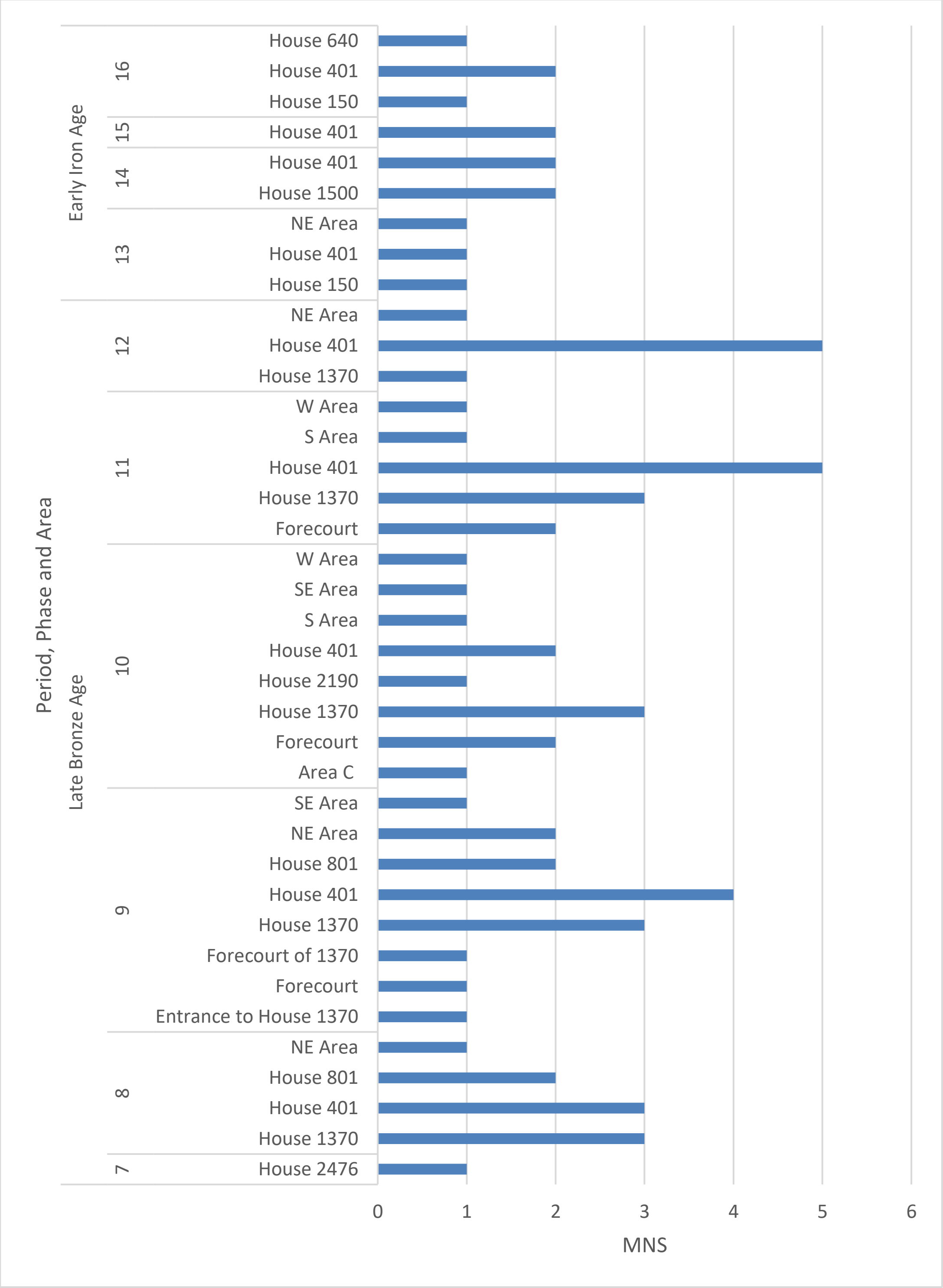

Figure 55 Minimum number of species by phase and area at Cladh Hallan

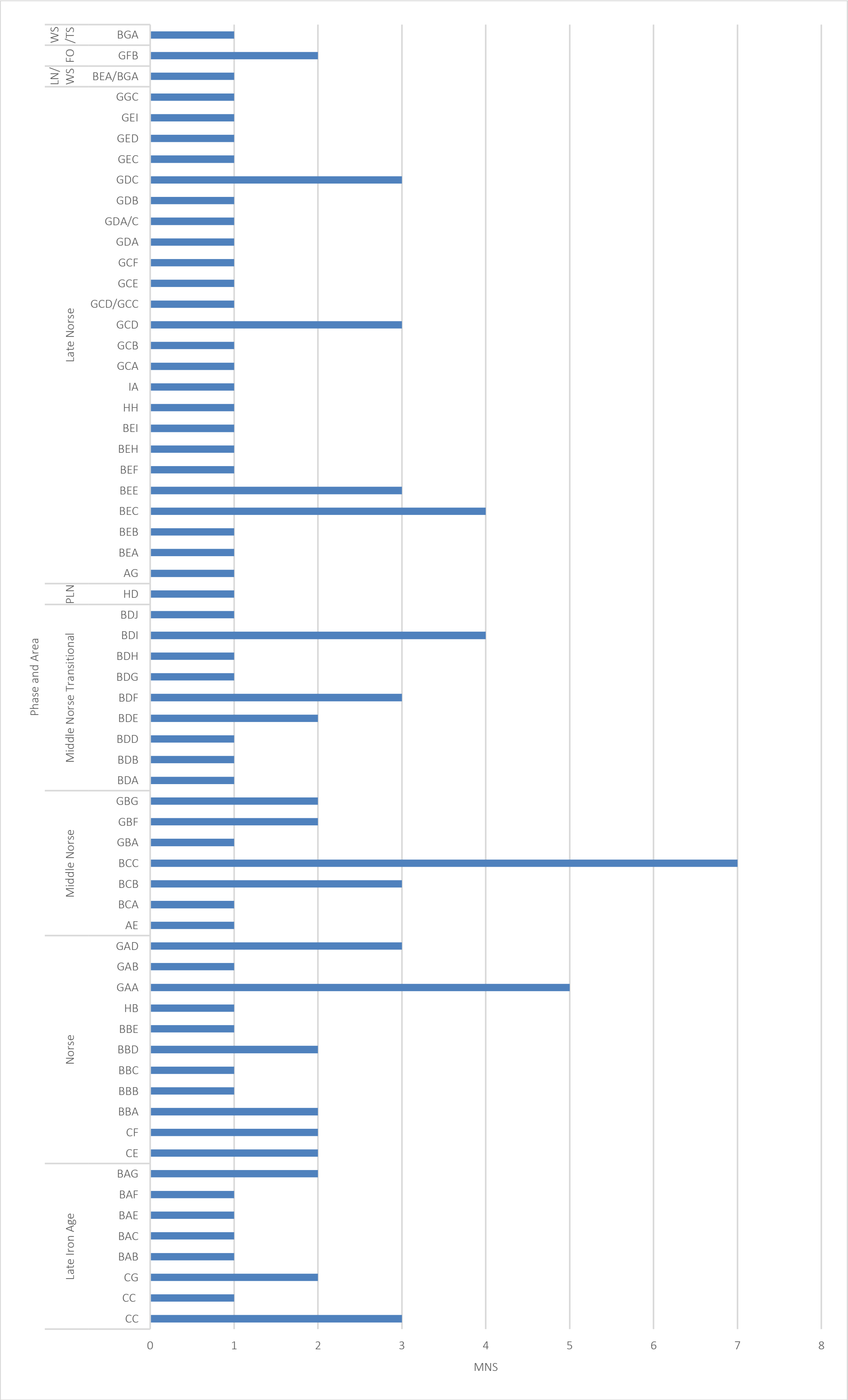

Figure 56 Minimum number of species by area at Bornais

The remains from Bornais show a similar pattern and multiple species are represented in many areas. The deposits with the greatest species diversity include the cultivation soils (GAA), house 2 occupation deposits (BCC), activity preceding house 3 (BDI), and deposits associated with the early occupation of house 3 (BEC).

The intensive sampling of a series of contexts also demonstrated that multiple species were present within individual contexts. At Cladh Hallan, context 1311, representing a floor deposit associated with house 401 in phase 9, produced a fragment of balaenid bone (SF 3149), a perforated vertebral epiphysis from a Delphinidae (SF 4683), a piece of worked bone, possibly representing a disc rough-out (SF 4583) from a Delphinoid and a vertebral epiphysis from a sperm whale (SF 4680). The latter was partially burnt but otherwise unmodified. The remains indicate the presence of at least three different species (MNS) within a single context. Likewise, fragments from equivalent floor deposits 466 and 455 in Early Iron Age phase 15 represented a blue whale and fin whale. Remains from other deposits further supported this, and context 2211 from Late Bronze Age (phase 9) House 1370, produced evidence of MNS of three (sperm whale, humpback whale and Delphinidae).

At Bornais, context 1101 from Late Norse group GCD was investigated in more detail and a series of ZooMS samples were taken to assess species diversity within this single layer. Three separate fragments were identified as sperm whale, and a worked piece of Balaenid bone was also recovered from this group (context 1101, SF 3346).

These results have identified a hitherto unrecognised level of species diversity within individual contexts and within many areas of the sites at Cladh Hallan and Bornais. The intensive sampling in particular challenges the assumption that cetacean bones within the same contexts represent the same fragmented pieces of bone.

4 CONCLUSIONS

This chapter has set out the results of analysis following the methods established in the previous chapters. Taxonomic identification has allowed for a closer characterisation of the remains than previously possible, and though morphological identification was in some cases hampered by the loss of diagnostic traits, the overall results provided a detailed characterisation of the cetacean zooarchaeological record.

A number of patterns were evident within the assemblages including:

- The presence of a wide variety of species throughout the prehistoric to Norse periods;

- The predominance of smaller species within the unmodified and modified element categories;
- The presence of larger species with higher degrees of bone modification, present within the modified element category and dominating the unworked and worked fragment as well as artefact categories;
- The presence of the same species spread across many areas of both sites and presence of a wide range of species within individual areas of each site;

These patterns aid interpretation of cetacean utility and procurement and are discussed further in the following chapters.

Chapter 7: Cetacean utility at Cladh Hallan and Bornais

1 INTRODUCTION

This chapter examines whether the detailed characterisation of the assemblages set out within the previous chapter allows insights into cetacean utility, drawing on a suite of indices established by previous studies (e.g. Monks 2005; Savelle and Friesen 1996; Whitridge 2002) in addition to a range of other zooarchaeological, historical, ethnographic and contextual data. Previous works have demonstrated that study of species, elements, modifications and spatial distributions of cetacean bone can all illuminate past patterns of utility (e.g. Monks 2005; Mulville 2002; Savelle and Friesen 1996). This chapter uses these characteristics as an interpretative strategy to investigate and understand cetacean bone utility from the Bronze Age to Norse period on the Hebrides building on the work of Mulville (2002). Where possible interpretations are also contextualised with reference to contemporary economies and activities, set out in Chapter 3. Aspects of the research undertaken at Bornais have been published within the site report for mounds 2 and 2A (Evans 2021; Sharples 2021), though the current dataset includes additional identifications (primarily within the small cetacean category) obtained after the publication of that work.

As established in Chapter 2, cetacean bone can be present on settlement sites for several reasons. While the bones of smaller species may have been transported back to site within cuts of meat (O'Connell et al. 1988; Savelle 1995: 141) larger species are more likely to be affected by the 'Schlepp effect' (Perkins and Daly 1968; Figure 57). Factors beyond meat utility therefore explain the presence of large species on settlement sites (e.g. Mulville 2002) and artefactual, architectural, oil and social utility have all been recognised as drivers influencing the transport of large bones back to settlement sites and are investigated within this chapter (e.g. Monks 2005; Savelle and Friesen 1996; Whitridge 2002). Remains which shed light on wider human-cetacean relationships are also reviewed (Jones 1998).

The structure of this chapter generally follows the process of butchering and utilising a whale carcass. Meat and blubber utility are therefore considered first, followed by artefactual (and architectural) utility, oil and fuel utility. The range of resources not typically represented archaeologically are then mentioned. The chapter ends with social utility and human-animal-landscape relationships which may be built up over longer periods of time and through interactions with, and use of, many cetaceans.

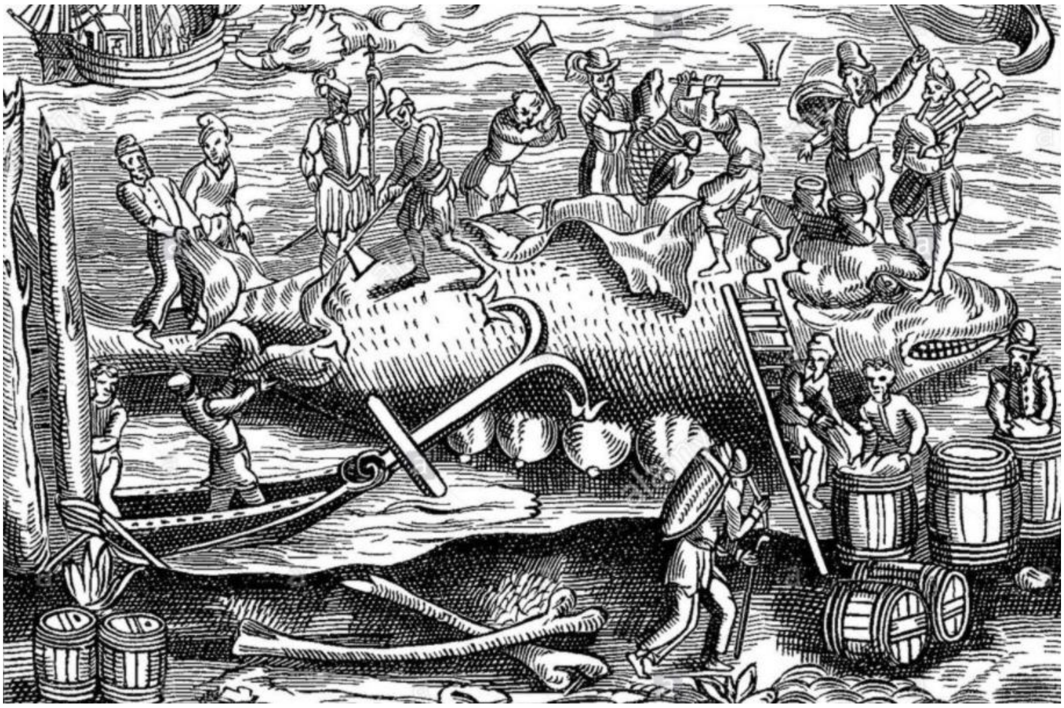

Figure 57 Woodcut showing the butchery of a large cetacean including removal of flesh on the shoreline, and selection of certain elements, from Des Monstres et prodiges by Ambroise Paré, 1574[13]

2 APPROACH TO THE INVESTIGATION OF UTILITY

This section provides an overview of the approach to the investigations on utility which are detailed in this chapter.

Archaeological evidence of cetacean utility is complex (Monks 2003). Characteristics of species and element both influence utility, while modifications and patterns of deposition are a result of utility, and all are potential clues within the archaeological record (Figure 58). In some cases utility is known (e.g. artefacts) and species and element preferences can therefore be explored. In others, taxonomic identity, elements, modifications and depositional patterns require investigation to determine the specific type of utility. Evidence for meat utility, artefactual utility, architectural utility, oil utility and social utility is explored within the Cladh Hallan and Bornais assemblages and the focus of the discussion varies depending on whether utility is known or under investigation.

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[13] The geographic context of the scene depicted by this woodcut is uncertain. It appears in a French publication on zoology, and appears alongside other 'monstrous species' from different parts of the world, including sea lions, crocodiles and ostriches (Enenkel and Smith 2014: 116). However, the scene of shoreline cetacean butchery is a common one in medieval literature, and many texts from countries bordering the North Atlantic such as the *Historia de Gentibus Septentrionalibus* (A Description of the Northern Peoples), by Olaus Magnus and the Icelandic *Jónsbók* include similar depictions (see Szabo 2008).

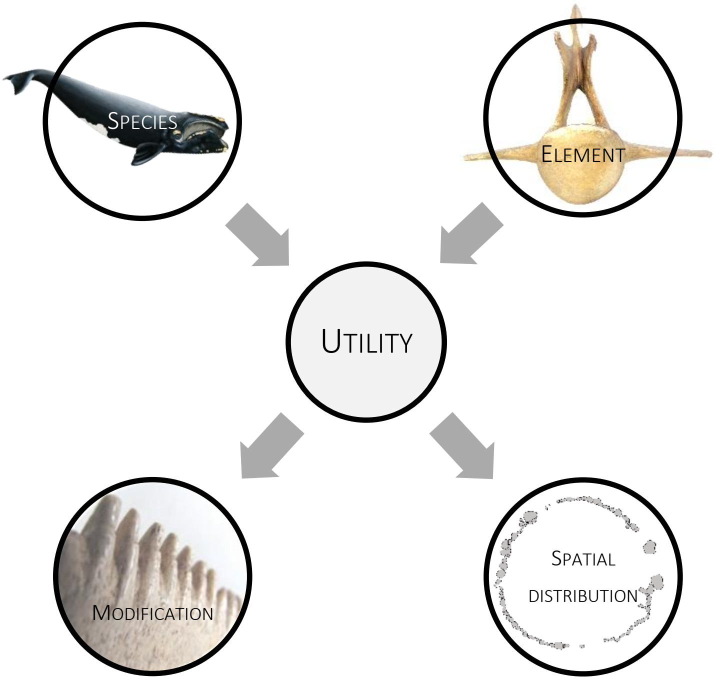

Figure 58 Relationship between utility, species, elements, modifications and deposition

Modifications lead the discussion within this chapter as they often represent the clearest evidence of the use to which the cetacean bone was put. These categories are not used restrictively, but rather as a 'way in' and to guide discussion which also draws on all other factors which relate to utility (Figure 58). The following section summarises the connection between modifications and bone utility for each of the modification categories. Figures 59 and 60 summarise modifications by taxa at Cladh Hallan and Bornais following data set out in the previous chapter.

2.1 ASSESSMENT THROUGH MODIFICATIONS

Bones represented due to their meat utility may be expected to show fewer signs of modification relating to subsequent bone use. It therefore follows that bone within the 'unmodified elements' and 'modified elements' categories discussed within this thesis (i.e., those categories which show little to no evidence of deliberate bone modification/working) are most likely to reflect meat utility. The discussion in Section 3 of this chapter is therefore focused on investigation of the taxa and elements represented within these categories, with the overall aim of establishing whether evidence of the use of cetacean meat is present within the assemblages. Changing patterns of meat utility through time are then explored.

Artefactual utility is self-evident in those bones which have been used to create artefacts. The artefact category therefore forms the basis for discussions of artefactual utility.

The fragmented bone categories are more problematic and utility must be investigated rather than assumed. Fragmentation may occur due to a variety of reasons including bone working, oil extraction, burning and processes such as gnawing or trampling (Annandale 1905; Betts 2007; Clark 1952; Hambrecht and Gibbons 2018; Heizer 1963). Evidence of gnawing was only reported on one bone (a delphinid mandible from Bornais) and the large-scale fragmentation seen within the assemblages is therefore not likely to be a product of gnawing. Trampling is also unlikely to be the main cause as many of the fragments were found to be extremely strong and some very dense (during sampling for ZooMS many scalpel blades were snapped) and trampling into the soft sands of the sites are therefore unlikely to have caused this degree of fragmentation, though this factor would benefit from further investigation (Monks 2003: 211). The potential that fragmented bone is a product of either bone manufacture or oil extraction is considered in Sections 5 and 6 of this chapter. The overall aim of these sections is to establish the reason for the presence of fragmented bone, and to explore the potential for cetacean bone use in bone manufacturing and as a source of oil.

Invisible resources are also touched upon to highlight the likelihood that other cetacean resources were also exploited by the inhabitants of Cladh Hallan and Bornais.

While the bulk of the chapter is concerned with practical uses to which cetacean bone was put, it is recognised that at times 'non-utilitarian dimensions…may have…influenced the distribution of … whale bone' (Savelle 1997: 882). Evidence for other aspects of utility is based on assessment of all available data, but in particular the discussion draws on comparisons of spatial and temporal distributions of bone, and structured deposits to investigate social utility (Whitridge 2002) and human-animal-landscape relationships (Jones 1998).

2.2 USE OF UTILITY INDICES AND SUPPORTING DATA

Patterns within taxa and elements identified within the modification categories are explored drawing on existing utility indices and other data as appropriate. Utility indices can be applied to zooarchaeological data in different ways, including through statistical analysis (e.g. Monks 2003) or on an *ad hoc* basis. In his statistical study Monks (2003: 210) found that 'the indices …do not explain, in a rigid statistical sense, the composition of the…whale bone assemblage' and that the indices required refinement for better results. The following discussion has therefore been based on an *ad hoc* use of the utility indices, drawing primarily on data such as the meat or oil content associated with a particular species or element, alongside other spatial, temporal, historical and ethnographic data where available.

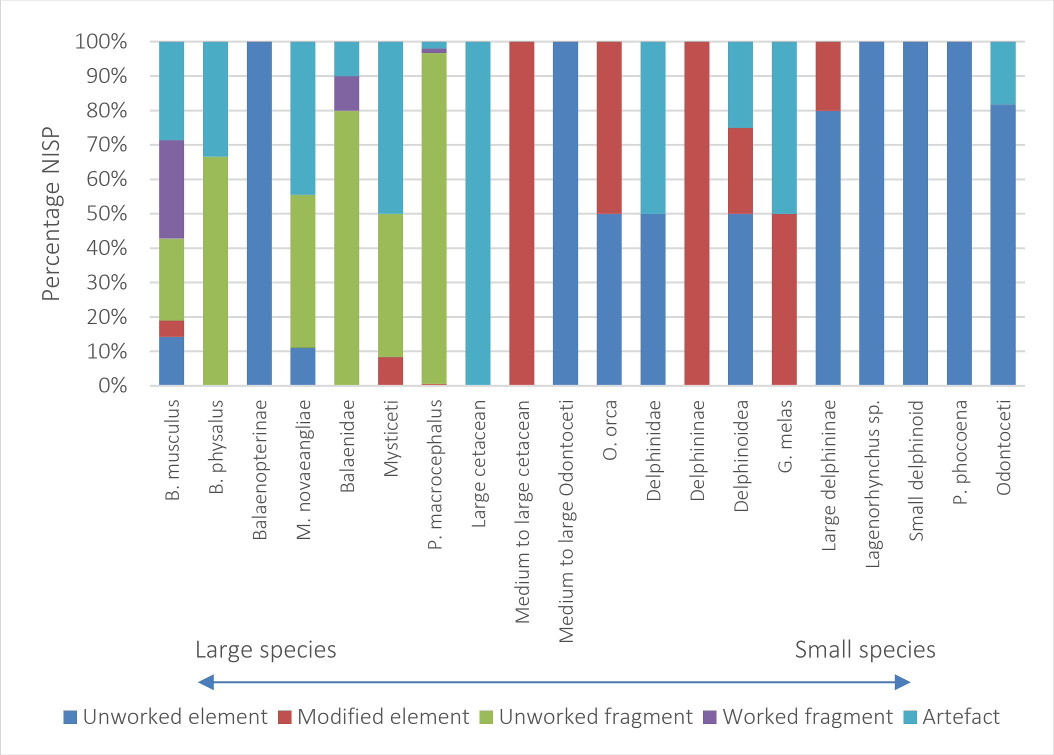

Figure 59 Taxa and modifications at Cladh Hallan

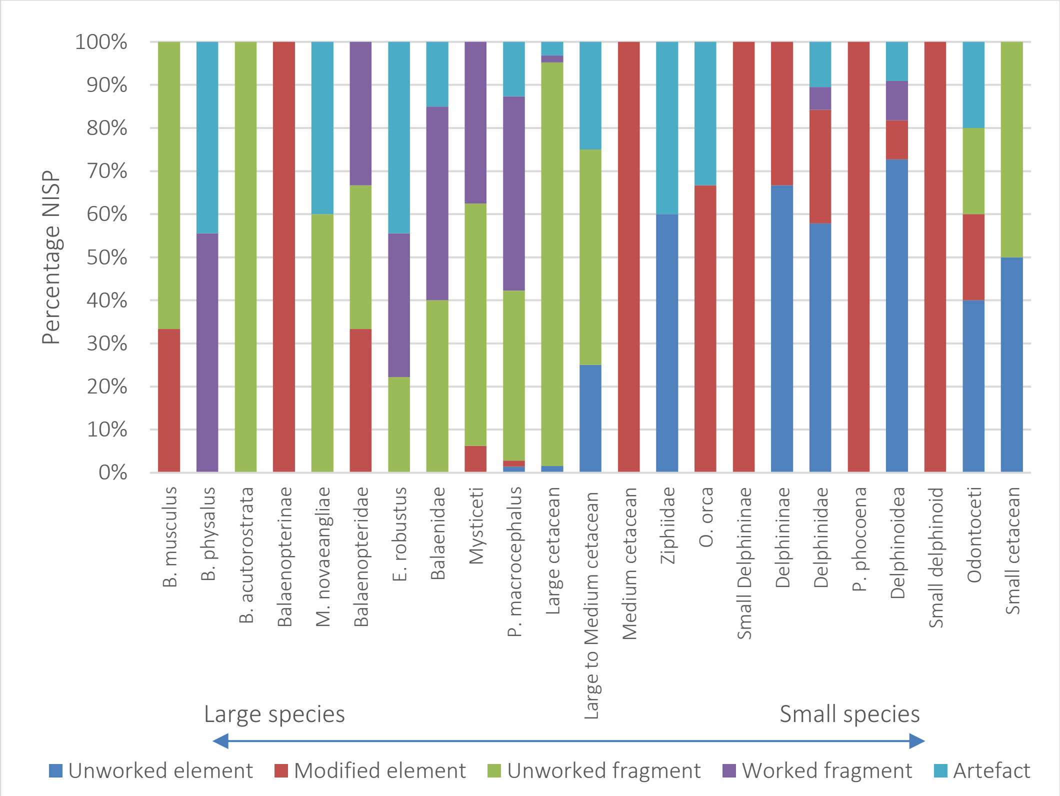

Figure 60 Taxa and modifications at Bornais

3 UNMODIFIED AND MODIFIED ELEMENTS: MEAT UTILITY

The following section investigates evidence for the presence of cetacean meat at Cladh Hallan and Bornais. Blubber is dealt with separately (Section 7 of this chapter).

3.1.1 TAXA, ELEMENTS AND THE MEAT UTILITY INDEX

As established in the previous chapter, the unmodified and modified element categories were dominated by Delphinoids at both sites (Figure 59 and 60). Larger species were also present within the modified element categories at Bornais and Cladh Hallan, though modification of these bones was greater than would be required for meat removal alone (Evans 2021: 284) and thus they are not discussed further here.

A range of Delphinoids were present at Cladh Hallan (overall NISP for Delphinoids was 23; see Chapter 6) within the unmodified and modified element categories including at least five different species including killer whale, pilot whale, at least two species of delphininae, and harbour porpoise. These species were represented primarily by elements with high meat utility (Savelle and Friesen 1996) and multiple species were represented by each element demonstrating no evidence of specific species selection (beyond the 'small cetacean/delphinoid' category; Table 11). Vertebrae have the highest levels of meat utility within small odontoceti, with the lumbar region being the highest-ranking, closely followed by the caudal region (Savelle and Friesen 1996: 715). Four lumbar vertebrae, and three thoracic and caudal vertebrae were recorded from Delphinids at Cladh Hallan, demonstrating the presence of spinal regions with high meat utility. The presence of articulating lumbar vertebra from a small dolphin recovered from House 401 in phase 16 supports the assertion that delphinoid vertebrae were probably brought back to site within cuts of meat.

Elements with lower meat utility (Savelle and Friesen 1996) occurred less frequently within the assemblage: only a single scapula (the only bone from a harbour porpoise) and phalange were recorded, and there were no crania from smaller species. Surprisingly, ribs from small cetaceans were not identified. These elements have relatively high meat utility, are relatively light, and are more difficult to separate from the associated muscle (Friesen and Morrison 2002). Ribs of larger species did occur, but all were worked in some way indicating that they are more likely to have been selectively transported back to site for their own utility as a raw material (e.g. Betts 2007).

Delphinoids were also represented at Bornais (NISP 45; see Chapter 6) and at least three different species were identified including killer whale, a member of the sub family delphininae and harbour porpoise. As at Cladh Hallan, most were present in the unmodified and modified element categories (Delphinoid NISP from these categories = 38). Most came from the Norse deposits and only a single delphinoid bone (a vertebra), was recovered from Late Iron Age deposits.

Five thoracic and five caudal vertebrae, two lumbar vertebrae and a single cervical vertebra (representing multiple different species; see Table 14) were recorded at Bornais, reflecting the presence of bones with high meat utility (Savelle and Friesen 1996). The likelihood that these bones arrived back on site within cuts of meat is further supported in Early Norse deposits by the presence of two likely articulating caudal vertebrae from a harbour porpoise (GAA, 2356), and two likely articulating mid thoracic vertebrae from a small delphinid (GAA, 1795) (Evans 2021: 284). Although vertebrae were most common and present in all Norse phases, most other elements within the cetacean skeleton were also represented at different times. Bones from the flipper were found in Early and Middle Norse deposits, while Early Norse deposits also included a single rib. Two metacarpals and a phalange from a Delphinid were found also within a single Early Norse context (1193) and may indicate an articulating flipper portion brought back to site within a cut of meat. However, flipper portions generally have lower meat utility (Savelle and Friesen 1996) and modifications (discussed below) may indicate that the bones were present on site for a purpose other than meat utility. Late Norse deposits contained head elements (teeth and mandibles) in greater proportions than earlier periods, but no flipper or rib portions. Teeth and mandibles have low meat utility, and may have been present on site for other reasons (see Sections 4 to 6 of this chapter).

3.1.2 NATURE OF THE MODIFICATIONS

While the current discussion focuses on the categories of unmodified and modified elements, where modifications do occur, they support the interpretation of these groups as representative of meat utilisation. At Cladh Hallan cut marks observed on the neural spine of a thoracic vertebra from a small cetacean, recovered from Late Bronze Age deposits (phase 7) (Figure 52, Chapter 6), and chop marks on the base of the articulating lumbar vertebrae from the bottlenose dolphin/ Risso’s dolphin (Early Iron Age, phase 16) are likely to demonstrate meat removal.

A greater degree of modification was observed on some of the delphinoid vertebrae from Bornais, thought to relate to rough chopping, resulting in the loss of some portions of the centra in some cases (e.g. Figure 53). This could relate to the chopping up of portions of the cetaceans, in association with butchery and meat utility. However, chopping is frequently employed early in the bone working process for primary reduction (e.g. Betts 2007). The nature of the chopped bone, which would primarily consist of small fragments of trabecular bone may argue against this interpretation (studies have shown that dense bone is typically preferred for artefact manufacture (Betts 2007)) and the artefact assemblage was found to be principally composed of larger species. Thus, chopping in these instances may be more likely to relate to butchery.

Flipper bones at Bornais also showed signs of modification. Those present in Early and Middle Norse contexts (871; 2275; 1053) were modified to a greater degree than would be required for meat removal. Pieces from 871, 2275 and 1053 represented the ends of the bone which had been chopped away from the rest of the bone possibly indicating primary reduction associated with artefact production (Figure 61).

Figure 61 Chopped end of the phalange or metacarpal of a delphinid (2275) from Bornais

3.1.3 MEAT USE IN CONTEXT

The correlation between unmodified and minimally modified elements, small species, and the presence of elements with high meat utility and associated butchery marks fits with the expected pattern of bone recovery within cuts of meat for smaller species (O'Connell et al. 1988; Savelle and Friesen 1996) and demonstrates that Delphinoids were likely valued at Cladh Hallan and Bornais in part for their meat utility. Evidence of portions with lower meat utility, and greater levels of modification seen on some bones indicates that meat utility may not have been the only reason Delphinoid bones were present on the sites. This following discussion places the results of the above assessment into context.

While the assessment of taxa, elements and modifications has indicated that cetacean meat was probably present at Cladh Hallan and Bornais, the evidence is small-scale on both sites. At Cladh Hallan only a handful of individuals are represented by the material discussed above suggesting that exploitation was very restricted. While it is possible that the bones represent only a portion of the overall number of cetaceans exploited for their meat utility, small-scale exploitation of marine mammals corresponds with the wider economic patterns at Cladh Hallan and other Bronze Age and Early Iron Age sites in the Hebrides (e.g. Smith and Mulville 2004). Sites of this period generally demonstrate a focus on terrestrial species with marine species making only a small contribution to the economy demonstrated by zooarchaeological assemblages (Smith and Mulville 2004) stable isotope and lipid residue analyses (e.g. Cramp et al. 2014; Jones and Mulville 2016).

Only a single delphinoid vertebra was identified in the Late Iron Age deposits from Bornais and as such conclusions cannot be drawn for this phase. Evidence is greater from the Norse period. While elements from Delphinoidea are present throughout the Norse period, the Early Norse period has slightly higher frequencies of Delphinoid elements than the Late Norse period, and contained articulating portions with high meat utility. This evidence may reflect initial consumption of meat from smaller cetaceans during the Early Norse period with a possible shift away from this dietary resource by Late Norse period, though bones with high meat utility are represented in all periods indicating that small cetacean meat was not entirely abandoned.

The consumption of delphinoid meat in the Norse period may reflect wider patterns which demonstrate intensification in fishing and consumption of marine resources around this time (Barrett et al. 1999, 2001; Barrett and Richards 2004; Harland 2006; Ingrem 2005; Richards et al. 2006). The evidence for delphinoid meat in the Early Norse period in particular may reflect patterns seen on other Norse sites in the North Atlantic, many of which demonstrate greater exploitation of marine and wild species within their earliest phases (e.g. Arge 2014; Brewington 2011; Church et al. 2005; Dugmore et al. 2005: 29). In the Late Norse period the possible decrease in use of Delphinoids for meat coincides with a phase when herring bones were found in their greatest densities at Bornais (Sharples et al. 2016), perhaps indicating that other marine species were not needed as dietary supplements by this time. Van den Hurk (2020: 115) made a similar suggestion based on the frequency with which cetacean bone is recorded on sites from these periods, noting a decrease in the number of sites with cetacean bone from around the end of the first millennium AD.

3.1.4 OTHER EVIDENCE FOR CETACEAN FLESH

While the bone assemblages at Cladh Hallan and Bornais form the basis for understanding patterns of cetacean use, it is possible that the bone present on the sites may represent only a small portion of the total number of cetaceans exploited. Cetacean meat and blubber can be easily separated from bone, and the bone itself may be left at shoreline processing sites (Mulville 2002: 40; Savelle and Friesen 1996). As discussed above and in Chapter 2, this factor particularly affects the larger species (Smith and Kinahan 2000: 95) and bones of these species are likely to be present on sites due to their own utility (evident at Cladh Hallan and Bornais by the greater degree of modification observed on bones from these species, discussed below).

The exploitation of the flesh of large whales may therefore have left no archaeological signature within the bone assemblage of settlement sites. While some authors working on arctic sites have demonstrated the importance of large cetaceans to former diets by identifying gaps in zooarchaeological assemblages, indicative of the absence of a focal resource: large cetaceans (e.g. Betts and Friesen 2013, see Chapter 2), these studies have hitherto required comparative analysis of multiple assemblages, not currently available in the Hebrides. Cetacean blubber, which can easily be removed from the carcass and is not associated with bone riders, is discussed below (Section 7).

3.2 SUMMARY

Investigation of taxa, elements, modifications and spatial distributions has revealed insights into cetacean meat utility during the prehistoric and Norse periods on the Hebrides. The data has demonstrated that a range of delphinoid species were probably exploited for their meat during the prehistoric and Norse periods. There is no evidence for specific species preferences, and a variety of different Delphinoids were utilised. The exploitation appears to have been low-level during all periods, though some temporal patterns are evident including a possible greater focus on delphinoid meat in the Early Norse compared with Late Norse periods. The flesh of large species is also demonstrated at Bornais by a humpback whale barnacle (Law 2021), which could reflect use of blubber or meat from this species during the Late Norse period.

4 ARTEFACTS

The utility of cetacean bone for artefact production is well recognised (e.g. MacGregor 1985; Mulville 2002; Szabo 2008) and previous studies have established factors which influence selection for artefact production, including element, bone density, size (Betts 2007), resilience and strength (Hallén 1994). This section investigates the use of different species and elements for artefact production in the Cladh Hallan and Bornais assemblages to determine whether preferences are evident.

Chapter 6 demonstrated that most artefacts were made from the bones of larger species (with different species taking precedence at different times) (see Evans 2021), though smaller species were also represented. The following section investigates whether any evidence of species selection is present when specific artefact types are considered.

Evidence of selection is also relevant for discussions on procurement (e.g. Hallén 1994) which take place in the next chapter. Standardisation in cetacean bone tool manufacture, and the repeated focus on cetacean bone for the manufacture of certain objects, is used as a line of argument by some considering evidence for procurement (e.g. Hennius et al. 2018; MacGregor 1974, 1985; Sjøvold 1971). However, taxonomic identification has previously been rare within these studies (though see Hennius et al. 2018). The current dataset therefore provides an opportunity to investigate whether repeated focus on particular species is evident among the artefact assemblages at Cladh Hallan and Bornais, with potential implications for procurement.

4.1 ARTEFACT TYPES: TAXA AND ELEMENTS

The following section investigates taxa and element patterns in artefact types.

Cetacean bone artefact types at Cladh Hallan and Bornais (defined in Clark et al. 2012; Davies and Slater forthcoming; Smith and Sharples 2021) are set out within Table 26 – 31, and include many of those which are common finds on Scottish coastal sites, including the ubiquitous perforated or worked bone discs and vertebral 'vessels', and other perforated flat pieces of bone, notched implements, chopping blocks, plaques and other objects (Clark 1947; Hallén 1994; Macgregor 1974; Mulville 2002; Szabo 2008: 152). The use and development of cetacean bone artefact types have been studied by previous authors (e.g. Hallén 1994; Szabo 2008; Petersen 1951; Sjøvold 1971, 1974; van den Hurk 2020) and these issues are therefore not generally readdressed here other than where new potential types are noted.

4.1.1 OVERVIEW OF TAXA AND ELEMENT SELECTION WITHIN TYPES

A range of artefact types were identified at Cladh Hallan and Bornais and a number of types are represented by more than one object, allowing for intra-type comparisons of taxonomic and element composition. The most numerous artefacts included worked or perforated bone discs, chopping blocks, textile tools, gaming pieces and plaques, and all held evidence of the use of multiple taxa (Table 26 and 28). Large species were most common though the bones of smaller species were also used in some cases. While the same artefacts were made from the bones of different species; the same species were also used to create a range of artefacts at both sites. Sperm whale, blue whale (at Cladh Hallan only), fin whale, humpback whale, gray whale (at Bornais only) and balaenid were repeatedly identified within the artefact assemblages, each used for a variety of different artefact types. Sperm whale was most common on both sites, accounting for 7 of the artefacts from Cladh Hallan and 9 from Bornais, and at the latter site evidence of use of sperm whale increases through time, with the greatest evidence for use in the Middle and Late Norse periods (Evans 2021: 286).

There was greater evidence for preferential use of particular elements (Tables 27 and 29). Vertebral epiphyses and ribs were the most common elements used for artefact production on both sites, and the Cladh Hallan assemblage in particular held high numbers of the former. However, a variety of other elements were also represented in smaller numbers on both sites including vertebrae, phalanges, teeth and skull fragments. This preference for vertebral elements[14] and ribs was also recorded by Hallén (1994: 195) in the assemblages from Foshigarry and Bac Mhic Connain. Use of ribs for artefact manufacture has also been investigated on other sites and these elements have been shown to be well adapted for use as a raw material for artefacts (with areas of dense bone, and relatively large size) (Betts 2007).

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[14] Hallén (1994) did not differentiate between vertebral epiphyses and the main body of the vertebrae.

These broad patterns characterise the artefact assemblage. However, a number of specific facets of the artefact assemblage were of particular interest in light of discussions on species and element selection within tool types and are discussed in further detail below. This includes patterns within the worked bone disc and plaque categories. Modified epiphyseal discs are noted as a potentially new type.

Artefact and Identification	Late Bronze Age	Early Iron Age	U/S	Total
Chopping block	**1**			**1**
Cetacea	1			1
Cist capping	**1**			**1**
P. macrocephalus	1			1
Worked bone disc	**9**		**1**	**10**
Mysticeti	1			1
P. macrocephalus	3			3
Delphinidae	3			3
Delphinoidea	1			1
Odontoceti			1	1
Cetacea	1			1
Modified epiphysis	**6**			**6**
M. novaeangliae	1			1
Mysticeti	4			4
P. macrocephalus	1			1
Hollowed vertebra	**1**			**1**
G. melas	1			1
Curved worked piece	**1**			**1**
M. novaeangliae	1			1
Flat notched implement	**2**			**2**
Balaenidae	1			1
Cetacea	1			1
Spatula	**1**		**1**	**2**
B. physalus	1			1
Cetacea			1	1
Flat or rectangular piece	**8**		**1**	**9**
B. musculus	2			2
M. novaeangliae	1			1
Large cetacean	1			1
Cetacea	4		1	5
Flat piece with multiple perforations		**2**		**2**
B. musculus		1		1
Cetacea		1		1
Hollowed long bone cut with depression	**1**			**1**
M. novaeangliae	1			1
Ornament	**1**			**1**
Odontoceti	1			1
Perforated fragment	**2**			**2**
Mysticeti	1			1

Cetacea	1				1
Perforated rectangular piece	**4**				**4**
B. musculus	2				2
Cetacea	2				2
Rod		**3**			**3**
B. musculus		1			1
Cetacea		2			2
Wedge shaped	**1**				**1**
Cetacea	1				1
Worked piece with depression	**3**				**3**
P. macrocephalus	2				2
Cetacea	1				1
Miscellaneous	**3**		**1**	**1**	**5**
Cetacea	3		1	1	5
Grand Total	45		6	4	55

Table 26 Taxonomic identifications of artefacts at Cladh Hallan

	Period			
Element and Artefact	Late Bronze Age	Early Iron Age	US	Total
Skull fragment	**2**			**2**
Cist capping	1			1
Worked piece with depression	1			1
Tooth	**1**			**1**
Ornament	1			1
Vertebra	**1**			**1**
Perforated rectangular piece	1			1
Lumbar vertebra	**1**			**1**
Hollowed vertebra	1			1
Vertebral epiphysis	**11**		**1**	**12**
Modified epiphysis	6			6
Worked bone disc	5		1	6
Rib	**2**		**1**	**3**
Curved worked piece	1			1
Flat or rectangular piece	1			1
Spatula			1	1
Phalange	**1**			**1**
Hollowed long bone cut with depression	1			1
Unknown	**26**	**6**	**2**	**34**
Grand Total	45	6	4	55

Table 27 Elements used for artefact production at Cladh Hallan

Artefact and Identification	Late Iron Age I	Early Norse	Middle Norse	Late Norse	Final occupation	Norse	Unphased and U/S	Total
Bone dice			**1**	**2**				**3**
B. physalus				1				1
P. macrocephalus			1	1				2
Bone pin		**2**						**2**
Cetacea		2						2
Bone point	**1**							**1**
Cetacea	1							1
Chopping block		**1**	**3**	**1**	**1**			**6**
B. physalus				1				1
Balaenidae			1					1
E. robustus		1	1					2
P. macrocephalus			1					1
Large to Medium cetacean					1			1
Comb and comb fragments	**2**		**2**	**2**				**6**
B. physalus			1	1				2
Balaenidae				1				1
P. macrocephalus	1							1
Cetacea	1		1					2
Door pivot	**1**							**1**
E. robustus	1							1
Flax scutcher						**1**		**1**
M. novaeangliae						1		1
Loom weight			**1**					**1**
O. orca			1					1
Miscellaneous	**2**	**1**						**3**
Delphinoidea		1						1
Cetacea	2							2
Object with incised lines	**3**							**3**
Cetacea	3							3
Perforated disc	**3**		**1**	**1**			**1**	**6**
Delphinidae			1					1
E. robustus	1							1
M. novaeangliae				1				1
Odontoceti	1							1
Ziphiidae	1							1
Cetacea							1	1
Perforated object			**1**					**1**
Cetacea			1					1
Pin beater		**1**						**1**
Cetacea		1						1
Plaque			**11**				**1**	**12**

Balaenidae			1					1
P. macrocephalus			4					4
Ziphiidae			1					1
Cetacea			5				1	6
Post			**1**					**1**
P. macrocephalus			1					1
Rod			**1**					**1**
Cetacea			1					1
Spindle whorl				**1**				**1**
Delphinidae				1				1
Weaving tablet		**2**						**2**
Large cetacean		2						2
Grand Total	**12**	**7**	**22**	**7**	**1**	**1**	**2**	**52**

Table 28 Taxonomic identifications of artefacts at Bornais

Element and Artefact	Late Iron Age I	Early Norse	Middle Norse	Late Norse	Final occupation	Norse	Unphased and U/S	Total
Skull		**1**						**1**
Chopping block		1						1
Vertebra			**1**	**1**				**2**
Chopping block			1	1				2
Caudal vertebra				**1**	**1**			**2**
Chopping block					1			1
Spindle whorl				1				1
Vertebral centrum			**1**					**1**
Perforated object			1					1
Vertebral epiphysis	**3**		**1**				**1**	**5**
Perforated disc	3		1				1	5
Rib	**1**		**3**					**4**
Chopping block			2					2
Door pivot	1							1
Post			1					1
Unknown	**8**	**6**	**16**	**5**		**1**	**1**	**37**
Total	**12**	**7**	**22**	**7**	**1**	**1**	**2**	**52**

Table 29 Elements used for artefact production at Bornais

4.1.2 EXAMINATION OF SELECT TYPES

Worked or perforated bone discs

In total 16 worked or perforated bone discs were recovered from Cladh Hallan and Bornais, The discs range in size from 12.4mm to 71.5mm in diameter and represent a variety of species. At Cladh Hallan worked bone discs from Late Bronze Age deposits were made from the bones of Delphinoid species (SF 4583; SF 4683; SF 3465; SF 3678); sperm whale (SF 3456 and SF 3453/4826, the latter two can be refitted) and Mysticeti (SF 3744) (with further generic identifications). At Bornais Late Iron Age deposits demonstrated use of gray whale (SF 1495) and beaked whale (SF 8522) for perforated disc manufacture (again with further generic identifications), while Norse deposits demonstrated use of humpback whale (SF 2694) and dolphin (SF 2332) bone. Thus, the bone discs represented the use of a range of different species with no evidence of a focus on any particular species (though numerous delphinoid discs are present at Cladh Hallan this may represent multiple species).

Most worked or perforated bone discs were also made from vertebral epiphyses on both sites, reflecting the preference for this element within the artefact assemblages. Most were also present as whole epiphyses and demonstrated minimal modification with the exception of perforations in some cases. However, a small number showed evidence of modification in size. Of particular note were two fragments of the same broken piece of sperm whale disc (SF 3453/4826) which had evidently been greatly reduced in size (see Figure 50 in the previous chapter) (the size reduction can be identified based on the scale and form of the fusion pattern).

Further modification was also evident in four discs from Cladh Hallan and one from Bornais which were found to be made from bone other than vertebral epiphyses. It was not possible to identify the precise elements from which these bones derived, however, they were certainly not from vertebral epiphyses given the orientation of the trabeculae. Those from Cladh Hallan included two perforated examples (context 1575; SF3744; context 473, SF 4213). The others were unperforated, and rougher in form, representing approximately circular pieces of worked sperm whale and Delphinoidea bone which may disc rough outs (phase 12, context 1315, SF 3456; phase 9, context 1311, SF 4583 respectively). The example from Bornais was made from humpback whale and came from Late Norse deposits (context 728, SF 2694). Hallén (1994: 217-9) similarly reported on a piece of cancellous bone from Foshigarry which had been rounded and perforated in a manner like the epiphyseal discs.

A perforated deer scapulae from Cladh Hallan (SF 4672) was also found to closely mirror the form of one of the smaller delphinoid discs (SF 4683): both are small and have a central perforation in a tear-drop shape (possibly reflecting the intended form of the perforation, or wear). The objects were both found on the same house floor and from within the same context (Phase 9, House 401, floor 1311; Figure 62). Wear on similar examples can sometimes be found along one side of the perforation or the outer edge of the disc and it has been suggested that a thread may have been passed through the perforation and 'looped round the object's edge' (Szabo 2008: 155), though wear differs between examples (Hallén 1994: 217) and ultimately the function is not certain (Szabo 2008). However, the similarity in form between the objects, and deposition within the same context, does suggest that the items are comparable, and the worked deer bone disc therefore represents the modification of bone from a terrestrial species to mimic the form of the cetacean bone discs. Interestingly in his assessment of the bone assemblage from Skara Brae, Foxon (1991) found that other materials such as antler tines had been shaped to mimic cetacean teeth and used for the same purpose (as pendants) (Foxon 1991: 162) providing parallels for the mimicry of cetacean bone objects with bone from other species at Cladh Hallan.

Use of different species and elements, and apparent need to fashion bones into circular form or to reduce the size of the discs may suggest that suitable cetacean bone epiphyseal discs were not always readily available at Cladh Hallan, Bornais and other prehistoric Hebridean sites (Hallén 1994).

Figure 62 Perforated bone discs with tear drop perforations (SF4672, left and SF4683, right)

Many interpretations have been put forward for these artefacts (Hallén 1994; Hedges 1987; Szabo 2008). Larger bones of this type have been interpreted as pot lids (Hallén 1994; Hedges 1987) and smaller examples as spindle whorls or children's toys, based on ethnographic evidence (Annandale 1905; Szabo 2008: 155-9). An example of use as a pot lid may come from a sperm whale vertebral epiphysis with burning on its flat side from Cladh Hallan (Figure 63). While the burning could be a result of use of the bone for fuel, the restriction of the burnt area to the centre of the disc indicates that the edges of a cooking vessel may have allowed for this pattern to form, supporting interpretation as a pot lid.

Figure 63 Sperm whale vertebral disc from Cladh Hallan (context 1311) possibly used as a pot lid

The range of sizes, species, and modifications to the discs within the Cladh Hallan and Bornais assemblages indicate the probability that the objects were put to a variety of uses and previous authors have highlighted the problems with current categorisation of cetacean bone objects (Szabo 2008). Further investigation using use-wear analysis would be beneficial to demonstrate whether the discs were put to different uses. It is possible that further assessment of use may allow the categories of worked and perforated bone discs to be further subdivided, and subdivision could reveal patterns of preference in species which are not evident using the current categorisations.

Plaques

The plaques are mentioned specifically here as the only example of an artefact type with evidence of taxonomic preferences. Plaques were the most numerous cetacean bone artefact type identified at Bornais and all were identified in Middle Norse deposits. As with other artefacts the plaques were made from a variety of taxa including balaenid (SF 1034), beaked whale (SF 5963), and sperm whale. The latter was most numerous, and four examples from this species were identified (SFs 2213, 3407, 5479, 6713). The use of sperm whale in four examples suggests a focus on this species for plaque production during the Middle Norse period (Evans 2021: 286). The function of these objects is uncertain and their forms vary possibly suggesting a range of uses (Sharples 2021: 241). A variety of interpretations have been put forward for plaques, ranging from textile tools to line-winding forks used in line fishing (Mulville 2002; Paterson 2018: 355). As with the worked bone discs, use wear studies have not yet been undertaken on the plaques and while the objects have similarities (including a relatively flat form and perforation, see Figure 64) many are broken hampering comparisons based on form and type.

Figure 64 Sperm whale plaque (left; SF 3407) and balaenid plaque (right SF 1034)

Modified vertebral epiphyses

Modified vertebral epiphyses were found only at Cladh Hallan and six examples were recorded. They are given specific mention here as a potential new type. This category of artefact, characterised by vertebral epiphyses represented by a portion of their edges only, and apparently deliberately rounded on their articular face, was created during the assessment of the material from Cladh Hallan (Figure 65). The purpose of the objects is uncertain and the author could find no other reference to comparable cetacean bone artefacts on other sites. However, as with the worked bone discs these objects were also made from different species including humpback whale (1226) and sperm whale (595) (and more generic identifications (412, 1226, 1512)), but all were made from vertebral epiphyses.

Figure 65 Side view of fragments of vertebral epiphyses from Mysticeti (context 1512), sperm whale (595) and Mysticeti (412) and humpback whale (1226) showing curve

4.2 SUMMARY

The data presented above reflects a complicated picture of use. However, a number of patterns are evident. Although there was a greater use of large species for artefact production, use was generally not species-specific at either site: different species were used for the same artefacts and the same species were used for a range of artefacts. The pattern may be due in part to the conflation of artefact types which could mask any underlying patterns in species preference. This was seen within the worked and perforated disc categories, where evidence for likely differing uses was apparent within the assemblages. Cetacean bone artefact assemblages would benefit from further detailed investigation using use-wear analysis after which species use may be readdressed.

An exception to the above comes with evidence for the more frequent use of sperm whale. Sperm whale is the most frequently identified species within the artefact assemblages suggesting a particular focus in the Late Bronze Age and Middle to Late Norse periods (Evans 2021).

Preferential use of vertebral epiphyses and ribs is evident within both the Cladh Hallan and Bornais assemblages. However, while epiphyses and ribs are most common, other elements were also used; some shaped into the same form as epiphyses. The evidence for use of multiple species for particular artefacts and modifications of bones to mimic the form of particular elements indicates that there may not have been reliable access to cetacean bone, leading the inhabitants of Cladh Hallan and Bornais to rely on a variety of species and elements for the same artefacts.

5 FRAGMENTED BONE AND ARTEFACT UTILITY

The following sections consider whether worked and unworked fragments are likely to relate to artefact manufacture, based on comparison of taxa and elements recorded within this category compared with the artefact category, and spatial distributions.

5.1 WORKED FRAGMENTS

5.1.1 TAXA AND ELEMENTS

The previous section demonstrated that vertebral epiphyses and ribs from large species dominated the artefact categories at Cladh Hallan and Bornais. Table 30 and 31 show taxa and elements identified within the fragmentary bone categories.

Fragments and elements	B. musculus	B. physalus	M. novaeangliae	Balaenidae	Mysticeti	P. macrocephalus	Cetacea	Grand Total
Unworked fragment	5	2	4	8	5	354	705	1083
Earbone							1	1
Skull fragment						337		337
Vertebral epiphysis	1				1			2
Unknown	4	2	4	8	4	17	704	743
Worked fragment	6			1		5	85	97
Skull fragment						3		3
Vertebral process	1							1
Unknown	5			1		2	85	93
Grand Total	11	2	4	9	5	359	790	1180

Table 30 Taxa and elements within the unworked and worked fragment categories at Cladh Hallan

Worked fragments generally represent the same species found within the artefact registers at both sites. The elements identified also represent some of those favoured for artefact production, however, worked skull fragments were also present on both sites, and fragments of sperm whale ivory were identified at Bornais (all from Late Norse deposits). Skulls were used for artefact production less frequently and these fragments may therefore not relate to artefact production.

Worked ivory

Use of marine ivory for artefact production is, however, known from contemporary historical sources and archaeologically. The trade in walrus ivory was at its peak in the 12th century (Seaver 2009; Star et al. 2018) and is represented locally on the Hebrides by the Lewis chessmen. While the chessmen were principally made from walrus ivory, a number of pieces are thought to be made from whale teeth (Robinson 2004: 62). The King's Mirror, a 13th-century Norwegian text, provides further evidence for the use of cetacean ivory during the Late Norse period, and reports that 'there is also a kind of whale called barðhvalr… and these whales have teeth large enough to be carved into fair-sized knife handles or chess men…one whale alone of this kind has so many teeth in the head that it has more than seventy' (Lindquist 1994: 995 translation from Kings Mirror). This quote, and the context of the text indicates that the species referred to is the sperm whale (Lindquist 1994: 184-188), demonstrating the wider context for use of sperm whale ivory and indicating the likelihood that the worked fragments from Bornais relate to artefact manufacture. This is further supported by form of the fragments, which have been worked into small pieces, one of which is of a similar size to the bone dice from the site, though it is rounded on one edge (Figure 66).

Figure 66 Worked sperm whale ivory (SF 5124) from Late Norse deposits at Bornais

Row Labels	B. musculus	B. physalus	B. acutorostrata	M. novaeangliae	Balaenopteridae	E. robustus	Balaenidae	Mysticeti	P. macrocephalus	Large cetacean	Large to Medium cetacean	Odontoceti	Delphinidae	Delphinoidea	Small cetacean	Cetacea	Total
Unworked fragment	2		1	3	1	2	8	9	28	59	2	1			1	1144	1261
Mandible										59	1					83	143
Skull							1		3								4
Rib											1						1
Vertebra																1	1
Vertebral epiphysis												1			1		2
Unknown	2		1	3	1	2	7	9	25							1060	1110
Worked fragment		5			1	3	9	6	32	1			1	1		128	187
Phalange or metacarpal													1				1
Skull		1					1		2							1	5
Tooth									4								4
Vertebral epiphysis						1											1
Vertebral process		2															2
Unknown		2			1	2	8	6	26	1				1		127	174
Grand Total	2	5	1	3	2	5	17	15	60	60	2	1	1	1	1	1272	1448

Table 31 Taxa and elements within the unworked and worked fragment categories at Bornais

5.1.2 SPATIAL DISTRIBUTION

At Cladh Hallan most worked fragments came from house deposits. These areas also held most artefacts, and most cetacean bone in general and as such they do little to illuminate the origins of the worked bone fragments.

At Bornais further evidence for the connection between worked bone and artefact production was found in spatial distributions: many worked fragments were found in areas associated with artefact production. Comb manufacturing for example took place within ancillary building 3 at Bornais (GCD). While no complete composite cetacean bone combs were recorded on the site, a number of worked fragments representing comb manufacturing debris were found to be of cetacean bone. The majority of these fragments were associated with the use of ancillary building 3 (GCD), dated to the 13th century and contemporary midden deposits (GDC) which represent material dumped from this structure (Sharples and Waddington 2020: 408). Antler was the primary material used in comb manufacture at Bornais, however, sperm whale bone fragments dominated the cetacean bone assemblage associated with comb working, though other taxa including balaenid were also identified (Evans 2021).

Three worked fragments of sperm whale ivory were also recorded within ancillary building 3 (GCD, contexts 1713, 886, 879), supporting the assertion that these fragments represent debris associated with artefact manufacture. The recovery of a modified killer whale tooth (1687; Figure 67) is of particular interest in this context. The tooth was found within ancillary building 3, and may have been intended for use in the same way as the sperm whale, indicating the use of different cetacean species in a similar manner – a practice which is demonstrated across the artefact assemblage. Teeth from small Delphinoids (52, 866/860) and beaked whale (s) (1427, 1395) were also found in Late Norse deposits, possibly suggesting wider use of cetacean ivory, though these were unworked.

Figure 67 Modified killer whale tooth (SF 5893) from Late Norse deposits at Bornais

5.1.3 SUMMARY

The evidence suggests that many worked fragments are probably representative of artefact manufacture, and both species and elements present represent those identified within the artefact assemblages. Worked pieces also indicate that cetacean ivory was used during the Late Norse period. However, skull fragments may be present on site for other reasons, discussed further below (see Section 6).

5.2 UNWORKED FRAGMENTS

This section briefly considers whether the unworked fragmentary bone assemblage is likely to relate to bone working.

5.2.1 TAXA AND ELEMENTS

Large whales dominate the unworked fragment categories and represent taxa also found within the artefact assemblage. However, small species are also found in smaller numbers within the artefact assemblage, and these are not represented within the fragmented assemblage.

Artefacts are primarily made from ribs and vertebral epiphyses. Though small numbers of epiphyseal fragments are present, it is skull fragments which are most common within the fragmentary bone assemblage at Cladh Hallan (Table 30). Few artefacts were made from skull bones and the porous trabeculae structure would make these bones a poor choice for most artefacts indicating that artefactual utility may not have been the sole driver in the production of the fragments seen within the Cladh Hallan assemblage.

At Bornais, while worked fragments reflect species also found within the artefact assemblage, the unworked fragment category contains species not represented by artefacts (Table 31). This includes the blue whale and minke whale. As at Cladh Hallan skull fragments are also found in higher numbers in the fragmentary bone categories compared with the artefact category, though ribs and vertebral epiphyses (and other elements used for artefact production) are also present.

5.2.2 SPATIAL DISTRIBUTION

As with the worked fragments, most unworked fragments from Cladh Hallan came from house deposits.

At Bornais, the distribution of unworked fragments differs from that of the worked fragments. The majority of unworked fragments from Bornais came from the Late Iron Age deposits (CC). Norse deposits also produced unworked fragments, and while numerous worked fragments were found in deposits associated with bone working (GCD/GDC) fewer unworked fragments were found within these areas. Instead most unworked fragments were found in cultivation soils, sands (GAA, GAD) middens (CF) and house deposits (BCC; BEC; BEE).

5.2.3 SUMMARY

It is likely that some of the unworked fragments represent bone working. However, differences between species and element profiles of fragmented bone and artefacts are present, and there are differences in the distributions of worked and unworked fragments which could indicate that fragmentation was not solely a product of bone working. Fragmentation can also occur as a result of oil extraction and this is considered further below.

6 OIL AND FUEL

Oil procurement was one of the main drivers for the modern commercial whaling industry and large amounts can be extracted from cetacean carcasses as blubber and from the crania of Odontoceti (most notably from the spermaceti organ of sperm whales; Figure 68). Oil (also referred to as fatty marrow or bone grease (Betts 2007; Kaufman and Forestell 1986; Slijper 1962)) is also found stored in the bones where it fills the voids between the trabecular structure (Monks 2005: 139). Historically this material has been used as a source of fuel, food, soap or lubricant (van den Hurk 2020: 35). Chopping up of cetacean bone for oil extraction is known both historically and archaeologically (e.g. Hambrecht and Gibbons 2018) and has ethnographic parallels in the Faroe Islands, Norway and among Arctic communities and fragmented bone may therefore reflect this process (Annandale 1905; Clark 1952; Heizer 1963). This section investigates all available evidence for the use of cetacean bone as a source of oil at Cladh Hallan and Bornais. Species and element identifications are compared with oil utility indices and modifications, spatial distributions and use are all drawn on as supporting evidence.

6.1 TAXA, ELEMENTS, FRAGMENTED BONE AND THE OIL UTILITY INDEX

Fragmentation within cetacean bone assemblages is often a product of oil extraction (e.g. Betts 2007; Hambrecht and Gibbons 2018) and the following section therefore considers the fragmented bone from Cladh Hallan and Bornais with reference to oil utility indices. Taxa and element profiles of the fragmentary bone assemblage are compared with data on the oil content of cetacean bones established by Higgs et al. (2001) and Monks (2005).

6.1.1 TAXA

Unworked fragments represent the remains of a range of primarily large species, which included sperm whale, blue whale, humpback whale and balaenids all of which identified on both sites, with fin whale also identified at Cladh Hallan and minke and gray whale identified at Bornais.

Higgs et al. (2011) studied differences in bone oil content between different species. This study found high proportions of oil in the bones of large taxa (including Mysticeti and the sperm whale), and lower concentrations in delphinoids (Higgs et al. 2011: 11). The fragmentary bone assemblages from both Cladh Hallan and Bornais are therefore composed primarily of species whose bones have a high oil content. However, these species were also valued for artefact production, evident in the frequent use of their bones for artefacts within the Cladh Hallan and Bornais assemblages (see Section 4), and thus this evidence is not sufficient to demonstrate oil utility.

6.1.2 ELEMENTS

Most of the fragmented bones from Cladh Hallan and Bornais did not retain sufficient morphological characteristics to identify elements. However, in a number of cases identification was possible and sperm whale skull fragments in particular were found to dominate the assemblage at Cladh Hallan (Table 30). Oil content is highest within the skull (Higgs et al. 2011) and up to 80-84% of all oil within the skeleton is contained within this element (Monks 2005: 140; Slijper 1962: 109). The choice of oil rich bones from oil rich species supports the interpretation that that at least some of the fragmented bones at Cladh Hallan represent extraction of oil from the cetacean bone. The repeated presence of fragments of sperm whale skull is particularly interesting in this light, given the large quantity of oil contained within the spermaceti organ, situated in the head of the whale (Watanabe and Suzuki 1950; Figure 68). Spermaceti oil was valued during recent history for the bright and clear light it produced when burned (e.g. Irwin 2012) and it is likely that the spermaceti oil would also have been used for fuel in the past. It is possible that the inhabitants of Cladh Hallan associated sperm whale bone with oil, and thus repeatedly used bone from the skull as a source of fuel.

Figure 68 Sperm whale skeleton and reconstructed spermaceti organ and junk suspended in the Natural History Museum, London. Photo by author

The skull fragments from Bornais also included sperm whale from Early Norse deposits, and large pieces of balaenid skull were found in Middle Norse deposits (Evans 2021: 284) and fin whale skull from the Late Norse period (Table 31). However, burnt fragments of mandible from a large species dominate the unworked fragment category on this site. Large baleen whales in particular have high oil contents in their mandibles (Higgs et al. 2011), and the mandible fragments may derive from one of these species, though this is not confirmed.

6.1.3 NON- FRAGMENTED BONE

While fragmented bone is the focus, a number of modified elements also warrant attention within this discussion. Late Norse deposits at Bornais produced Delphinoid mandibles (contexts 52, 1072). While these bones have low meat utility the mandibles of odontoceti are known to contain oil (Higgs et al. 2011: 11; Lantz and Gunasekera 1955) and may therefore have been present on site for their oil rather than meat utility. However, it is also possible that these mandibles may represent the exploitation of cetacean ivory during the Late Norse period (discussed above).

6.2 BURNT BONE

Burning of cetacean bone for use as a fuel source (one of the uses of oil) is recorded through ethnographic evidence (e.g. Betts 2007) and has also been noted on a number of archaeological sites (Childe 1931; Clarke 1947; Gibbons 2018; Hambrecht and Gibbons, 2018). Evidence for burning which may reflect oil utility is examined here through consideration of quantities of burnt bone and patterns of burning among taxa and elements.

Burning was evident within the Cladh Hallan and, to a greater extent, Bornais assemblages (the latter reported on in Evans 2021). Generally burnt bone made up only a small proportion of the assemblage at Cladh Hallan (4% in total; Table 32) and while most species and elements could not be identified those which could were predominately from sperm whale skull, adding weight to the suggestion that oil from the head of this species was utilised as a fuel source at Cladh Hallan. Although the proportion of burnt bone was small, burning was also found on artefacts (SF 3711, 3811) and large pieces of cetacean bone (e.g. SF 5018) whose spatial distributions shed further light on cetacean bone and fuel utility, discussed further below.

Elements with evidence of burning	B. musculus	Balaenidae	Mysticeti	P. macrocephalus	Medium to large cetacean	Delphinidae	Cetacea	Grand Total
Skull fragment				6				6
Thoracic vertebra						1		1
Caudal vertebra					1			1
Vertebra							1	1
Vertebral epiphysis			1	1				2
Unknown	1	1		2			40	44
Grand Total	1	1	1	9	1	1	41	55

Table 32 Burnt bone from Cladh Hallan

Bornais has a larger burnt bone assemblage (Table 33) (Evans 2021: 283). As at Cladh Hallan most burnt bone could not be identified. However, where identifications were achieved these included oil rich cetacean bones including those from large species, and with skull and mandibles represented.

Row Labels	Balaenidae	P. macrocephalus	Large cetacean	Large to Medium cetacean	Medium cetacean	Delphinoidea	Small delphinoid	Cetacea	Total
Skull	1							1	2
Ear bone								1	1
Mandible			59					83	142
Thoracic vertebra						1	1		2
Vertebra	1				1		1		3
Vertebral epiphysis		1		1					2
Unknown	1							759	760
Total	3	1	59	1	1	1	2	844	912

Table 33 Burnt bone from Bornais

6.3 SUPPORTING EVIDENCE: ARTEFACTS AND SPATIAL DISTRIBUTIONS

This section reviews other evidence for oil utility at the sites, primarily referring to spatial, contextual and artefactual evidence as available.

6.3.1 Cladh Hallan

Chapter 6 demonstrated that fragmented bone, including fragments of sperm whale skull, were found across the site in the Late Bronze Age phases including within all of the houses. The distributions of burnt bone reflect this pattern and burnt fragments are found in many of the houses particularly during the Late Bronze Age (Table 34). The distribution of fragmented and burnt bone may represent use of cetacean bone as a fuel source in all houses during the Late Bronze Age. A fragment of burnt blue whale bone was also recorded from house deposits dating to the Early Iron Age, possibly representing continued use of oil rich species for fuel.

Row Labels	B. musculus	Balaenidae	Mysticeti	P. macrocephalus	Medium to large cetacean	Delphinidae	Cetacea	Grand Total
Early Bronze Age							**1**	**1**
NE Area							1	1
Late Bronze Age		**1**	**1**	**9**	**1**	**1**	**34**	**47**
Entrance to House 1370				1				1
Forecourt of 1370				1				1
House 1370		1	1				13	15
Forecourt				1			1	2
House 401				2			2	4
House 801				4		1	3	8
House 2190					1			1
N Area							1	1
NE Area							13	13
SE Area							1	1
Early Iron Age	**1**						**6**	**7**
House 401							2	2
House 150	1						3	4
House 1500							1	1
Grand Total	**1**	**1**	**1**	**9**	**1**	**1**	**41**	**55**

Table 34 Spatial distribution of burnt bone at Cladh Hallan

The deposition of very large skull fragments, some of which had burning on them, in the wall beside the entrance to House 1370 in phase 8/9 (SF 5018) may also represent a store of bone to be used within the houses as fuel (Figure 69). This fragment is discussed further below for its role as a structured deposit (Section 8.2). Large fragments may have been brought into the house, and broken down into smaller fragments within the houses allowing for the oil to be extracted, and producing the pattern of large numbers of small fragments found in the house floors. Skull fragments were found within all houses during this phase, including relatively large skull fragments found within House 801 (contexts 822, 832, 1149, 1150).

Figure 69 Large fragment of sperm whale skull recovered from the wall next to the entrance of House 1370 (SF5018)

The connection between cetacean bone and fuel is apparent within the artefact assemblage at Cladh Hallan. Two objects interpreted as lamps have been identified in phase 9 and 10 deposits. One was formed from a rectangular slab of bone made from the sperm whale skull, with a circular depression burnt black (SF 3811; see Figure 46). This represents the only artefact made of sperm whale skull. Its use as a raw material for the manufacture of this object may therefore have been closely linked to the fuel utility of the bone. The absence of other sperm whale skull artefacts is likely to reflect the paucity of the bone for artefact production, due to the porous structure. The second object was also made of sperm whale though the element could not be determined. It formed a rounded lump of bone, also with a circular depression with a darkened area indicative of heating (SF 3711). Blubber and oil were both used as a fuel source in the past (recorded historically by Olaus Magnus in the 16th century; van den Hurk 2020: 35) and either could have been burnt within these lamps.

6.3.2 BORNAIS

Distributions of burnt bone also aid interpretation at Bornais. Late Iron Age deposits associated with the wheelhouse (CB; CC) held the highest frequency of burnt bone and includes a large number of pieces burnt accidentally when the first phase of the wheelhouse was burnt down (CB). However, another group of burnt material was present in the infilling of the final wheelhouse (CC) which may have been deliberately burnt (Evans 2021; Sharples 2012). This included numerous burnt fragments of mandible from a large species of cetacean which may reflect fuel utility.

Norse deposits on mound 1 (CE; CF) also produced large quantities of burnt cetacean bone. The majority came from midden deposits (CF) which also contained other animal bone, some of which was also burnt (Sharples 2012: 170). However, while these Norse deposits were in formation, Late Iron Age deposits were also eroding (Sharples 2012: 172) and some of the material (particularly that from CF) is likely to be redeposited.

Row Labels	Balaenidae	P. macrocephalus	Large cetacean	Large to Medium cetacean	Medium cetacean	Delphinoidea	Small delphinoid	Cetacea	Grand Total
Late Iron Age		**1**	**59**				**1**	**572**	**633**
BAE								1	1
BAG								3	3
CB								7	7
CB/CC								2	2
CC		1	59				1	557	618
CG								2	2
Early Norse				**1**		**1**		**12**	**14**
BBD						1		6	7
GAA				1				5	6
GAD								1	1
Middle Norse								**50**	**50**
AD								2	2
BCA								1	1
BCB								2	2
BCC								41	41
GBA								4	4
BDF								1	1
BDG								1	1
BDH	1								1
BDI	1							2	3
HD	1							1	2
Late Norse					**1**			**30**	**31**
BEC								11	11

BEE								3	3
BEI					1				1
GCD								1	1
GCF								3	3
GDC								2	2
GEC								1	1
GEF								6	6
IA								2	2
IB								1	1
Final occupation								**1**	**1**
GFB								1	1
Norse							**1**	**173**	**174**
CE								17	17
CF							1	156	157
Unphased and U/S								**1**	**1**
BGA								1	1
Grand Total	**3**	**1**	**59**	**1**	**1**	**1**	**2**	**844**	**912**

Table 35 Spatial distribution of burnt bone at Bornais with high frequencies of burnt bone highlighted

Norse deposits on mounds 2 an 2A also included evidence of burnt bone, and many came from the Middle Norse occupation of House 2 (BCC) and the early occupation of Late Norse House 3 (BEC) (Table 35). The majority of the burnt bone from House 2 came from a context which may represent a dump of hearth material (1302), and although a smaller quantity of bone was recovered from House 3 (BEC), over 40% of the bone fragments from this group were burnt (Evans 2021: 283-4). The focus of burnt bone in these domestic contexts is likely to demonstrate the use of the cetacean bone as fuel. While species could not be identified in most cases unburnt bone from the same groups as burnt bone has been identified. Unworked fragments and other material from BCC and BEC (Table 35), was dominated by the bones of large cetaceans, and in particular Mysticeti. While interpretation must be tentative in the absence of direct identifications, this pattern suggests that the burnt bone from these groups derives from larger taxa, and probably Mysticeti (Evans 2021: 284).

6.4 SUMMARY

The fragmented and burnt bone assemblages from both Cladh Hallan and Bornais are primarily composed of the remains of oil-rich species and elements, including skull fragments from sperm whales, balaenopterids and balaenids. While fragmentation can occur due to bone working or other factors, the evidence set out here has shown that oil extraction is the likely cause for at least some, if not most, of the unworked fragments found at Cladh Hallan and Bornais, and evidence from burnt bone suggests use of this material as a fuel source.

7 ‘INVISIBLE’ PRODUCTS

Many cetacean products would leave no trace in the archaeological record (see Chapter 2). While the evidence reviewed above indicates that cetacean remains were put to a variety of uses, drawing on their meat, artefactual, architectural oil and fuel utility, it is also likely that other resources, including blubber, skin, sinews (e.g. Figure 70), spermaceti and potentially products such as ambergris were also used in the past. These typically ‘invisible’ resources are demonstrated at Bornais by the identification of a humpback whale barnacle in final occupation deposits (Law 2021: 334). The barnacle indicates the presence of humpback whale flesh on site at a time when it has not been identified within the bone record and demonstrates that the flesh of large cetaceans may have been transported back to site, potentially for meat consumption or for blubber use, or use of the skin, hinting at the otherwise invisible use of this resource (Smith and Kinahan 2000).

No other direct evidence of perishable cetacean remains have been identified at Cladh Hallan and Bornais (though see Section 8.1.1 for potential indirect evidence). However, ambergris is depicted on maps from the 18th century which show that it was known to wash up on the west coast (see Figure 6), demonstrating that it was also probably available to the inhabitants of both settlements, along with all other cetacean remains.

Figure 70 Example of caudal ligament from a cetacean twisted into a rope 'of great strength' (photo by author, object held by NHM Wandsworth)

8 BEYOND FUNCTIONAL UTILITY: SOCIAL UTILITY, SEASCAPES, SPECIES AND STRUCTURED DEPOSITS

The previous sections have all focused on the aspects of functional utility which guided cetacean bone use at Cladh Hallan and Bornais. The current section seeks to go beyond this, recognising that there are often non-utilitarian aspects of animal bone use and deposition (Hill 2013; Jones 1998; Savelle 1997: 882; 2002). The following sections investigate the social utility of cetaceans at Cladh Hallan and Bornais (Section 8.1), and evidence for human-animal-landscape interactions through structured deposits (Section 8.2).

8.1 SOCIAL UTILITY

This section investigates social dimensions of the cetacean bone assemblages from Cladh Hallan and Bornais. Social archaeology covers a broad spectrum of ideas but generally aims to examine how social dimensions of past communities influenced and structured archaeological remains. Social relations have been the focus for others studying cetacean zooarchaeology, and status has been explored by a number of researchers (e.g. Gardiner 1997; Szabo 2008; van den Hurk 2020). Others have considered the occurrence of whales on the coast as catalyst for social aggregation events (Evans et al. 2016) and a stage against which social relationships and tensions can be played out (Szabo 2008). Szabo's (2008) work in particular wove together historical and archaeological evidence in a manner which illuminated social aspects of cetacean utility.

While historical and ethnographic data is often used to derive a nuanced understanding of social aspects of cetacean use, studies have demonstrated that intra-site distributions of species and elements can reflect social processes (e.g. Savelle 2002; Whitridge 2002).

Comparisons are generally required to understand social aspects of cetacean bone assemblages. The differences between Cladh Hallan and Bornais, the former with a series of contemporary houses occupied through multiple phases, and the latter with a sequence of consecutive houses and ancillary structures means that different interpretive methods are required to understand social utility of cetacean bone. At Cladh Hallan discussion is focused on a comparison of spatial differences between the distribution of elements and species, using comparison of the cetacean bone assemblages within the different houses to lead the discussion. The social utility of cetacean bone at Bornais is discussed in light of historical evidence which provides insights into the varied rights to cetaceans based on status. As these discussions relate to acquisition of cetaceans they fit with the theme of the next chapter: procurement, and as such are discussed there (see Section 6.2.4 in Chapter 8).

The following section therefore draws on wide range of evidence including spatial distributions of species and elements, and wider historical and zooarchaeological evidence, to investigate social aspects of the cetacean bone assemblage at Cladh Hallan.

8.1.1 SOCIAL DIMENSIONS TO SPATIAL AND TEMPORAL DISTRIBUTIONS OF SPECIES AND ELEMENTS AT CLADH HALLAN

Chapter 6 demonstrated that sperm whale skull fragments were distributed between the different houses at Cladh Hallan during the Late Bronze Age. Phases 8 and 9 produced large numbers of fragments, many of which were from House 801 (Figure 72), whilst House 1370 had the tooth of a sperm whale set vertically into the floor and a large piece of sperm whale skull situated outside. Evidence for sperm whale in House 401 was lesser in phase 9 (with only one sperm whale fragment identified in the house), though skull fragments from this species were found within the forecourt and a piece of sperm whale skull had been used to cap a stone-cist under the entrance to this structure (Parker Pearson et al. forthcoming; see Section 8). Additionally, other Late Bronze Age phases produced higher numbers of sperm whale fragments from within this and other structures. Comparisons are more difficult for the Early Iron Age as excavation generally focused on a single house per phase, but the evidence shows that blue whale remains were spread across much of the site during this period.

The repeated presence of the same species between the houses may indicate the possibility that cetacean resources were being shared between the site’s inhabitants in the Bronze Age and Iron Age. The butchery of a large cetacean such as a sperm whale or blue whale would have been an intensive task. Historical sources from the Hebrides and beyond indicate that such tasks were typically undertaken by groups larger than an individual household. Following butchery the resulting whale products would often be distributed between those involved in the procurement and processing, leading to the distribution of cetacean remains between different groups (Baldwin 2008; Evans et al. 2016; Kishigami 2013). It is likely that the remains from Cladh Hallan reflect these social processes and demonstrate group cooperation and the sharing of resources between the Late Bronze Age and Early Iron Age inhabitants at the site. The sperm whale deposits are particularly interesting in this light, and point to special significance placed on this animal, reflected by the presence of this bone across the site and more specifically by the deliberate setting of a sperm whale tooth in one of the house floors (discussed further in Section 8).

Other studies have demonstrated that aggregations of widespread groups can also occur for the exploitation of a cetacean (Evans et al. 2016) and it is possible that other contemporary inhabitants of the Hebrides also partook in whale butchery alongside Cladh Hallan's inhabitants. Unfortunately, few contemporary assemblages have undergone taxonomic identification (see Appendix 2), though a fragment of large cetacean bone was identified in Late Bronze Age levels at Barvas (Cowie and MacLeod Rivett 2010), and a fragment of balaenopterid bone was identified at Northton (Finlay 2006: 173- 174) which could represent the same species found at Cladh Hallan. Investigation of contemporary assemblages and the application of taxonomic identification and aDNA analysis could shed light on the potential that individual cetaceans were shared between sites during this period (e.g. Evans et al. 2016; UHI 2019b).

The wider social context of deposition also warrants consideration. The Bronze Age- Iron Age transition in Britain was marked by social and economic upheaval (Needham 2007). Such periods are frequently associated with a rise in activities associated with the reaffirmal of group bonds such as feasting. Evidence of feasting in this period is well attested (e.g. Madgwick and Mulville 2015) and other activities such as resource sharing may too have been used to reaffirm social bonds in this period. The butchery and distribution of a cetacean carcass is comparable to feasting events in many ways: it represents a distinct event, one which would have required considerable community participation through labour, likely involving many individuals from the wider contemporary Hebridean community (e.g. Baldwin 2008). Evidence of on-site distributions of cetacean bone during the Late Bronze Age and Early Iron Age phases at Cladh Hallan demonstrates sharing of this resource, and this may have been mirrored within the wider community. The butchery of a large cetacean therefore may have provided an opportunity for the reaffirmal of social relationships at a time of upheaval, perhaps leading to the special focus placed on large cetacean species at Cladh Hallan, as physical demonstrations of these social processes. The incorporation within the architecture of the site (discussed further below) may have been deliberate displays and reminders of the socially meaningful event.

While the same cetacean resources may have been shared, the remains from Cladh Hallan also demonstrate that multiple different species were present within each house. House 401 in particular had high numbers of species in each phase, even during phases where larger amounts of cetacean bone were recovered from other areas (for example in phase 9 House 401 produced 97 pieces of cetacean bone and at least 4 different species while, House 801 produced 193 pieces but evidence of only 2 species). It is possible that higher species diversity within House 401 represents social processes. Differential access to cetacean resources has been found to relate to status in other areas (e.g. van den Hurk 2020; Whitridge 1999; 2002). This is of interest in light of the other remains from House 401. Evidence of bronze-casting was found within this house and weaponry and ornaments were also present, all indicating that the inhabitants may have been well-off with potential implications for status (Parker Pearson forthcoming). Access to a variety of cetacean remains may therefore be a reflection of social standing during the Late Bronze Age.

The lower number of sperm whale skull fragments in phase 9 deposits associated with House 401 is interesting considering the evidence for social difference and greater access to other cetacean remains, and it is possible that the inhabitants had preferential access to other oil-rich parts of the whale which may not have left a trace (such as blubber or spermaceti). Ethnographic literature provides ample evidence for blubber possession an expression of social difference amongst Inuit communities (Rasmussen 1931; Whitridge 1999: 350), and other zooarchaeological studies have demonstrated the presence of these 'invisible' resources through conspicuous absences in the bone record (Betts and Friesen 2013), as suggested here.

8.1.2 SUMMARY

This section has demonstrated that the distributions of bones from particular species may have had social implications. At Cladh Hallan sharing of cetacean resources likely occurred between the houses, and some may have had preferential access to a larger range of species and particular portions of the whale. These patterns may provide preliminary evidence of social aspects of cetacean exploitation and distribution in prehistoric Scotland. Analysis of material from other sites would provide much needed comparisons enabling these patterns to be further investigated.

8.2 SEASCAPES, SPECIES AND STRUCTURED DEPOSITS

It has been increasingly recognised that human-animal relationships go far beyond the utilitarian, and past relationships between humans and animals were complex, and at times inextricably linked to landscapes (and seascapes) (Bradley 2000a; Hill 1995, 2013; Jones 1998; Russell 2012). This section examines the human-animal-landscape/seascape interactions through the lens of structured deposition within the cetacean bone assemblages.

Structured deposits, i.e. remains which have been deliberately placed or arranged in a manner not indicative of ‘expedient discard’, are taken to demonstrate ‘deposition as a meaningful practice’ (Bradley 1990; Hill 2013; Garrow 2012: 98; Grant 1991; Richards and Thomas 1984; Wilson 1992), and where such deposits incorporate faunal remains they hold great potential for allowing insights into human-animal relationships. Garrow (2012) defines interpretations of structured deposition on a spectrum ranging from material culture patterning (i.e. patterns in the distributions of material culture) to deposition of ‘odd deposits’ which include things like headless animal burials, such as the dog burials found at Cladh Hallan, for example (Mulville et al. 2011). While many studies focus on the intentional meaning of deposition, it is recognised that some deposits may be laid down unintentionally, in the course of ’everyday’ social practices (Garrow 2012: 110; Thomas 2012: 126). It is this perspective which has been taken above in the investigation of patterns of deposition of cetacean bone fragments at Cladh Hallan, which are interpreted to reflect everyday social processes and not deliberate deposition. These deposits and patterning are considered to be meaningful but not necessarily intentional.

The following section will focus on deposits which do appear to have been deliberately laid down and may have held or expressed intentional meanings. Studies of such deposits vary but many focus on features such as pits, ditches, boundary, foundation and closing deposits (Garrow 2012; Hill 1994; Thomas 1991) in addition to other remains such as refuse and midden deposits in some cases (Hodder 2007; Madgwick and Mulville 2015; Needham and Spence 1997). Animal remains may be included within structured deposits as individual bones, groups of bones or articulated remains. The latter are frequently termed Associated/Animal Bone Groups (ABGs) (e.g. Hill 1995; Morris 2011). Varying definitions of ABGs exist, though most incorporate complete articulated or articulating animal remains, or portions of an animal, and animal remains which are disarticulated when deposited but can be identified as deriving from the same animal (Morris 2011).

The practice of burying faunal remains within pits and postholes beneath settlements on the islands (often interpreted as foundation or closing deposits) is well attested on Hebridean sites from the Late Bronze Age onwards (Campbell 1991, 2000; Mulville et al. 2011: 206). This practice extended into the Norse periods, and a large number of pits were identified under the floor of Bornais House 1 (Sharples 2020: 96). Whether these represent ritual or ‘special’ deposits is a matter of debate, and interpretations of such deposits from across a wide area range from purely economic to ritual (see Morris 2011 for a summary of work) with sacrifices and feasting forming key interpretations of these remains in the Western Isles

(Mulville et al. 2003, 2011). Studies from zooarchaeological assemblages on the Western Isles have demonstrated a focus on terrestrial species within sub-floor articulated deposits, and in particular sheep and cattle, though sometimes also dog. Deer are absent from these deposits, taken to reflect a special significance, though they are present in the patterns of repeated elements found around hearths from the Late Iron Age, also evidence of structured deposition (Mulville et al. 2003: 32; Mulville and Thoms 2005).

Cetaceans are rare but not unknown in structured deposits of the Hebrides. The following sections will focus on the interpretation of structured deposits including articulating cetacean remains in addition to those in potential foundation deposits and closing deposits, and those in structural contexts. The latter are included here as although the assessment initially viewed these in light of cetacean bone architectural utility indices (Evans 2021b: 228) (and correlations were found between elements used architecturally at Cladh Hallan and Bornais and those which have demonstrated high architectural utility owing to their physical properties (Savelle 1997)) this did not adequately explain the apparently special nature of many of the remains and the way they were deposited, and constituted only a ‘thin description’ of the remains (Geertz 1973; Jones 1998: 309).

Jones (1998) and Mulville (2002) have both studied elements of structured deposition within the cetacean bone zooarchaeological record. The current work will build on the findings of these earlier studies and brings cetacean taxonomic identification into the discussion, information which it has not previously been possible to assess owing to the lack of taxonomic identifications for most cetacean material. Taxonomic identification within the assemblages from Cladh Hallan and Bornais therefore provide an opportunity to add greater depth to our understanding of human-cetacean interactions (Mulville 2002).

The structured deposits under investigation here are:

- A thoracic vertebra from a killer whale (SF 5356) from the fill (2907) of a posthole beneath House 401 in Phase 8, found alongside foundation deposits within underfloor pits and postholes at Cladh Hallan (Parker Pearson forthcoming; Figure 71);
- A sperm whale tooth (SF 4564) found within House 1370 (phase 9) at Cladh Hallan. The tooth was set vertically on its point with its root facing northeast into a fill layer (2210) overlaying the first house floor (2211) and before the deposition of the next house floor (1369) (Parker Pearson forthcoming; Figure 54);

- A large piece of sperm whale skull used to cap an otherwise stone-lined cist in Phase 8, which lay under the entrance to House 401 at Cladh Hallan (Figure 72);
- A large piece of sperm whale skull found in the wall at the entrance to House 1370 at Cladh Hallan (SF 5018) (Figure 72);
- A sperm whale rib shaped into a stake (SF 5929) and used to demarcate the easternmost edge of the stone robbing from Middle Norse House 2 at Bornais (Evans 2021: 228);
- A sperm whale rib used as a chopping block (SF 6391) and placed in the robbed-out entrance to House 2 (2247) at the end of the Middle Norse period (Evans 2021: 228); and
- Articulating remains at Cladh Hallan.

Articulating remains have also been identified at Bornais. These comprised two mid thoracic vertebrae from a small delphininae (context 1795) and two probable articulating caudal vertebrae from a harbour porpoise (2356). These remains are from the primary cultivation soils, thought to have been formed by ash and occupation debris spread over the cultivated fields (Sharples 2020: 97) and appear unlikely to reflect deliberate deposition. They are therefore not considered further here.

8.2.1 CLADH HALLAN

The following sections explore potential structured deposition of cetacean bone within foundation deposits, structural deposits and as articulating remains at Cladh Hallan. The evidence from Cladh Hallan is considered, along with potential parallels. The section ends with consideration of the meaning of these deposits.

Foundation deposits

While foundation deposits are common on Hebridean sites, bone remains which are typically interpreted as such have been human burials and animal burials from terrestrial species, in particular sheep, cattle and dog (Mulville et al. 2003). These deposits are often considered to represent sacrificial offerings interred prior to the occupation of a new structure or floor (Mulville et al. 2011). At Cladh Hallan (and other sites such as the Early Iron Age Hornish Point; Barber et al. 1989) incorporation of both humans and animals within these burials led Mulville et al (2003: 31) to suggest that strong human-animal relationships existed, which eventually culminated in the substitution of human burials with animal ones indicating a parity between humans and animals; ‘animals were substituted ‘kin’ of people’ (Mulville et al. 2003: 31). The use of animal burials indicative of these strong human-animal bonds was common throughout the Bronze Age and into the Middle Iron Age. The Late Iron Age saw a shift in patterns of human and animal burial which has been interpreted to reflect an alteration in human-animal relationships to a situation of human domination over animals (Campbell 2000: 194; Mulville et al. 2003: 31).

While the focus has previously been on terrestrial species, consideration of the remains from Cladh Hallan suggests that cetaceans may too have been incorporated in foundation deposits. This includes a killer whale vertebra incorporated within a foundation pit/posthole and a sperm whale tooth which is set into a deposit which overlays the first floor (2211) in House 1370 and before the deposition of the next house floor (1369). Its deliberate placement is clear, and it may also be seen as a foundation deposit to the later house floor.

Parallels for the killer whale vertebra may be found in deposits which have hitherto been interpreted solely from an architectural or artefactual perspective. At numerous Iron Age sites cetacean vertebrae are found in sub-floor pits and postholes. Some have been hollowed out leading to the frequent interpretation of these features as post sockets. At the Middle Iron Age wheelhouse of A’Cheardach Mhor two large vertebrae, with processes partly removed, were reportedly ‘set in clay below floor level’ (Young and Richardson 1960: 164). The vertebrae were accompanied by stones interpreted as packing material. While they may have served this function, the deposit also included worn hammer stones, a smaller cetacean vertebra and a hammer made of the burr and brow tine of antler (Young and Richardson 1960: 142). The accompanying remains therefore may not fully be explained by the interpretation of the large vertebrae as purely functional post sockets (though they may have served this function), and the nature of the material deposited alongside the vertebrae may hint at deliberate and meaningful deposition. The Iron Age wheelhouse at Sollas provides another example of a sub floor cetacean vertebra. This site included around 150 foundation pits, and within one pit (Pit SW15) was a hollowed out cetacean vertebra, interpreted as a ‘cup’. While Campbell (1991) indicated the similarity with the A’Cheardach Mhor deposits, neither authors discuss the potential for the cetacean remains to reflect foundation deposits. Reconsideration of previous evidence from A’Cheardach Mhor and Sollas may therefore suggest that the practice of including cetacean remains within prehistoric foundation deposits (as seen at Cladh Hallan) may be wider than previously assumed, and consideration of other foundation deposits may therefore shed light on human-cetacean relationships.

There are no known direct parallels for the sperm whale tooth and although worked sperm whale teeth have been found on prehistoric sites from across Europe (Corchón and Álvarez-Fernández 2008; Pétillon 2016; Poplin 1983; Schuhmacher et al. 2013) these sites do not include evidence of deposition in a manner comparable to the remains at Cladh Hallan. However, a possible comparable find may come from a Great White shark's tooth found at site of Llanmaes in South Wales. This tooth was deposited within a post-hole beneath a Middle Bronze Age structure and is therefore generally contemporary with Cladh Hallan, potentially suggesting a wider practice of incorporating the remains of particular marine animals within structured deposits (Gwilt and Lodwick 2009; Gwilt et al. 2016).

Architectural elements

Sperm whale bone was also used structurally at Cladh Hallan, incorporated within the capping of an otherwise stone-lined cist in Phase 8, which lay under the entrance to House 401 (Figure 72) and another large piece of sperm whale skull was found in the wall at the entrance to House 1370 (SF 5018) (Figure 72). While these bones have obvious potential as architectural components due to their large size and therefore value as bulk materials (Savelle 1997), the placement of the remains is of interest. Both occur in highly visible locations close to the entrances of Houses 401 and 1370. Parallels for these finds also exist. At Dun Vulan a piece of sperm whale skull was used to cover a stone-lined drain (Mulville 2002: 41) reminiscent of the use of sperm whale skull at Cladh Hallan and wider comparisons can also be drawn with the use of whale skulls over passageways in Skara Brae (Jones 1998: 310).

Articulated remains

Articulated remains are a common feature of structured deposits. While articulated burials have hitherto only been recognised as including terrestrial species (principally cattle, sheep and dog) the current work has identified articulating cetacean remains at Cladh Hallan. Two lumbar vertebrae of a large delphininae were recovered from House 401, dating to Phase 16 (the Early Iron Age). The vertebrae, complete with their unfused epiphyses, were recovered from a deposit potentially derived from a collapsing roof (context 407). While this does not indicate deliberate deposition, the layer below 407 was a deep deposit of compact sand (409). Within this layer, immediately above its base, were placed sherds of a single pot (SF 2046-48, 2058). Also within this layer was an antler pick (SF 2056), and a bone needle (SF 2057). The deposit was characterised as midden material, though the pot sherds are interpreted as deliberately deposited, and the layer could be considered to represent a structured deposit placed at the end of the structure's life. Associations between midden material and structured deposition are well known, particularly from the Late Bronze Age/Early Iron Age in the south of the UK (e.g. Madgwick and Mulville 2015). While the cetacean bone overlays this deposit, the articulating nature of the bone suggests that the deposition of the cetacean bone may too be structured in this context. Depositional practices for articulating remains were complex at Cladh Hallan, and included apparent sacrifices with animals likely killed *in situ* in pits (as seen in one of the sub-floor dog burials) in addition to the deposition of animal limbs which had been butchered and the bones then carefully collected and deposited together in individual pits (Mulville et al. 2011). While further assessment such as histological analysis would be required to investigate the specific details of deposition of the cetacean vertebrae (following Mulville et al. 2011) the bones have butchery marks suggesting meat removal, but have been deposited within the same context. This suggests parallels with the structured deposition of terrestrial species at Cladh Hallan, indicating the possibility that the cetacean remains may too have been set down as structured deposits, laid down as the occupation of House 401 ended.

Meaning

Evidence of the structured deposition of cetacean bone is therefore demonstrated at Cladh Hallan by foundation deposits and elements incorporated within the site's architecture. Articulating remains may too reflect structured deposition though additional analysis would be required to investigate this potential further. The following discussion therefore focuses primarily on the sperm whale and killer whale bone, and examines the potential meaning of deliberate deposition.

Previous studies of human-animal-landscape interactions may shed light on the meanings of these deposits. Such studies have found a connection between deposits or depictions of certain species and certain locations (e.g. Jones 1998; Mulville 2002; Whittle 2000). Jones (1998) reviewed Neolithic deposition of animal remains on mortuary and settlement sites in Orkney, and demonstrated a connection between sites, species and locations. In Neolithic Orkney eagle remains were deposited on cliff-top mortuary sites, while cetacean bones were excluded from these deposits and instead found only on coastal settlement sites (Jones 1998: 314). The animals deposited on different sites were found to be those which best signify particular aspects of the site's landscape, through their occupation of it (Ingold 1996). Jones (1998) found evidence that 'more powerful animals (were) actively used in reaffirming ideas of place' (Jones 1998: 314), and that 'whales…the largest sea animals… constitute the most obvious aspect of the sea' (Jones 1998: 314). Thus, whales were used to reaffirm ideas of place focused around the coast and sea, and the structured deposits therefore provide part of a 'conceptual map of the resources located in any one part of the landscape' (Jones 1998: 315). Not only this, it was also argued that as the species chosen represent powerful animals and that incorporation within structured deposits indicates that prehistoric communities may have drawn on this power. Jones (1998) indicates that this power may have been drawn on through the manner of acquisition, arguing that sea eagles would have been difficult to obtain and necessitated dangerous activities in cliff-edge environments. Foxon (1991) similarly suggested that use of cetacean tooth pendants at Skara Brae could represent a display of power from their wearers, derived in this case from the analogy of power from their animal origin (rather than through the manner of acquisition).

While Jones (1998) suggested that whales as a broad category represent the most obvious animal aspects of the sea, selection of particular species may reflect the iconic or powerful nature of those chosen. Both species identified at Cladh Hallan have a number of unique attributes which make them iconic species. Sperm whales are the largest of the toothed whales and are easily distinguishable by their large, squared heads, filled with spermaceti, and their sizable teeth (Carwardine 2020: 140-146). Killer whales have unique black and white markings and the huge dorsal fin which reaches up to *c*.2m in height in some individuals (Carwardine 2020: 262). Their behaviour is also unusual and the species are known for aggressive attacks on other large marine species, from seals to small dolphins and even the great whales (Carwardine 2020: 266). Both the sperm whale and killer whale can easily be perceived as the 'powerful animals' which Jones (1998) refers to: these species are to the seas what the eagles are to the skies. The Great White shark's tooth deposited at the contemporary site of Llanmaes (Gwilt and Lodwick 2009; Gwilt et al. 2016) can also be interpreted in this light, and demonstrates a comparably powerful marine animal represented by one of the characteristics which best represents this power, i.e. its sharp teeth.

Figure 71 Thoracic vertebra from a killer whale from phase 8 (context 2907, SF 5356) underfloor deposits

The deposits therefore contain the remains of unique species, and importantly, the remains reflect exactly the aspect of each species which makes it iconic. Sperm whales are represented by the tooth and head, and the killer whale is represented by a thoracic vertebra which sits in the region of the spine beneath the huge dorsal fin. Only the sperm whale and killer whale are within structured deposits or architectural contexts in the true sense, but other remains may also reflect a focus on iconic characteristics of particular species, and it is of note that the humpback whale is present on site, represented by portions of its flipper. The humpback whale has the longest flipper relative to body length, this length and the unusual tubercles found along the flipper's margins make it one of the species' unique physical attributes (Carwardine 2020: 128). This parallels the findings of Jones's study (1998: 315) which demonstrated that the animals in Neolithic Orkney were 'represented by certain elements of the skeleton, such as the wings, head and feet…. which most obviously represent birds'. Likewise then, the whales at Cladh Hallan are represented by the feature which most obviously represents them.

Although there are no direct parallels for the sperm whale tooth set vertically into the floor (though the shark's tooth does provide an interesting comparison) the Neolithic site of Skara Brae did produce evidence for a range of marine ivory including killer whale, pilot whale and other delphinoid teeth. While these teeth were not used in structured deposits some of which were perforated for use as pendants, while others were worked into beads (Foxon 1991: 134-7). The remains were interpreted as displays of power rooted in the powerful nature of the cetaceans from which they originated. The inhabitants of Cladh Hallan may too have drawn on the powerful nature of the sperm whale and killer whale through creation of structured deposits. Their inclusion within foundation deposits, which have been shown to demonstrate parity between humans and animals (Mulville et al. 2003: 31) and which appear to demonstrate that animals could be substitutes for people, suggests that transferrance of animal traits to people may have been possible. Thus, the incorporation of powerful animals within the foundation and structural deposits could therefore have reflected on the settlement and its inhabitants.

The timing of the use is also notable in the wider context of shifting patterns of activity within the landscape. Prehistoric communities settled the Hebridean machair in the Early Bronze Age (Sharples 2009), and thus by the Late Bronze Age the landscape was still one of relatively new settlement. Whales may have been used in architecture and structured deposits as a means of expressing this new relationship with the coastal environment and in particular with the west coast, where strandings of the sperm whale and other large species are common owing to their offshore migrations routes which pass to the west of the Hebrides (Clark et al. 2010; Pollock et al. 2000). This demonstrates that the relationship with the landscape may have been specific and localised, developed with an understanding and memory of the habitats and association of certain species with particular parts of the local seascape and shoreline (Ingold 1996). The whales did not just represent the sea: sperm whales represented the west coast. In this context the sharing of sperm whale bone between the houses, which occurred within the same phases as the structured deposits and architectural pieces, and the associated social implications which shed light on human cooperation and relationships, may have simultaneously reflected and reaffirmed relationships with the wider environment including specific cetacean species and coastal locations (Figure 72 summarises this evidence). These relationships may have endured through Hebridean prehistory, evidenced by the use of the sperm whale skull at the Middle Iron Age site of Dun Vulan (Mulville 2002).

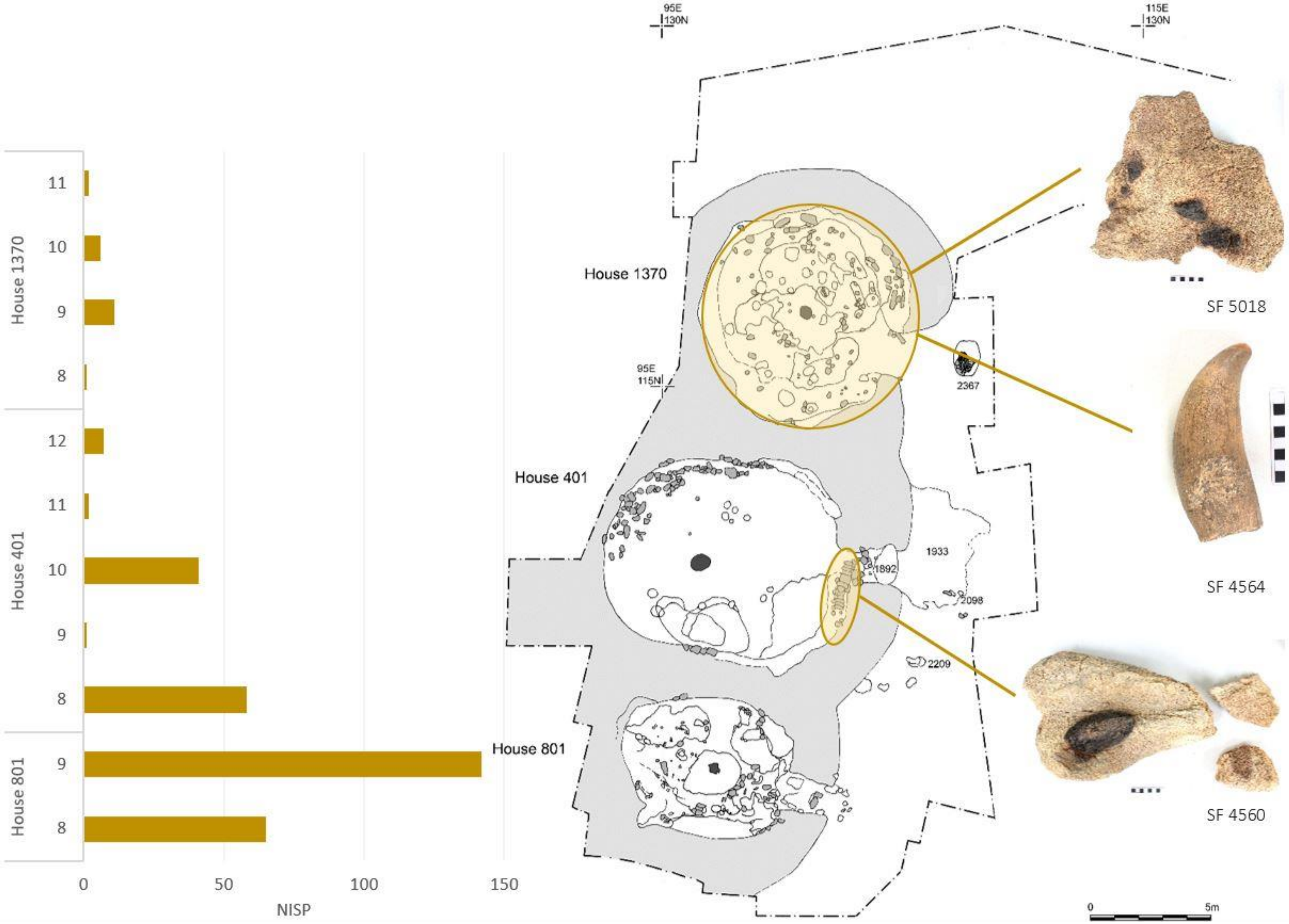

Figure 72 Sperm whale in Late Bronze Age Houses 801, 401 and 1370 showing NISP per phase and spatial layout of structured cetacean deposits and architectural pieces

8.2.2 BORNAIS

The following sections explore potential structured deposition of cetacean bone at Bornais. The evidence from Bornais is considered, along with potential parallels, and meanings are thereafter explored.

Structured deposits

The two key deposits under discussion from Bornais are both sperm whale ribs, deposited following the end of use of the Middle Norse House 2. One of the ribs had been shaped into a stake and used to demarcate the easternmost edge of the stone robbing from Middle Norse House 2, and was likely used as a marker used during the construction of the later House (House 3). The other rib was used as a chopping block and placed in the robbed-out entrance to House 2 at around the same time (Evans 2021b: 228). The deposits, and their placement at an entrance and boundary, are of interest in light of findings from excavations of Viking Age longhouses in Scandinavia, many of which have provided evidence of structured deposition at and below entrances (in addition to placement of objects above doors), where a range of objects ranging from quernstones to animal remains have been identified (Eriksen 2019). These patterns of deposition at entrances and boundaries have also been identified in Anglo-Scandinavian England, and ABGs in particular have been noted in these locations, though the practice of structured deposition appears to have been less prevalent than in Scandinavia (Eriksen 2019: 169; Hamerow 2006; Hill 1994; Morris 2011: 114; Thomas 2012: 99). Incorporation of cetacean bone into Norse structures is also known from other sites in the Scottish Islands, for example, at Drimore, Cille Pheadair and Freswick Links (e.g. Batey 1987: 75; MacLaren 1974; Mulville 2002). At the former, a cetacean vertebra, interpreted as a door socket, is found at the entrance to the longhouse and therefore represents an additional example of cetacean bone in association with entranceways in the Western Isles (MacLaren 1974).

Historical sources provide further insights into deposition of animal remains at entrance ways. The account of al-Turtūshi, an Arabic-Hispano Jewish merchant who travelled to Hedeby (Denmark) around AD 1000 is particularly interesting and tells of a practice involving animal sacrifice at the gate of a house (Eriksen 2019: 170). The purpose of the sacrifice is not detailed within the account, but Eriksen (2019) suggests the practice of placing particular items or animal remains at entrances in the Norse period may have been to establish them as 'guardians of the spaces within', and that particular items were chosen for deposition due to their inherent qualities, meanings or associations. The meanings of cetacean bone are explored below.

Meaning

Contemporary texts shed light on the meanings and associations of cetaceans within Norse society. Turning first to general associations of whales, Szabo (2005, 2008) noted a 16th-century text relating to northern Scandinavia which illuminated human-animal-landscape relationships and aids our understanding of potential meanings behind the structured deposition of cetacean bones. The text, written by Olaus Magnus, demonstrates the incorporation of cetacean remains into architecture in northern Scandinavia, noting its architectural utility. However, it goes beyond this and shows that even after incorporation within the domestic structure the bones were believed to retain their association with the whale, and even passed this on to the structure's inhabitants. "'Those who sleep inside these ribs are forever dreaming that they are toiling incessantly on the ocean waves or, harassed by storms, are in perpetual danger of shipwreck" (Olaus Magnus 21.24, ed. Foote 1996, 1107). The animal's character and environment were brought into the house through the use of its bones (Szabo 2005, 2008: 204-208). While these texts relate to arctic communities of northern Scandinavia, Szabo (2008: 209) draws parallels with the beliefs of Icelandic fishermen who are inspired by dreams to find the best fishing spots, suggesting that the dreams arising in whale bone houses may have reflected whalers' connections with the sea. Although the texts do not indicate whether similar sentiments were held by the Norse, they do demonstrate the wider applicability of interpretations which focus on the continued association of habitat with the bones of animals which once inhabited these environments (Jones 1998).

Norse texts also demonstrate great familiarity with cetaceans and many of the species known today are recognisable within the historical documents (Lindquist 1994; Szabo 2008: 182). These documents demonstrate knowledge of the biology and physical characteristics of many cetaceans in addition to providing descriptions of the behaviours of certain species. Whales are also categorised within some texts as good or bad. The category of 'illhveli' (bad whale) was applied to those species considered poor for consumption, and potentially dangerous or even malicious when encountered at sea (Szabo 2008: 187). The humpback and the right whale or bowhead, for example, were thought to be malicious whales known to attack ships (Szabo 2008: 186). Sperm whales are depicted in numerous Norse texts (e.g. Lindquist 1994), though the 13th-century Kings Mirror provides one of the clearest descriptions of physical form allowing the species to be identified with relative certainty (something which is not always possible from the historic texts; see Lindquist 1994). In addition to the clear description of form, the sperm whale is reported as being ‘neither savage [or: excited] nor cruel, but rather of a gentle nature’ (Lindquist 1994: 955). The text, which is broadly contemporary with the Middle to Late Norse transition at Bornais (Sharples 2020: 538), may therefore shed light on perceptions of this species at the time of deposition of the structured deposits. It is of interest therefore that the sperm whale is chosen for structured deposition, rather than species which were believed dangerous. Considering the wider interpretations of deposits associated with entrances on Scandinavian sites (Eriksen 2019) it is possible that the sperm whale’s gentle nature may have been drawn upon in structured deposits, potentially to offer protection to the settlement. As we have seen, the bones may too have retained their association with the sea, and this protection may therefore also have extended beyond the settlement and into the marine zone.

These deposits also occur in the Middle Norse period at a time when there was increasing use of sperm whale. This may reflect a Norse response to the specific animal environment of the west coast of the Hebrides, an assertion which will be elaborated on below by reviewing the finds in light of the wider evidence for the responses of Norse settlers to North Atlantic environments through changing patterns of animal use.

Evidence from across the North Atlantic demonstrates that the Early Norse settlers took with them certain ideas and resources which shaped the economies of this era. These early economies, or ‘landnám package’, were discussed in Chapter 3. Following the initial settlement Norse communities across the North Atlantic began to adapt and respond to their new environments. In a local context pig was abandoned quickly, likely owing to the recognition of the highly destructive effect of this species on the fragile machair (Sharples et al. 2016). Delphinoids also appear to have been used for meat consumption in the Early Norse period, and less so in later periods when the local herring fishery had become well established (see Section 3 in this chapter), all demonstrating the development of the Norse relationship with the local animal and physical environment. Further afield other connections between cetacean species and place became evident, demonstrated by the presence of pilot whale bones in the Faroe islands, which have been identified on the 12th to 14th century AD settlement of Í Uppistovubeitinum in Leirvík (Arge 1997)[15] and remain a

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[15] Excavations at the Norse settlement of Niðri á Toft have also identified pilot whale bones but the methods of excavation have led to some uncertainties around dating and the methods used for cetacean bone identifications is uncertain, and they have not been backed up by modern analysis placing some doubt on the identification (Arge *pers. comm*.; Dahl 1951: 89-93 translated in Stummann

focus on that island group today (Joensen 2009). In this context, use of the sperm whale within the structured deposits at Bornais may, like the earlier prehistoric material, represent a response to place and an emerging relationship between the Norse inhabitants and iconic species of their west coast landscape and seascape.

8.2.3 SUMMARY

This section has reviewed evidence from a series of deposits in which cetacean bone appeared to have been deliberately placed or incorporated as an architectural component. The evidence was reviewed in light of other studies which have investigated human-animal-landscape relationships and demonstrated that the deposition of cetacean bone at Cladh Hallan and Bornais reflects a focus on iconic species encountered along the west coast of South Uist (primarily as stranded individuals). There is particularly compelling evidence from Cladh Hallan that unique attributes of iconic species were the focus for special deposits, while the Norse remains may reflect deposition of certain species at particular locales to invoke protection which may be associated with the contemporary perceptions of particular cetacean species. The Norse material also represents localised responses to animals and landscapes which were occurring across the North Atlantic at this time.

9 CONCLUSIONS

This chapter has reported on the investigation of cetacean use at Cladh Hallan and Bornais. It has demonstrated that when modifications, species, elements and spatial distributions are considered, drawing on utility indices, historical and ethnographic evidence, they provide a basis for characterisation of the ways cetaceans were used in the prehistoric and historic periods. The work has also shown that distributions and use also reflect social utility and wider human-animal-landscape relationships.

The assemblages from Cladh Hallan and Bornais proved to be complex, with evidence of meat, artefactual, architectural and oil utility, coupled with evidence of social and human-animal-landscape dimensions to distribution. It is likely that cetaceans moved through different phases of use; and the same animals may have been exploited for multiple reasons (as seen in other areas e.g. Monks 2003) and acquired a multitude of meanings. Evidence of this varied use is present within the assemblages. The meat of smaller species was

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Hansen 2003: 43; Dahl 1970). Analysis from other cetacean bone assemblages including Undir Junkarinsfløtti is awaited (Brewington 2011; Chrurch et al. 2005: 187).

consumed, however, their bones were also used for artefact production and possibly also oil extraction though to a lesser extent than the bones of the larger species. Large species are represented within each area of utility: their bones dominate the artefact assemblages, fragments represent oil extraction. Evidence of their flesh was also present at Bornais (and may be inferred in House 401 at Cladh Hallan), demonstrating the use of meat or blubber (Law 2021). Although the cetaceans were clearly put to a variety of uses, broad divisions are evident and the treatment of large and smaller species differed, though use was not generally species-specific. An exception to this is the use of the sperm whale (Figure 73) and multiple indicators suggest a focus on this species for a variety of uses in both the Late Bronze Age and Middle to Late Norse periods which may have transcended functional utility to become a wider expression of the relationships between people, cetaceans and seascapes. Discussion in the next chapter turns to a specific aspect of human-cetacean relationships, that of procurement.

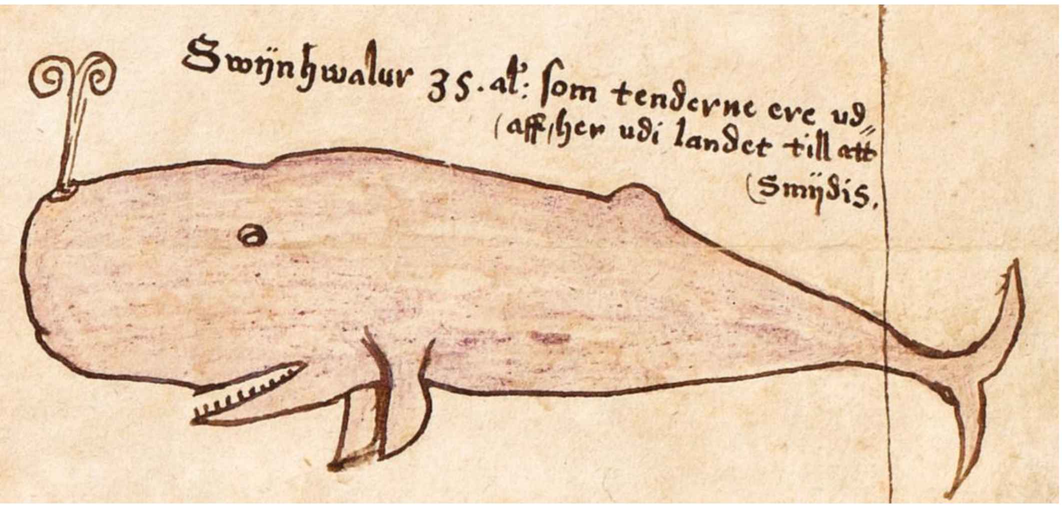

Figure 73 Sperm whale depicted in in Jón Laerði Guðmundssyni's text, the Natural History of Iceland Source: https://nmsi.is/frettir/jon-laerdi-og-natturur-natturunnar/

Chapter 8: Cetacean procurement and Hebridean marine exploitation strategies

1 INTRODUCTION

This chapter investigates the nature of cetacean procurement at Cladh Hallan and Bornais. Specifically, it examines whether species identified on the sites represent the remains of stranded or hunted individuals. Establishing modes of procurement is a complex process fraught with difficulties (see Chapter 2), and so to do this a wide range of evidence is drawn upon, including evidence for the different habitats and behaviours of cetacean species, evidence for other types of marine exploitation in the periods under study, evidence from the uses to which cetacean remains were put (see previous chapter) and supporting evidence from comparative zooarchaeological assemblages, historical and ethnographic literature. The following section outlines the specific approach to interpreting procurement.

2 APPROACH TO UNDERSTANDING CETACEAN PROCUREMENT

Previous studies have commented on cetacean procurement in the Hebridean past (e.g. Hallén 1994; Mulville 2002), however, the data on which to base these discussions was limited and Mulville (2002: 45) set out the need for further taxonomic identification to discern potential patterns which may aid understanding of procurement strategies. Application of new methods of identification have enabled the current study to provide further detail on cetacean species through the Bronze Age, Iron Age and Norse periods, and patterns of procurement can therefore be reassessed.

Chapter 2 reviewed approaches to identifying the nature of cetacean procurement from archaeological remains. Past studies have shown that procurement is influenced by a complex interplay of factors including cetacean species and habitat; and human factors including drivers for procurement, skill and experience with marine exploitation and site location relative to cetacean habitats (Clark 1947; Glassow 2005; Yesner 1995).

The approach to characterising cetacean procurement within this chapter therefore relies on identifying where interactions between human and cetacean populations could have occurred. There is little chance of active procurement if habitats of live animals and human zones of marine activity do not intersect (Krupnik and Kan 1993: 6). Potential human-cetacean interactions are identified based on the habitats of the different cetacean species present in each period at Cladh Hallan and Bornais, and contemporary use of local seascapes evident within the wider zooarchaeological assemblages from the sites. Where interactions with live cetaceans could have occurred, the possibility of active procurement is further investigated with reference to zooarchaeological data including utility of cetacean remains, evidence of species selection, and other supporting evidence including historical and ethnographic data (principally set out in Chapter 3), and information from contemporary sites.

This structure is followed, with potential interactions and procurement being considered chronologically due to the need to consider contemporary economies and zones of maritime activity.

3 CETACEAN PROCUREMENT IN CONTEXT: STRATEGIES, SEASCAPES AND SPECIES

Before delving into a detailed interpretation of procurement, it is first necessary to provide some evidence as a framework to allow understanding of the focus of later discussions. This backdrop relates to procurement strategies, Hebridean seascapes and habitats of cetacean species in nearby waters.

3.1 HISTORICAL EVIDENCE OF NORTH ATLANTIC PROCUREMENT STRATEGIES

The following section reviews evidence for cetacean procurement strategies in the North Atlantic. It seeks to do a number of things: firstly, to demonstrate the variety of procurement techniques employed by past peoples in the North Atlantic and specifically to challenge the perception that harpoon whaling was the only available method (following Lindquist 1997: 40). Perceptions of the prevalence of harpoon whaling, from historical accounts, commercial whalers and modern-day Aboriginal Subsistence Whalers, has greatly influenced assessments of the ability of prehistoric communities to actively procure large cetaceans (e.g. Clark 1947; Schuhmacher et al. 2013). It has encouraged the view that active procurement of the larger balaenopterids and sperm whales was beyond the reaches of prehistoric communities (e.g. Clark 1947: 88). However, as will be seen, where environments allowed for recovery, these species were likely targeted using different techniques. Strategies are varied and the historical documents for the North Atlantic reflect this.

Secondly, it seeks to demonstrate the importance of specific species and local seascapes to procurement strategies. Human-animal-landscape interactions are of recognised importance in studies of past procurement including within studies of cetacean acquisition (e.g. Stuart 1998; Yesner 1995). The connection between species, seascape and strategies is evident within historical texts concerning whaling in the North Atlantic, and these factors are discussed in the following section to provide a backdrop for interpretating potential Hebridean procurement strategies through time.

The following section sets out historical and linguistic evidence for key North Atlantic procurement strategies and is primarily based on the work of Lindquist (1993, 1994, 1997) and Szabo (2005, 2008). While the broad categories of procurement strategies set out below are primarily recorded in the North Atlantic, similar methods are also recorded elsewhere across the globe suggesting wider applicability of these categories (e.g. Ellis 1992; Krupnik and Kan 1993) and demonstrating that they may be of use for interpreting prehistoric as well as historic material in the North Atlantic. Strategies, species targeted and seascapes in which these strategies were employed are highlighted.

- **Naturally stranded whales.** This can be the exploitation of already deceased stranded whales or the killing of live individuals which stranded naturally. All species present within nearby waters are typically represented by strandings as these reflect both the biodiversity and the relative abundance of cetacean populations (Pyenson 2011).
- **Assisted stranding and trapping**. This is where cetaceans are encouraged by a variety of different strategies to strand (Szabo 2008: 250). These include ebb-stranding, driving and trapping (Lindquist 1994, 1997). Once stranded cetaceans are then dispatched using a variety of tools including lances, spears and projectiles (Gardiner 1997). These methods remove the need for vessels to tow a dead whale to shore (Lindquist 1994, 1997).
    - **Induced ebb stranding**: Cetaceans naturally entering in shallow waters can be encouraged to strand by trapping or preventing their return to deeper waters through fear or physical restraints (e.g. Szabo 2008: 204). The cetaceans are stranded as tidal waters ebb away and killed. This was an early form of cetacean procurement employed in the North Atlantic (Lindquist 1994: 312, 315). Prey targeted ranged from large rorquals to dolphins (Lindquist 1997: 28) and include species which naturally occur inshore.
    - **Drive-hunts:** This was a cooperative venture, involving a series of people who typically surround a pod of cetaceans in boats using either sound or missiles to frighten them ashore. This practice often took advantage of locations where the surrounding landscape acts as a natural trap (Lindquist 1994: 311)[16]. The Faroese drive fishery for pilot whales is a continuing example of the method in practice

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[16] In the Faroese pilot whale drive bays with the highest success rates include those without the presence of steep shelving close inshore, known in Scandinavia as a marbakki, although other factors are also noted to affect success such as the proximity of settlements and occurrences of natural strandings (Bloch and Joensen 2001: 63; Fielding 2013).

(Lindquist 1994: 314; Joensen 2009). Pilot whale drive fisheries were also historically undertaken in Shetland, Orkney and the Western Isles. Evidence for targeted species differs from large to small, though exploitation of the latter using this method has been most common in the North Atlantic (Kerins 2010: 86; Lindquist 1994: 320-1; Sanderson 1992; Schnall 1993: 11). As with induced stranding, records suggest the species targeted occurred naturally within the inshore area. The records of typically larger species such as fin whales being exploited are from areas in which this species occurs closer to the shore (e.g. Sanderson 1992).

  - **Trapping**: This also involves encouraging or frightening cetaceans towards a natural or man-made trap. Projectiles or harpoons may then be used to wound and eventually kill the cetacean, once trapped, after which it may drift ashore. Methods employed to drive the cetaceans include shouting and beating the boats (as in drive-whaling), while trapping may include nets (including herring nets (Lübbert 1865)), timber barriers or other more substantial structures akin to large fish traps (Lindquist 1997: 37). Cetaceans may also be trapped within nets, both deliberately and accidentally, and smaller species were frequently killed in this manner (e.g. Harvie-Brown and Buckley 1888: 38). Lindquist (1994: 328) asserts that both the Norwegian Gulathing Law and Magnus Lawmender's Code make early references to trapping, indicating the existence of the practice during the 11th century and possibly earlier. Whaling bays may have been relatively widespread in Norway from the medieval (Norse) period with one also recorded in Shetland (Lindquist 1994: 360, 1997). Minke whales, killer whales, pilot whales and other delphinoid species were trapped using this method in the North Atlantic, again largely representing species which naturally occur inshore.

- **Drift whaling:** This strategy involved the active wounding of a cetacean at sea (typically a large species) and then waiting for the animal to die and strand (Lindquist 1994, 1997; Szabo 2008: 250). Wounds were inflicted with the use of piercing tools, such as spears, lances or arrows, and crucially not harpoons (Lindquist 1997). According to Norse texts this method was possible from individual vessels with small crew (see Lindquist 1993: 35, 1994; Schnall 1993) and is thought to have been a key procurement strategy employed by the Norse (Lindquist 1994). The Norse texts have frequent references to 'shooting' whales but place little focus on recovery (which would necessarily be a very difficult task for the large whales); and the complex legal situations regarding drifting whales and marked shots all point toward use of drift strategies as an important mode of recovery (in contrast to methods of towing whales ashore, discussed below). The practice of wound, drift and strand whaling (here termed drift whaling) was clearly well-established by the time the 11th century Gulathing Law was written, indicating an earlier origin (Lindquist 1994, 1997). Evidence of this practice is echoed by a multitude of later Norwegian, Icelandic and Faroese laws and sagas penned over hundreds of years (see Lindquist 1993, 1994; Schnall 1993). The practice is documented in Norway and Iceland and the frequency with which whales drifted far beyond the area of their wounding[17] hints at the high loss rate using this method (Lindquist 1994, 1997: 45). Large balaenopterids and other species were caught using this method.

- **Harpoon and tow.** This method involved the use of a harpoon, typically a barbed or toggled instrument and line, which was used to tether either a drogue/float or vessel to the cetacean, with the aim of tiring the animal and allowing towing thereby ensuring recovery. Balaenids were the original target species, due principally to their slow swimming speeds and tendency to float once dead owing to their thick blubber layers, which aided recovery and towing (Lindquist 1993: 35). Balaenopterids, which have thinner blubber layers, tend not to share these characteristics, and would have been much more difficult to harpoon and tow back to shore owing to their tendency to sink when dead (Nousek-McGregor et al. 2014). They were rarely targeted before modern whaling – the blue and fin whales were the final species attracting the attention of commercial harpoon whalers (Lindquist 1993: 22). While this method was used by the Basques, the Norse too may have used harpooning (Szabo 2008) in particular for smaller species (Lindquist 1993: 27, 1997: 40), though there remains debate on whether the Norse employed the method for the procurement of large species (Lindquist 1993, 1997: 40; Schnall 1993: 12; Szabo 2008). The practice involved an active method of recovery (towing) and allowed for exploitation further from the shore. Nevertheless the species targeted are typically coastal in their distributions. Further afield other subsistence whalers today target sperm whales, bowhead whales, gray whales and humpback whales who venture near enough to land to be sighted using this method (e.g. the Lamalera of Indonesia, Alaskan hunters,

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[17] Lindquist (1997: 44) reports that a blue whale came ashore in Greenland in the late 14th century, having been shot by an individual in the west fjords of Iceland (identified by the marked shot).

Makah Tribe of Washington and whaling communities of Bequia (Clark 2019; IWC 2018a, b, c)).

The influence of local seascapes and the habitats of different cetacean species on procurement is clear within historical documents. Many demonstrate exploitation focused within a particular area, with methods tailored to that locale, and exploitation of the range of species which inhabit the area. This is particularly true of the methods for assisted stranding which tend to include use of the natural environment, though it is also likely to have affected other methods. Drift whaling methods are likely to have seen greater success in areas where currents provide stranding hot spots, and most documents show use of the method in the deep, bounded waterways of the North Atlantic islands. Hebridean seascapes were outlined in Chapter 3, and feed into the discussion below.

3.2 HEBRIDEAN SEASCAPES AS PROCUREMENT ENVIRONMENTS

The Hebridean environment was introduced in Chapter 3. This section gives a brief overview of key elements of the Hebridean seascape which are of relevance to the discussion on procurement, and in light of the procurement strategies reviewed above. This is followed by a review of species found at Cladh Hallan and Bornais and their primary habitats in adjacent waters (see Appendix 1 for further detail).

As demonstrated above, the local environment is an important factor in cetacean procurement (Lindquist 1994; Szabo 2008; Yesner 1995). Today, South Uist's coastline is characterised by the long sandy bays which face out to the Atlantic on the west coast and the rugged inlets of the east coast (Figure 74). The bays and inlets of the east coast provided a series of different opportunities for active procurement in light of the strategies outlined in the previous section. Documents from the 16th century indicate the use of fish traps in the lochs of the east coast, which may also have trapped smaller cetaceans (Monro 1549) and later documents demonstrate the practice of drive whaling and trapping within the east coast lochs (and in Lewis in similar lochs which occur on the west coast) and small enclosed sandy bays (Harvie-Brown and Buckley 1888: 38; Martin, 2010).

The west coast of South Uist has a very different character and today the long beaches do not form enclosed embayments. It is therefore less well suited to the entrapment of cetaceans and there are no records of whaling along the west coast until the modern period when whales were harpooned offshore and towed back to the whaling station at Bunabhainneadar (Harris) (Tønnessen and Johnsen 1982). However, coastal change may have occurred in the period since Cladh Hallan and Bornais were inhabited, and a sea inlet is depicted just to the south of Bornais on maps from the 18th century (Figure 74). There are a series of freshwater lochs in this area now but the map indicates that they may once have been connected to the sea, and could represent potential trapping environments. Environments on nearby islands, including scattered skerries and sand bars, may also have been well suited to trapping and other methods of procurement (e.g. Figure 75).

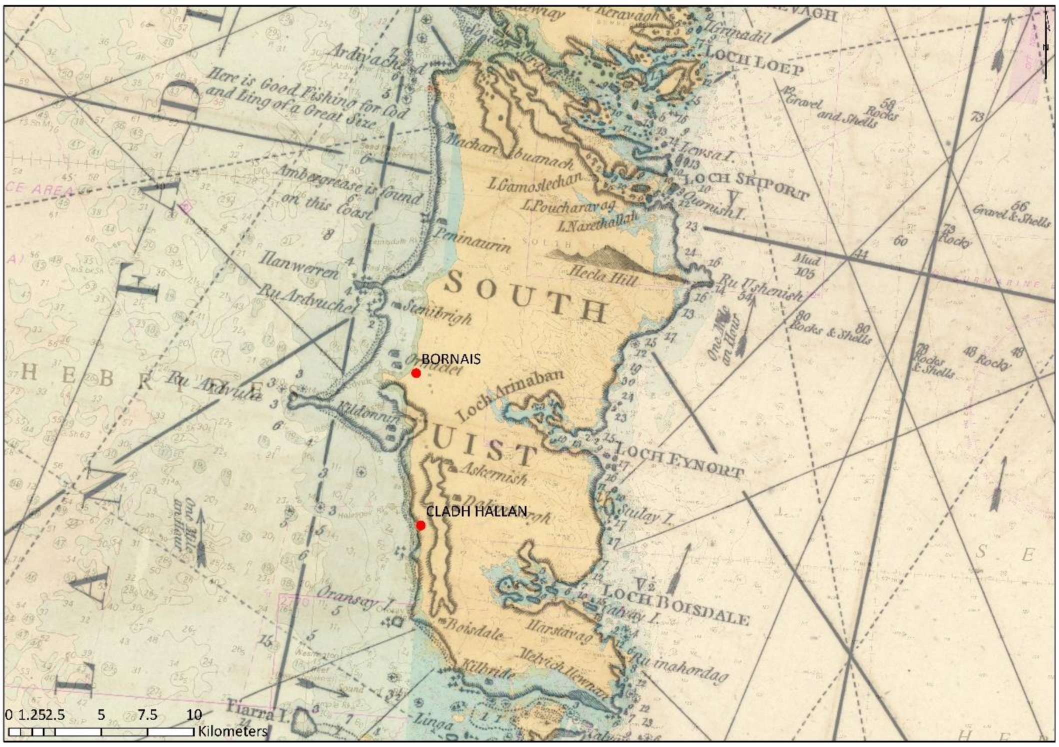

Figure 74 Approximate location of Cladh Hallan and Bornais compared with Joseph Huddart's late-18th century map of the Hebrides and underlain with the modern admiralty chart for the area[18]

Strandings along the west coast are also very common and the west coast of Scotland generally has been identified as a strandings hotspot (Coombs et al. 2019: 1540-1). This reflects the effects of the North Atlantic drift, and the proximity of these areas to the continental shelf edge which forms a key migration route and feeding area for many larger species, and generally hosts high species diversity, as does the Sea of Hebrides (Clark et al. 2010; Coombs et al. 2019: 1546). Cetaceans, as well as other products such as ambergris (see Figure 74) wash up along this coast, and it is conceivable that drift whaling could be successfully employed on this coast, capitalising on the favourable currents and likelihood of recovery through strandings.

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[18] While the 18th century chart is useful for assessing broad differences in past landscapes, some landscape features, including Rubha Ardvule, the promontory to the west of Bornais, are exaggerated. Although coastal change and erosion have occurred the exaggeration of the promontory is likely due in large part to the inaccuracies of charting during the 18th century (Robinson 1962).

Figure 75 Sandy embayments on North Uist and nearby archaeological sites

Many species identified on the sites are present within the strandings record (NHM 2018). Exceptions are the right and gray whale, the populations of which are known to have been decimated in the north-east Atlantic by whaling which took place prior to the collection of strandings records. It is, however, likely that these species were present within the area and stranded historically. It is possible therefore that the assemblages could represent the exploitation of naturally stranded individuals. However, active procurement is also possible. The habitats of different species are examined below to form a backdrop for understanding where potential interactions between human and cetacean populations may have occurred in the past.

3.3 SPECIES AND HABITATS IN AND AROUND THE HEBRIDES

This section gives an overview of cetacean habitats in the waters surrounding the Hebrides. Cetacean distributions relate to a range of factors including the presence of prey species and oceanographic features such as temperature, salinity and depth (e.g. Pollock et al. 2000: 11). The locations in which cetaceans are found therefore alter between areas, according to these factors.

Relationship to the shore (i.e. inshore/offshore) has been defined here as this is likely to influence the potential for perception by human communities: a key factor governing procurement (Yesner 1995). The taxa are categorised according to whether they are typically found offshore in the Hebrides, or inshore, following definitions of these areas set out in Chapter 3. Table 36 therefore represents a broad characterisation of the habitats of different species in Hebridean waters, and the discussion which follows contains more detailed information on habitat. Where species-level identifications were not obtained habitats have generally not been defined (unless the taxonomic identification is sufficient to characterise habitat).

The taxa can be broadly grouped into larger offshore species (including sperm whale, blue whale, fin whale and beaked whales) larger inshore species (balaenid, gray whale, humpback whale, minke whale) and delphinoids (orca, pilot whale, harbour porpoise, large delphininae and lagenorhynchus) all of which occur inshore at times.

		Cladh Hallan			Bornais					
	Hebridean Habitat	Early Bronze Age	Late Bronze Age	Early Iron Age	Late Iron Age I and II	Early Norse	Middle Norse	Late Norse	Norse	Unphased and U/S
Inshore	**Inshore***		**10**		**7**	**4**	**13**	**5**		
	Balaenidae		10		4	3	9	4		
	E. robustus				3	1	4	1		
	Year Round Inshore and Offshore		**12**	**3**		**1**	**1**	**5**	**1**	
	Large delphininae		1	3						
	O. orca		2				1	2		
	M. novaeangliae		9			1		3	1	
	Year Round Inshore			**1**		**2**		**1**		
	P. phocoena			1		2		1		
	Year Round to Seasonally Inshore		**1**							
	Lagenorhynchus sp.		1							
	Offshore and Seasonally Inshore		**2**							
	G. melas		2							
	Seasonally Inshore							**1**		
	B. acutorostrata							1		
	Year Round Offshore and Occasionally Inshore		**374**	**1**	**3**	**16**	**21**	**40**		
	B. physalus		2	1	1		2	6		
	P. macrocephalus		372		2	16	19	34		
Offshore	**Offshore and Occasionally Inshore**				**1**		**1**	**3**		
	Ziphiidae				1		1	3		
	Year Round Offshore		**4**	**17**		**2**	**1**			
	B. musculus		4	17		2	1			
	Not Defined	**7**	**760**	**72**	**707**	**130**	**216**	**142**	**215**	**9**
	Total	**7**	**1163**	**94**	**718**	**155**	**253**	**197**	**216**	**9**
	MNS per period	**1**	**9**	**4**	**6**	**7**	**8**	**10**	**3**	**1**

Table 36 Cetacean taxa through time and their Hebridean habitats

3.3.1 LARGER OFFSHORE TAXA

Sperm whale, blue whale, fin whale and beaked whales are all are offshore taxa typically encountered on seasonal migrations, the routes of which roughly follow the edge of the continental shelf which lies c. 50 miles west of the Outer Hebrides (Boyd and Boyd 1996; Evans 2012; Pollock et al. 2000), though individuals may come further inshore on rare occasions (HWDT n.d., a, b). Beaked whales are found offshore in Scottish waters, and due to their deep diving habits are rarely encountered at sea. Around Scotland most beaked whales occur far offshore, off the shelf edge. All species may occur closer inshore in other areas. Around Iceland and the Faroes, for example, deep waters are located close to shore and the large species can therefore be found much closer to the shoreline, as discussed above (Lindquist 1994).

3.3.2 LARGER INSHORE TAXA

Balaenids within the assemblages likely represent right whales (see Chapter 6). Right whales are critically endangered today, though prior to extensive exploitation associated with commercial whaling they are thought to have had critical habitat within UK waters (Clark et al. 2010: 18). This species has a preference for coastal waters, and studies of surviving populations indicate they calve in coastal areas, and migrate following the coasts to cooler feeding grounds (NOAA 2015: 11). Right whales may therefore have passed through Scottish inshore waters on their migrations.

Gray whales are now extinct within the North Atlantic but inhabited these waters historically (Mead and Mitchell 1984). They are a migratory species and favour shallow waters during their migrations. Their feeding style is unique amongst cetaceans and relies on bottom feeding in shallow muddy bays (Reiley et al. 2008). In the extant North Pacific population feeding takes place in latitudes comparable to those of the Western Isles (Dunham and Duffus 2002; Kitchener et al. 2021; Moore et al. 2003; Swartz 2018) and a recent study has suggested that foraging grounds for this species may have been located in the southern North Sea and potentially around the north of Scotland (van den Hurk 2020: 150) suggesting that the species may have regularly been present in Hebridean inshore waters during migrations and while feeding.

Humpback whales pass through Scottish waters on their seasonal migrations between cool summer feeding grounds and warm breeding and calving areas. Although most sightings occur in deeper waters beyond the 1000m depth contour (Clark et al. 2010: 62; Pollock et al. 2000) they are relatively regular visitors in the waters around the Hebrides, both within the Minch and Sea of Hebrides, and off the west Atlantic coast of the islands (HWDT 2018: 54).

Minke whales are common near the coasts of the Hebrides both in the Minch and around the Inner Hebrides. They occur inshore seasonally and are focused within the Sea of Hebrides (NatureScot 2020a), though they also occur on the Atlantic side of the islands (HWDT 2018: 15). Their smaller-scale movements are also seasonal and thought to relate principally to the presence of prey species, in particular sand eel and herring (Clark et al. 2010: 42).

3.3.3 DELPHINOIDS

Pilot whales are typically an offshore species with high numbers located in deep waters to the west of Scotland (Clark et al. 2010: 53) however, pods have been recorded in the bays around the Hebridean coast where they were historically taken by drive whaling (Harvie-Brown and Buckley 1888: 38). It is not known why this species occur inshore at times; their key prey species are squid, found in deep waters though they occasionally eat some fish species (Clark et al. 2010: 53). Killer whales likewise occur around the coast. Those sighted regularly in the Hebrides today have been identified as a distinct type; the West Coast Community (Carwardine 2020: 277) and favour marine mammals for their diet, taking seals and other small cetaceans, though other types of Orca (including fish-eaters) may also move through Hebridean waters. Orcas are known to come close inshore when chasing their prey and are seen within bays (Evans 2000; HWDT 2021).

The identifications of larger delphininae indicate the presence of either Risso’s dolphin or bottlenose dolphin. Both occur in inshore waters, and there is a community of bottlenose dolphins which inhabit the Sound of Barra, just to the south of Uist. They can be found close to both the west and east shores of South Uist and come into very shallow waters in the area (Evans 2000). Risso’s dolphin is more common in the north Minch, though sightings of the species close around South Uist’s shores and in shallow waters on both the east and west coast are also reported (Evans 2000; HWDT 2021).

White beaked and white sided dolphins (Lagenorhynchus) are reported from inshore waters, though the former is more common inshore while the latter prefers deeper offshore waters. When inshore both appear to frequent the north Minch and can be found in large numbers in that area (HWDT 2021). While the white beaked dolphin is typically an inshore species they are rare in very shallow waters, though can be seen in deeper coastal waters around South Uist (Evans 2000). The white sided dolphin is likewise rare in shallow waters (Evans 2000).

Harbour porpoises are very common in the waters around the Hebrides and the area may be used for calving and breeding (Clark et al. 2010: 23). In Scottish waters the species feed on a variety of small fish including herring, sandeels and gadoids including immature saithe (Evans 2000; Pollock et al. 2000: 13). Harbour porpoises occur close inshore within shallow waters and many have been reported within the sea lochs of South Uist’s east coast (Evans 2000; HWDT 2021).

3.4 SUMMARY

This information provides a broad framework for characterising interactions between cetaceans and humans at Cladh Hallan and Bornais. The following sections compare habitats of species identified with zones of marine activity to determine potential interactions. The nature of procurement is then further investigated with reference to the zooarchaeological data (species, quantities and evidence for utility discussed in the previous chapter), in addition to historical sources (reviewed in Chapter 3) and ethnographic evidence where available.

4 HUMAN- CETACEAN INTERACTIONS AND PROCUREMENT IN THE BRONZE AGE AND EARLY IRON AGE

This section examines all evidence for the nature of cetacean procurement in the Bronze Age and Early Iron Age. The discussion principally aims to characterise procurement at Cladh Hallan, though comparative sites are reviewed in Section 4.2.4 to aid this discussion. Chapter 3 provides additional context for the discussion set out below. In particular it sets out evidence for seafaring technology and marine exploitation, and the nature of this exploitation including evidence for how and where it was undertaken (from the shore, in the nearshore area etc).

4.1 IDENTIFYING INTERACTIONS: TAXA, HABITATS AND ZONES OF MARINE EXPLOITATION

Middle Bronze Age cetacean remains were not identifiable to species and as such habitats could not be established. The following discussion therefore focuses on the Late Bronze Age and Early Iron Age remains. Identified species from these periods were dominated by those with offshore habitats, due to the large number of sperm whale bone fragments identified during Late Bronze Age deposits, though blue whale also formed an important part of the assemblage and fin whale was also identified. All are typically found offshore in the waters around the Hebrides, though individuals may stray closer to the coast on rare occasions (Clark et al. 2010).

During the Late Bronze Age inshore species such as balaenids are also clearly represented, as are others which occur inshore and offshore including humpback and killer whales, pilot whales and large delphininae (either Risso's dolphin or bottlenose dolphin). In Early Iron Age phases 13- 15 this pattern changes with the NISP dominated offshore species (in particular blue whale) with no direct evidence for species which occur regularly inshore. Some generic evidence for a range of other species is present, but inconclusive. Early Iron Age phase 16 includes positive identifications of inshore species including harbour porpoise and Risso's dolphin or bottlenose dolphin all of which occur close to the coast and are well known around South Uist today (HWDT 2018). Offshore species are again reflected by the presence of blue whale. The presence of these species, and implications for procurement, is considered in the context of the site and Hebridean economies during the Late Bronze Age and Early Iron Age (see Chapter 3).

Archaeological and zooarchaeological evidence indicates that marine exploitation was limited during the Late Bronze Age and Early Iron Age, and terrestrial resources were the focus of contemporary communities. Evidence from fish, seal and bird bone assemblages do, however, indicate a low level of marine exploitation, focused on inshore and coastal environments (e.g. Ingrem forthcoming), though with some potential for travel further offshore indicated by the gannet remains (Best and Mulville 2013: 423) which likely indicate water-borne travel to coastal nesting sites rather than open water exploitation. The assemblages also demonstrate that a small-scale inshore fishing strategy operated at Cladh Hallan (and other contemporary sites), focusing on immature saithe which can be caught from the shore or nearshore in small boats using nets or rod and line (Ingrem forthcoming; Figure 76). Exploitation of other marine species included seals, though remains indicate that this exploitation was limited and likely represents occasional predation at haul-out sites (Smith and Mulville 2004: 50). Human-cetacean interactions with inshore species, and stranded offshore species are therefore most likely.

Figure 76 Fishing for small species such as immature saithe from the shore (source: Shetland Museum Archive, 00419).

4.2 DISCUSSION

The preceding section established where human-cetacean interactions are likely to have taken place based on evidence from Cladh Hallan. The following section takes this information into account to determine the nature of procurement. Where live interactions are a possibility evidence for the utility of cetaceans, and remains from contemporary cetacean zooarchaeological assemblages, are considered to establish whether there is any evidence for active procurement.

4.2.1 LARGE OFFSHORE TAXA

There is no evidence for activity in offshore environments where migrating offshore species such as sperm whales, blue and fin whales are typically found. These species, which include the largest whales alive today, are also fast swimmers (e.g. Cetacean Rescue and Research Unit n.d). Historical documents indicate that balaenopterids may have been targeted in Icelandic waters by wounding and allowing the large whales to drift and strand (Lindquist 1994: 28). However, the species occur closer inshore and within fjords in Iceland and thus recovery would have been more likely than wounding an animal in the open ocean. While chance sightings of live individuals who strayed further inshore than their normal range probably did occur, these are likely to have been rare events. Even where they did occur it is very unlikely that Cladh Hallan's inhabitants, who otherwise only exploited the smallest of marine species (juvenile fish) would have attempted active procurement. Additionally, despite the significance of offshore species, and in particular the sperm whale (see Chapter 7), there is nothing within the evidence which suggests the presence of more than one individual of each species and there is therefore no evidence for repeated exploitation which may be expected if deliberate whaling was occurring (though DNA analysis may shed future light on quantification).

In the Hebrides all species may have been encountered as stranded individuals. Sperm whales are frequently found stranded on the long beaches of the west facing Hebridean coast (Cerón-Carrasco 2005; Coombs et al. 2019; Figure 77), and historical records indicate that Hebridean communities did exploit stranded individuals of this species at least as early as the 18th century (Baldwin 2008: 71). Stranding of other species may have been more common prior to the decimation of whale populations caused by commercial whaling. The Cladh Hallan community may have encountered stranded cetaceans, particularly on the west coast, while carrying out their other maritime activities such as inshore fishing (Ingrem forthcoming) and gathering of marine molluscs from nearby rocky shores (Parker Pearson and Smith forthcoming).

While active hunting of these species is unlikely, ethnographic evidence provides interesting insights into active engagement with strandings which suggests lack of hunting did not necessarily equate to passive scavenging (which is a loaded term with implications relating to the importance of the resource (see Domínguez-Rodrigo 2002)). The Tikigaq people of Alaska, for example, have myths which depict whales being lured ashore by music and this connection between music and whales is a key component in the human-cetacean relationship (Lowenstein 1993; Sakakibara 2009; Whittle 2000: 251). This example, while specific to a particular community and location, demonstrates that past communities may have engaged with the procurement process in varied and complex non-physical ways. It is possible that the inhabitants of Cladh Hallan also engaged in activities which aimed to influence strandings of the animals which were clearly significant to them (see Chapter 7).

Figure 77 Sperm whale stranded on the west coast of the Outer Hebrides in 2019 (source: SMASS 2020)

4.2.2 LARGE INSHORE TAXA

Large species including the balaenids and humpback whale may have been encountered live in inshore areas while the inhabitants of Cladh Hallan were engaging in other maritime activities such as inshore fishing. These species are present throughout multiple Late Bronze Age phases (Chapter 6), however, the MNI for each is one and the humpback whale is represented by multiple body parts (a rib, vertebral epiphysis and flipper bones) supporting this quantification.

Humpback and right whales are slower swimmers, and were often foci for early whaling ventures (Ellis 1992: 84; Mead and Mitchell 1984; Reeves and Smith 2007) using the harpoon and tow method of procurement (Lindquist 1994). The general focus of the Bronze Age and Early Iron Age economy away from marine resources suggests that the inhabitants of Cladh Hallan are unlikely to have had the necessary skill or technology to engage in the harpoon and tow method of whaling. It is possible that these species may have been procured by methods of assisted stranding or by trapping within the bays of the east coast. However, Cladh Hallan is located some way from the east coast and opportunistic sightings of whales along this coast are less likely due to the probable focus of activity around settlement sites on the machair in the Bronze Age (Sharples 2009). Methods of drift whaling for the exploitation of these species is a possibility on the west coast. However, these methods would also involve use of piercing weapons or projectiles from boats suggesting that this too may be unlikely. Evidence for utility is explored below to further examine the possibility of active procurement.

Utility and procurement

The previous chapter established that the artefactual and oil utility of large species were valued at Cladh Hallan, and both the balaenid and humpback whales were represented in the artefact and fragmented bone categories. While utility can represent a driver for procurement (and standardised use of cetacean bone is frequently cited as an argument for active procurement; e.g. Hennius et al. 2018; MacGregor 1985; Sjøvold 1971) utility of the large inshore species was generally lower than that of the large offshore species. The NISP of the balaenid and humpback whales was lower than that of the sperm whale and blue whale and they were used for fewer artefacts. A greater level of significance also appears to have been placed on remains of offshore species, and the use of sperm whale in particular indicates the importance of offshore species.

If the large inshore species were actively procured we may expect to see evidence of it within the ways the bone was used. The focus of use on offshore species suggests that inshore species were not being actively procured. Overall, the evidence from contemporary economies, cetacean bone utility and use of the wider landscape indicates that active procurement of these species is unlikely. It is more likely that these species were stranded individuals, as with the large offshore species, though as we have seen procurement through strandings need not have been a passive process.

4.2.3 DELPHINOIDS

Delphinoids including the killer whale and pilot whale identified at Cladh Hallan and Northton (Finlay 2006: 174) and large delphininae (either Risso's dolphin or the bottlenose dolphin), Lagenorhynchus sp (either white-beaked or white-sided dolphin) and the harbour porpoise may also have been encountered inshore. In all, twenty-three delphinoid bones represent the remains of at least five individuals at Cladh Hallan. While all are found within the inshore area (covering the area between the shore and out to six nautical miles), many also occur very close to the shore creating greater opportunities for these species to have been encountered by the inhabitants of Cladh Hallan while fishing for immature saithe, which can be found very close to the shore and have historically been caught from the shore (Ingrem forthcoming).

It is possible that these species could have been procured while engaging in fishing activities, and historical evidence indicates that Delphinoids were often caught opportunistically or accidentally alongside fishing ventures in later periods (Harvie-Brown and Buckley 1888: 38). However, if the inhabitants of Cladh Hallan were practising deliberate and planned dolphin or porpoise hunting, we may expect more evidence of this from the site in the form of higher numbers of bones (e.g. Glassow 2005) and although multiple species are represented in some phases the number of elements remains low. It is possible that the low numbers reflect either the practice of leaving bones at shoreline processing sites or a low-level exploitation of small cetaceans. Utility is examined below to further investigate the potential for active procurement of delphinoids at Cladh Hallan.

Utility and procurement

As discussed in the previous chapter, Delphinoids are likely to have been used for meat, and to a lesser extent artefact production.

The presence of delphininae bones with cut marks indicative of meat removal (phase 7, context 2476) and articulating vertebrae from a large delphininae (phase 16, context 407) suggests the recovery of delphinoid meat back to the site. As meat products would spoil relatively quickly (e.g. Szabo 2008: 87-89) this may be indicative of active procurement rather than exploitation of stranded animals which are more likely to be in a state of decomposition.

The cetacean bone artefact assemblage from Cladh Hallan, examined in the previous chapter, however, argues against systematic and active procurement of delphinoids. Standardised use of cetacean bone and focus on cetacean bone for the manufacture of certain products on other sites has been interpreted as evidence of reliable access to cetacean bone via active hunting (e.g. Hennius et al. 2018; MacGregor 1985; Sjøvold 1971, critiqued by Hallén (1994)). At Cladh Hallan epiphyseal discs of delphinoids formed part of the artefact assemblage. However, bones from other species were also worked into discs the same size and shape as delphinoid vertebral epiphyses. These included one made from worked deer bone (phase 9, SF 4672) which mirrored the form of a perforated delphinoid vertebral epiphysis (SF 4683) found on the same house floor. Others made from bone not identifiable to element, though certainly not from vertebral epiphyses were also found in phase 10 (context 1575; SF3744) and phase 12 (context 473, SF 4213). Two other approximately circular pieces of worked sperm whale and Delphinoidea bone may be disc rough outs (phase 12, context 1315, SF 3456; phase 9, context 1311, SF 4583 respectively). Use of different species and apparent need to fashion bones into circular form within the size range of delphinoid vertebral discs may suggest that suitable cetacean bone epiphyseal discs were not always readily available, and systematic or regular hunting of delphinoids therefore unlikely.

4.2.4 COMPARATIVE HEBRIDEAN SITES

The data from Cladh Hallan can be compared to the restricted remains from other Scottish sites to further investigate evidence for the nature of procurement in this period. Although a small but consistent presence of cetacean bone is noted on Scottish coastal prehistoric sites generally (Mulville 2002), relatively little cetacean bone has been recovered from settlements of the Bronze Age and Early Iron Age, though there are very few extensively excavated settlements of this date and in general the focus of study has been on remains from later periods (e.g. Hallén 1994). As mentioned previously excavation methods and identification skills of those involved in excavation and post-excavation work may bias results (Chapter 2). However, sites which have both Bronze Age and later levels have also reported more cetacean bone from the later periods (e.g. at Cill Donnain (Vickers et al. 2014) and the Udal (Finlay 1984)), indicating that to some extent this pattern may not solely be the result of biases. A number of reports from other Bronze Age sites also note that cetacean bone was present, but not quantified. This is the case for cetacean bone from the Early Bronze Age site at Manish Strand, Ensay (Simpson et al. 2003: 182) and Cill Donnain (Vickers et al. 2014: 161). At other sites such as the Udal cetacean bone is not yet quantified for Bronze Age levels, though Finlay (1984: 45) indicates that 'the quantity of whale bone recovered could have derived from beached individuals with no necessity for deliberate pursuit'.

For other sites such as Northton cetacean bone was quantified, with some elements morphologically identified and at least some fragments recorded (Finlay 1984, 2006). Three cetacean bones were reported from Late Bronze Age midden layers at this site (termed midden I) including two which were identified as possible killer whale and pilot whale (Finlay 2006: 174). A fragment of balaenopterid bone was also reported from later midden deposits (midden II) (Finlay 2006: 174). The material from Northton therefore mirrors offshore and inshore species identified at Cladh Hallan in the Late Bronze Age and Early Iron Age, though quantities of cetacean bone are restricted to a small number of pieces. Small cetacean bone assemblages have also been recovered from the Early Bronze Age phase of Sligeanach on South Uist which included five pieces of unidentified cetacean bone (Sharples et al. 2012) and from Machair Mheadhanach, also Early Bronze Age in date from which a single piece of possible unidentified cetacean bone was reported (Hamilton and Sharples 2012). A fragment of large cetacean bone was reported from Late Bronze Age levels at Barvas (Cowie and MacLeod Rivett 2010), and a small number of pieces (not further quantified or identified) were recorded in Late Bronze Age/ Early Iron Age levels at Baleshare (Halsted 2003: 143) though there is some uncertainty regarding the dating of this site. Part of an unidentified cetacean vertebra was recorded at Hornish Point (James and McCullagh 2003).

In this context, Cladh Hallan, with its high quantities of cetacean bone fragments, is a notable exception (Smith and Mulville 2004: 53). This is likely due in some part to thorough excavation methodologies and extent, extensive sieving, and the 'Jacqui Factor' (i.e. the influence of Mulville, a specialist in archaeological cetacean remains, during excavation and post-excavation works). However, Cladh Hallan is an unusual site and the remains are of a very different character to other contemporary excavated sites in the Hebrides. The wider Cladh Hallan bone assemblage also has other unusual characteristics (such as the greater presence of deer compared with most other Bronze Age sites) (Mulville forthcoming). The possibility therefore exists that cetacean utilisation was greater at this site than its contemporaries and evidence reviewed in the previous chapter also indicates that cetaceans were significant at this site. Reanalysis of cetacean bone from comparable settlement sites such as Jarlshof (and, in an earlier context, Skara Brae) would provide important comparative material. Recent analysis of two pieces of cetacean bone from later deposits at Jarlshof are discussed in Section 5.2 below (Kitchener et al. 2021).

However, in a Hebridean context, where identification of material from other sites has occurred the evidence demonstrates use of both inshore and offshore species, as at Cladh Hallan. Further detailed analysis of the existing assemblages is required for an in-depth comparison, though at present nothing from the contemporary assemblages provides any indication of active procurement.

4.3 SUMMARY

Overall, it is unlikely that the Late Bronze Age and Early Iron Age inhabitants of Cladh Hallan engaged in deliberate and active cetacean procurement. There is no overlap between the habitats of large offshore species which dominate the assemblage and the marine environments frequented by Cladh Hallan's inhabitants while engaging in inshore fishing or other marine activities, and it is likely that encounters with live sperm whales, blue whales and fin whales were rare. Thus, despite the significance of the sperm whale in particular exploitation of stranded individuals is most likely.

Although interactions with live inshore species undoubtedly occurred, given the apparent focus of the economy away from marine resources and the low level of marine exploitation active exploitation of large and small inshore species is also unlikely. The few delphinoid elements which are present may be more likely to have come from the exploitation of freshly stranded individuals, accidental or opportunistic catches whilst inshore fishing. This conclusion is supported by the evidence from the artefact assemblage which indicates that there was not a reliable supply of delphinoid bone.

5 HUMAN- CETACEAN INTERACTIONS AND PROCUREMENT IN THE LATE IRON AGE

This section examines all evidence for the nature of cetacean procurement in the Late Iron Age. The discussion principally aims to characterise procurement at Bornais, though comparative sites are reviewed in Section 5.2.2 to aid this discussion.

5.1 IDENTIFYING INTERACTIONS: TAXA, HABITATS AND ZONES OF MARINE EXPLOITATION

Late Iron Age cetacean remains include a range of taxa for which habitats could be defined. Large inshore taxa including balaenid and gray whales are represented by the highest NISP, with large offshore taxa including sperm whale, fin whale and beaked whale also present. Small taxa were represented by a single delphinoid bone for which habitat could not be determined due to the generic identification. The presence of the large species, and implications for procurement, is considered in the context of the site and Hebridean economies during the Late Bronze Age and Early Iron Age.

Contemporary marine exploitation strategies and seafaring ability were reviewed in Chapter 3 and are summarised here. As with the Bronze Age and Early Iron Age, economies during the Middle to Late Iron Age were focused on terrestrial species though there is evidence of increased use of wild and marine species compared with the preceding period and compared with other areas of the UK (Jones and Mulville 2016: 675). Immature saithe continued to be the principal fish species targeted, though other inshore species were also taken and remains are broadly indicative of a continuation of the inshore fishing strategies seen in the Bronze Age though with evidence of some intensification (Cerón- Carrasco 2005; Evans and Ingrem 2021; Ingrem 2012; Jones and Mulville 2016: 674; Serjeanston 2013: 77; Smith and Mulville 2004: 54). Other marine species targeted include seals, which may have been caught on the shore or in shallow waters (Duck 2007; Mulville and Ingrem 2000:261), though their remains are generally only present in low numbers on most sites. As in the Bronze Age avian remains are dominated by seabirds, which were present in unusually high numbers at Bornais (Best 2013: 151; Cartledge and Serjeantson 2012: 342). Exploitation is likely to have focused on cliff-side nesting sites, indicating seaward travel to these sites (Best 2013: 183). Evidence from the distribution of sites dating to this period indicate that South Uist was a densely populated landscape (Sharples 2012), a factor which likely led to the reorientation of land division from north-south to east-west (Parker Pearson et al. 2004: 103), effectively leading to activity on both the east and the west coasts.

As in the Bronze Age human-cetacean interactions with inshore species, and stranded offshore species are therefore most likely. It is very unlikely that the inhabitants of Bornais would have regularly encountered large offshore species such as the sperm whale, fin whale and beaked whales, other than through strandings and the occasional presence of an individual inshore.

5.2 DISCUSSION

5.2.1 LARGE OFFSHORE TAXA

As in the Bronze Age it is likely that fast-swimming offshore taxa including blue whale, fin whale, sperm whale and beaked whales were procured as stranded individuals: their primary habitat falls outside of the inshore area in which maritime activities were focused during the Late Iron Age. However, the presence of inshore and slow swimming species indicates the potential for other forms of procurement.

5.2.2 LARGE INSHORE TAXA

The cetaceans identified in Late Iron Age I and II deposits at Bornais were dominated by large, slow-swimming inshore species. These species are likely to have been encountered by the inhabitants of Bornais during other inshore activities such as fishing, and the characteristics of the cetaceans indicates the potential for active procurement at a time when marine exploitation was on the rise. Balaenids, humpbacks and gray whales were among the earliest to be targeted by whalers due to their slower swimming speeds, the inquisitive nature of the humpback, and the nearshore habitats of the right whale and gray whale (Ellis 1992: 84; Mead and Mitchell 1984; Reeves and Smith 2007). These species have been targeted by numerous different methods worldwide, including from small rowing boats, whaleboats and dugout canoes by crews using nets, harpoons, and lances (Ellis 1992; Huelsbeck 1988; Takahashi et al. 1989) and some areas show a reliance on all three species (Krupnik and Kan 1993), targeted due to their similar natures and habitats. There is early evidence for their exploitation in the North East Atlantic (e.g. Lindquist 2000; see below).

As we have seen, Hebridean Iron Age economic strategies involved exploitation of the nearby environments and inshore waters. It is therefore likely that, if whaling developed during the Hebridean Iron Age, local inshore species and seascapes would have been the foci of exploitation. Bornais lies on the west coast of South Uist, closest to the exposed long west-facing beaches of this island, and is 10km from the east coast and 4km from the westernmost tip of the nearest sea loch, Loch Eynort, one of lochs which indent the east coast. The east coast lochs present opportunities for trapping, driving, and drift whaling which could have been employed on all large inshore species, and historic maps also show a sea inlet curving round from the south of the site on the west coast which could have been used to trap cetaceans while the long sandy beaches provide further opportunities for using the drift whaling, or assisted strand, methods.

Both species and seascape therefore allow for the active procurement of the right, gray and humpback whales. The following section reviews uses of cetacean bone at Bornais for further insights into procurement.

Utility, tools and procurement

The bone assemblage from the Late Iron Age deposits at Bornais was sizeable: larger than that of any later (Norse) phases (see Chapter 6). Over 700 pieces of cetacean bone were recovered, the majority of which came from Late Iron Age I deposits (NISP 700). The number of cetacean bone artefacts was also higher than the Early Norse period which followed (see Chapter 6, Table 18), and previous studies have found greater evidence of cetacean bone tools on Iron Age sites compared with earlier and later periods (Mulville 2002). Extensive use of cetacean bone during the Iron Age is demonstrated by the increase in the number of sites with cetacean bone dating to this period compared with earlier periods (e.g. Hedges 1987; Szabo 2005, 2008). The evidence from Bornais and further afield therefore indicates the extensive utility of cetacean bone during the Iron Age, which could have formed a driver for active procurement.

Taxonomic identifications could not be achieved on many of the Iron Age artefacts from Bornais mainly due to the degree of burning, though where multiple identifications were achieved within a single artefact category they demonstrated that use was not species-specific (though gray whale was used for two artefacts – the only species to be represented by multiple identifications in the artefact categories during the Late Iron Age; see Chapter 6). Perforated bone discs were found to be made from gray whale and beaked whale, indicating use of inshore and offshore species for the same purpose. Likewise worked fragments also derived from inshore and offshore species, all of which argues against a regular supply of bone from species which could be actively procured.

Additionally, no evidence of meat utility was identified on the site. Only one bone contained evidence of possible meat removal, a fragment of a vertebral neural spine from a fin whale (1526, SF 5404). Chop marks on this bone occur in the region of muscle attachment sites and may therefore indicate the removal of flesh, however it is also possible that the piece was used as a chopping block or cutting surface or that rotten flesh may have been removed to allow use of the bone for artefact manufacture. The bone was from a fin whale which are typically found in offshore areas, vastly decreasing the chances that this individual was actively procured.

Unfortunately, the high degree of burning on most of the Late Iron Age material from mound 1, and the small size of the mound 2 assemblage (NISP 18), limits interpretation of utility in relation to procurement. However, remains from other sites may shed more light. These remains are reviewed below.

Comparative sites on the Hebrides and Northern Isles

The presence of cetacean bone on archaeological sites increased in the Iron Age, and cetacean bone has been found on the vast majority of Hebridean sites from this period (Mulville 2002; Smith and Mulville 2004: 54). Comparisons can be drawn with the remains from Bornais. The evidence from the Western Isles can also be compared with that from further afield, in particular from mainland Scotland and the Northern Isles which formed part of the wider Pictish Kingdom with which the Hebrides were connected during the Late Iron Age (Sharples 2012, 2020). This section sets out an overview of quantities of bone reported and species identified to determine whether the focus on inshore species apparent in the assemblage from Bornais can be seen at other sites from these areas, and to examine any evidence for modes of procurement.

Quantities of cetacean bone reported in published accounts concerning Iron Age Hebridean sites are set out in Appendix 2. While they indicate the presence of cetacean bone at the majority of sites in this period, they are derived from different forms of quantification, making detailed comparisons difficult. Some, such as McCormick (2006) report on the number of fragments, while others such as Serjeanston (2013), refer to identified bones, suggesting that fragments are not included. Additionally, some sites, such as the Udal, have not been fully assessed. Without consistent methodologies applied to sites across the board, little can be learned from current quantification breakdowns of cetacean bone alone, though the number of sites which cetacean bone does suggest an increased focus on this material (Mulville 2002) which could represent a driver for active procurement.

Taxonomic identification sheds further light on the potential for whaling in this period. While the majority of bones have not been identified to species, two samples from A' Cheardach Mhor and two from Galson have been identified using ZooMS (Buckley et al. 2014) and bones have been identified from a number of sites using morphology (Finlay 1984; McCormick 2006: 172). Table 37 sets out identifications, and shows that a range of species have been identified on the Middle to Late Iron Age Hebridean sites and while species from offshore areas are present, it is those with inshore habitats which are most frequent. Samples analysed from the Iron Age site of A'Cheardach Mhor, South Uist, produced identifications of humpback whale (Buckley et al. 2014). Two possible balaenid bones were also identified (morphologically) at Bruach Ban (Finlay 1984) and another at Cnip (McCormick 2006). Other inshore species including bottlenose dolphin, Risso's dolphin, minke whale and possibly pilot whale were also identified morphologically at other Iron Age sites (Campbell 1991; Finlay 1984). Like Bornais therefore, other Iron Age Hebridean sites also show a focus on inshore species.

The sizable Iron Age cetacean bone artefact assemblages from the Udal, Foshigarry, Bac Mhic Connain and Sollas also deserve special consideration (Hallén 1994; Foxon 1991). Large numbers of cetacean bone artefacts have been recovered from these sites including tools which may have been used in cetacean procurement and processing. Artefact typologies are problematic (Clark 1947), however, evidence of wear on the working ends of tools classed as 'blubber mattocks' has been analysed (Rees 1979: 40), and findings demonstrated the possibility that some of these objects were used for blubber processing (Hallén 1994: 203; Rees 1979: 320). Additionally, potential harpoons (the first occurrence in the Hebridean archaeological record since the Mesolithic period) have also been identified at Foshigarry (Beveridge and Callander 1931: 334, fig. 17; find number GNA 37; Hallén 1994) and Bac Mhic Connain (GNB 14). These are not made from cetacean bone but could have been used in procurement. Comparison of the environments in which these sites lie provides some interesting observations (Figure 75). They are situated on the margins of North Uist, close to the Sound of Harris and in an area where there are inlets, scattered islands and skerries, and expanses of shallow sands. These landscapes present a variety of different possibilities for cetacean procurement. Methods of assisted stranding could have been employed on the vast sands intertidal sands, and the intricacy of the coastline would provide numerous opportunities for trapping of cetaceans.

Identification[19] and Hebridean Habitat	**Bornais Mound 1** Late Iron Age	**Bornais Mound 2** Late Iron Age	**A'Cheardach Mhor** Iron Age	**Galson** Iron Age	**Cnip** Middle Iron Age	**Sollas** Middle Iron Age	**Udal** Middle Iron Age	**A'Cheardach Bheag** Middle Iron Age	**Bruach Ban** Middle to Late Iron Age	**Bruach a Tuath** Middle to Late Iron Age
Inshore*										
Balaenidae		4		**1**	*1*				*2?+*	
E. robustus	2	1								
Year Round Inshore and Offshore										
M. novaeangliae			**2**							
T. truncatus						*1*				
G. griseus			*1*							*1*
Offshore and Seasonally Inshore										
G. melas							*1?*			
Seasonally Inshore										
B. acutorostrata								*1*		
Year Round Offshore and Occasionally Inshore										
B. physalus		1		**1**						
P. macrocephalus	2									
Offshore and Occasionally Inshore										
Ziphiidae	1									
H. ampullatus								*1*		
Year Round Offshore										
B. musculus						*2*				
Not defined										
	695	12	4			*5*	*2*			
References										
	This study and Buckley et al. 2014		Buckley et al. 2014; Finlay 1984	Buckley et al. 2014	McCormick 2006	Campbell 1991; Finlay 1984	Finlay 1984	Finlay 1984	Finlay 1984	Finlay 1984

Table 37 Taxa identified on Middle and Late Iron Age sites in the Hebrides

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[19] Identifications for Bornais follow the method set out within this thesis. For other sites those in bold are ZooMS identifications (from Buckley et al. 2014) and are considered secure. The remainder, shown in italics, are based on morphological identifications given by other authors. Methodologies have not been stated by these authors and morphological identifications may therefore not be accurate.

The possibility of whaling in this period, demonstrated by evidence from the Hebrides, is now considered in light of evidence from further afield, turning first to the Northern Isles.

Few cetacean bone assemblages from other areas of Iron Age Scotland have been analysed in detail hampering wider comparisons. However, DNA analysis has recently been applied to a number of sites from the Northern Isles (Orkney and Shetland) which provide important comparative material (Kitchener et al. 2021; UHI n.d.). Remains from the Middle to Late Iron Age site, the Cairns (Orkney), included identifications of fin whale, sperm whale, gray whale, humpback whale, right whale and minke whale ((UHI n.d), closely mirroring the species identified at Bornais. Gray whale has also been identified at the Middle Iron Age broch at Howe (Orkney) and Iron Age broch of Gurness (Orkney) and from Iron Age deposits at the multiperiod site of Jarlshof (Shetland) (Kitchener et al. 2021: 20). These sites therefore also demonstrate use of inshore species indicating the potential for active procurement (though full results from the ongoing DNA analysis is awaited).

Szabo (2008) also investigated cetacean bone from Late Iron Age to Norse deposits at Pool (Orkney). The study determined that a range of species were present in Late Iron Age and interface levels, including sperm whale, sei whale, minke whale, killer whale, pilot whale, bottlenose dolphin, Risso's dolphin and harbour porpoise and the majority of the bones were found to represent juvenile individuals, and primarily delphinoids[20] (Szabo 2008: 173-4). The species identified include those from a range of environments, but many, including the Delphinoids represent inshore species. The presence of juvenile cetaceans was found to coincide with a period of decline in the site's economy, and Szabo (2008) suggested that site's inhabitants may have turned to marine resources including juvenile cetaceans and seals as a supplementary resource (Bond 1998: 86; Szabo 2008: 176). Parallels can be drawn with Iron Age sites on the Hebrides, where inhabitants also turned to wild resources when faced with struggling agricultural economies. At Pabbay seals became a focal resource (Mulville and Ingrem 2000:261; Smith and Mulville 2004: 54), while inhabitants of the Shiant Islands turned to birds from the nearby puffin colonies (Mulville and Ingrem 2000). All demonstrate exploitation of the local wild environment when agriculture was failing, and Szabo's (2008) study shows signs that cetaceans may have been included within this pattern in Orkney, but potentially also within the Hebrides.

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[20] Only a single delphinoid bone was recovered from Late Iron Age deposits at Bornais (context 308) and as such the evidence is too limited for any inferences to be made regarding procurement. The one surviving epiphyseal disc was, however, fused to the centrum (the other side was broken).

Wider evidence of interactions with cetaceans may also come from the Pictish carved stones found primarily on mainland Scotland. The Pictish beast, a common figure on the carved stones, has been interpreted by some as a cetacean (e.g. Samson 1992), and its depiction on stones also carved with fish supports the interpretation of the figure as an aquatic creature (Figure 78). While debate on the identity of the beast is ongoing (Samson 1992), if representative of a cetacean it could indicate importance placed on marine mammals during the Late Iron Age, lending support to increasing interactions and the potential for active procurement.

Figure 78 Rhynie Pictish symbol stone (the Craw Stone) showing a salmon and the Pictish beast, possibly a cetacean. Image from RCAHMS SC 337025

Overall, while the different species may be an indication of communities who exploited any available stranded cetaceans, the repeated presence of slower swimming inshore taxa on Hebridean and some Orcadian sites, and in particular Balaenidae (probably right whales) and gray whales (Kitchener et al. 2021), and to some extent humpbacks, on at least three different sites in the Hebrides (Bornais, A'Cheardach Mhor and Galson) and four sites from the Northern Isles of particular interest. While these species are extremely rare, and the gray whale is extinct in Scottish waters today, in prehistory they may have been more abundant and it is thought that the right whale once had critical habitat in UK waters (Clark et al. 2010: 18) both this species and the gray whale possibly using the area for feeding (Rodrigues et al. 2018). The species inhabited and moved through nearshore waters and are likely to have been encountered by Late Iron Age communities while engaging in fishing for immature saithe and other inshore fish. Other species including the bottlenose dolphin, Risso's dolphin, pilot whale and minke whale identified at other sites (Campbell 1991; Finlay 1984) may also have been encountered in this way.

Evidence from across Atlantic Scotland therefore supports the possibility of active cetacean procurement focusing on inshore species. The wider contemporary context from other areas bordering the North Atlantic and North Sea are now considered to investigate additional evidence for cetacean procurement in the Middle to Late Iron Age.

Historical evidence and wider comparisons

Although Hebridean society during the Iron Age may have been principally focused on internal relationships and exploitation of local environments by the Late Iron Age connections with the Pictish kingdom are evident (Armit 1996; Sharples 2012, 2020; Sharples et al. 2004), and wider connections are indicated by general similarities in architecture, burial practices (of the Late Iron Age) and ceramics, particularly with the northern world (Henderson 2000: 150; Rennell 2015; Serjeanston 2013: 98), while the style of artefacts and presence of material not available on the Hebrides indicates connections with southern Britain (Sharples 2012: 251). This evidence suggests that consideration of activities across a wider area may allow insights aiding understanding of cetacean procurement.

Historical sources indicate whaling practices existed in many areas of the north-eastern Atlantic at this time, many of which are thought to have focused on the same large inshore species found at Bornais. The right whale was the principal focus for the Basque whale fishery which was in progress around the Bay of Biscay by c. AD 1000, and historical documents suggest the industry may have begun in the seventh century AD (Urzainqui and Olaizola 1998). A document dating to AD 670 records the import of casks of whale oil to the abbey of Jumièges, associated with Basque whaling (Hennus et al. 2018). Bede also records whaling occurring in Britain in AD 731, noting that 'seals as well as dolphins are frequently capture and even whales' (Mulville 2002: 36), indicating that both large and small species were taken around the UK. Aelfric's Colloquy, though dating from a little later (c. AD 1005) also refers to whaling in Britain, and while the species is not explicitly clear linguistic analysis has led some to suggest that the species referred to may be a right whale or gray whale (Lindquist 2000: 18).

Further afield, an increase in the importance of marine resources occurred in Scandinavia from c. AD 400 – 600, reflected by an upsurge in the relative proportions of fish bones on some sites (Barrett 2016b: 251; Enghoff 2016: 153) with evidence for the use of netting in Denmark (Enghoff 2016: 153) and deep-sea fishing in northern Norway (Perdikaris and McGovern 2008) and a dramatic increase in the creation of boat nausts (Wickler and Nilsen, 2012: 11) all pointing to intensified marine activities. This intensification may also have been coupled with whaling activities. Artefacts such as gaming pieces, plaques and weaving swords which in Scandinavian contexts are frequently found to be made of cetacean bone have been argued to indicate the presence of a regular supply of cetacean bone, through active whaling from the 6th century AD (e.g. Hennes 2018; Sjøvold 1971: 1204). ZooMS analysis undertaken on nine cetacean bone gaming pieces, dating to between AD 620 and 950, showed that all those identified were from balaenids indicating a focus on this species: potential evidence for active procurement (Hennes 2018), though a small dataset. Contemporary remains from northern Norway also add strength to the argument. Sites such as Skjærvika, Finnmark dating from between AD 600-900, have produced evidence of hundreds of slab-lined pits, thought to have been used for processing blubber from marine mammals (Nilsen 2017: 4). Balaenid bone has been found in association with some of these pits, suggesting that whale carcasses and blubber may have been processed here. The authors use this evidence to suggest that a whaling industry may have developed in northern Norway from around the 6th century AD, focused on the exploitation of the right whale, and supplying whale bone products to other parts of Scandinavia. Later sources, such as Ohthere's late-9th century account of whaling in northern Norway seem to support this suggestion (Clark 1947: 86; Szabo 2008: 59).

Archaeological and historical evidence therefore demonstrate the likelihood that active whaling was taking place in Norway, Britain and around the Bay of Biscay during the Scottish Late Iron Age, focused on the same large inshore species which have been identified at Bornais and other Scottish Iron Age sites.

5.3 SUMMARY

The apparent increase in cetacean bone, repeated presence of right, gray and humpback whales as well as other inshore species on sites of this period in the Western Isles, Orkney and Shetland (Kitchener et al. 2021; Szabo 2008; UHI n.d.), and hints of active whaling from historical documents and contemporary sites in Europe presents the interesting possibility of active whaling at Bornais, at a time when marine and wild resources may have been more actively exploited. Evidence for activity on both the east and west coasts also indicates that encounters with cetaceans may have been more regular, and in environments where active procurement may have been more likely to succeed. This, coupled with the presence of tools which may have been used in the killing and processing of cetaceans at other Hebridean sites, all strengthens the possibility that active procurement could have taken place. However, while these factors may have allowed for active procurement strategies to develop, they do not prove their existence and all species may have been acquired through strandings. Research using aDNA to identify the number of individual whales (MNI) represented by the Late Iron Age material, along with detailed analysis from other contemporary sites to investigate the extent of the presence of balaenid, gray and humpback whales, could throw additional light on the tantalising potential for active procurement in this period, as could more detailed reanalysis of assemblages from sites which could represent promising whaling locales (e.g. Figure 75).

6 HUMAN- CETACEAN INTERACTIONS AND PROCUREMENT IN THE NORSE PERIOD

This section examines all evidence for the nature of cetacean procurement in the Norse period. The discussion principally aims to characterise procurement at Bornais drawing on wider historical and archaeological data. As shall be seen, as the corpus of historical evidence grows from around 1000 AD, an increasingly complex picture of cetacean procurement emerges. The following sections follow the structure of discussion in earlier sections, however, additional sections are also included where historical documents provide evidence of particular facets of interest in regards to cetacean procurement. In particular these relate to interactions with the herring fishery, and social facets of acquisition of cetaceans encountered on the shoreline.

6.1 IDENTIFYING INTERACTIONS: TAXA, HABITATS AND ZONES OF MARINE EXPLOITATION

Norse deposits contain the highest levels of taxonomic diversity and include a number of species whose habitats can be established. Large species with offshore environments are well represented, including sperm whale (which occurs in the highest quantities), blue whale, fin whale and beaked whales. Inshore taxa are also well represented with balaenid, gray whale, humpback whale and minke whale present. Delphinoids include the killer whale and harbour porpoise (in addition to generic evidence for other taxa) which can be found in inshore waters. The presence of these species, and implications for procurement, is considered in the context of the site and Hebridean economies during the Norse period.

Zooarchaeological evidence demonstrates an upsurge in marine exploitation during the Norse period. While terrestrial resources remained the mainstay of the economy wild resources gained importance and fishing became a major activity (Barrett et al. 2000; Barrett and Richards 2004: 262-4; Best 2013; Dunwell et al. 1995; Jones and Mulville 2018; Serjeantson 1984; Smith and Mulville 2004: 55). Fish assemblages demonstrate that herring was the target species in the Western Isles (contrasting with the predominance of cod on sites in the Northern Isles), though a wide range of species were used (Ingrem 2005, 2018, 2020: 574). The evidence indicates exploitation of herring on spawning grounds (Evans and Ingrem 2021: 321), possibly focused to the east of the islands, in the Minch and Sea of the Hebrides (see Chapter 3 for full discussion) and other fish species identified could also have been caught from the inshore area (Evans and Ingrem 2021). Seals were caught in low numbers, probably reflecting occasional encounters at shoreline pupping sites (Evans and Ingrem 2021: 325) though the bird bone assemblage which is heavily focused towards seabirds includes species which could have been exploited at sea or on onshore breeding and nesting sites (Best 2021: 345).

Therefore, as with earlier periods, human-cetacean interactions with inshore species are most likely. However, the frequency of interactions is likely to have risen during the Norse period due to the increased time spent at sea engaging in other marine activities. Wider marine travel also occurred, for a variety of reasons including trade, exploration and settlement (e.g. Dugmore 2005; McGovern 1990) and interactions with offshore species may also have occurred more frequently. While interactions may have occurred with greater frequency, the development of the herring fishery was also coupled with specific restrictions on cetacean exploitation in other Norse-occupied areas (Szabo 2008). This is examined further below to feed into the discussion on procurement.

Cetacean procurement and the herring fishery

Many species identified in the Norse period occur alongside herring shoals, and a number are known to prey on herring. These include most balaenopterids including the fin whale, minke whale and humpback whale (Clark et al. 2010: 42, 61; HWDT n.d. a; HWDT 2018: 55). Minke whales in particular are closely association with spawning shoals off the west coast of Scotland (Clark et al. 2010: 42). Harbour porpoises and killer whales also feed on herring (Carwardine 2020: 277; NatureScot 2020b), though the West Coast Community (ecotype) of killer whales which frequent the area today are thought to feed on marine mammals.

Ecology of the right whale and gray whale populations within the North Atlantic are not well known as the species are rare and extinct in this area respectively (Clark et al. 2010). As such consideration of potential interactions with the herring fishery are not certain. Gray whales are bottom feeders and as such are not likely to have targeted herring, however, their diet does include herring eggs and their presence on spawning grounds around the Hebrides in the past is therefore possible (Reiley et al. 2008). Right whales typically target zooplankton and so interactions with herring may be less likely. Other key species including the sperm whale are not known to target herring and focus principally on squid (Pollock et al. 2000: 62).

While many of the species which prey on herring were probably encountered by the inhabitants of Bornais while engaging in herring fishing historical sources indicate they may have been actively avoided at these times. Early Norse laws, the Gulathing Law Code, (written in the 11th century AD) dictated that 'If a man shoots at a whale in a herring shoal[21] and thus drives away the gift of god, he shall owe a fine of forty marks' (cited in Szabo 2008: 187). While the exact species is not immediately evident in this text it indicates that the nature of human-cetacean interactions was guided by ecological observations and whales may have been specifically avoided while fishing for herring. This is later reiterated in the 13th-century document the *King's Mirror* (Konungsskuggsjä) which provides a more detailed description of the species in question, including an approximation of its length (around 30 ells). The description given in the latter text has led Lindquist (1994: 994-995) to suggest that the species in question was a fin whale though other species of balaenopterid are also possible including minke whale and humpback. Although created in Norwegian and Icelandic the texts broadly indicate that there was a belief that some species of whale drove the herring inshore, towards the fishermen and to hunt this whale could lead to the loss of the shoal. While Lindquist (1994) identified the species mentioned in the King's Mirror as a fin whale, herring form part of the diet of many species of cetaceans, including other balaenopterids and the documents appear to protect species which accompany herring shoals (HWDT 2018; Nordgaard 1903). It is possible that active procurement of all such species were avoided while fishing for herring. While many species could have played the role of the fish driver, historical texts apply the term only to large species. Delphinoids are not considered fish drivers and later texts (reviewed in Chapter 3) demonstrate that smaller

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[21] The terminology here implies shooting rather than harpooning and is therefore indicative of the wound drift and strand method (drift whaling) (Lindquist 1994)

species were caught alongside herring (Baldwin 2008: 7, 114; Cowan 2000; Harvie-Brown and Buckley 1888; Monro 1549).

The following discussions considers the potential methods of procurement of the different species taking account the potential interactions and restrictions. Historical evidence is more abundant for the Norse period, and this evidence is discussed along with that from the zooarchaeological data, and utility and use.

6.2 DISCUSSION

6.2.1 LARGE OFFSHORE TAXA

Blue whale, fin whale, sperm whale and beaked whales all identified at Bornais. These offshore taxa were probably primarily encountered as stranded individuals along the west coast, and Norse texts provide extensive evidence of the use of stranded whales (e.g. Szabo 2008) suggesting the likelihood that most were procured in this manner (Evans and Ingrem 2021: 327). This is discussed further in Section 6.2.4.

Although these taxa are chiefly found in offshore areas they may have been encountered by Norse inhabitants of Bornais when occasional individuals strayed into nearshore environment (in the case of fin whales, potentially in association with herring shoals (Clark et al. 2010: 61; HWDT n.d. a)) or when the Norse community made seaward voyages. These interactions are likely to have occurred less frequently than interactions with inshore species, however, encounters with live individuals of these species would provide occasional opportunities for active procurement. This possibility is explored further below.

Utility and procurement

The previous chapter established that large species were used for their artefactual, oil and fuel utility. Middle and Late Norse deposits in particular contained the greatest evidence for artefact production using cetacean bone. However, although the use of cetacean bone was extensive there is generally little indication that it was species-specific; the bones of different species (with different habitats) were used for the same types of artefact, such as combs, dice, chopping blocks and perforated discs. Special focus on sperm whale is, however, apparent during the Middle and Late Norse periods. This species was used most frequently in artefact production, and its bones were also used as structured deposits at the time the Middle Norse house (2) was abandoned, and the later Norse house (house 3) was constructed (Evans 2021b: 228). Despite the apparent focus on this species it does not prove active procurement, and in the Late Norse period worked sperm whale ivory occurs alongside a worked killer whale tooth in an area of the site associated with artefact production, while the teeth of beaked whales and Delphinoids are also present on the site suggesting the collection of a range of cetacean ivory which argues against access to a regular supply from any one species.

Absence of a regular supply may suggest that systematic hunting of these species was not practised; an assertion which is supported by their offshore habitats. However, it does not rule out opportunistic hunting of individuals which occurred inshore.

Historical evidence and comparative sites

Expanding on the information above, we can draw on detailed accounts of different species characteristic and exploitation from other contemporary Norse-settled areas to assess usage of the same species. Sperm whales and balaenopterids are discussed in contemporary texts.

There are specific references which indicate active hunting of the sperm whale within the historical documents (Kitchell and Resnick 2018: 1668-9). *De Animalibus*, written in the 13th century by Albertus Magnus, describes a cetacean which can be identified as a sperm whale. The text indicates that many of this species were captured, with specific references to individuals caught in the southern North Sea (Kitchell and Resnick 2018: 1668-9). While the typical habitat for sperm whales is offshore waters, the southern North Sea is a recognised hotspot for sperm whale strandings (IJsseldijk et al. 2018: 2; Smeenk 1997) and medieval communities surrounding the southern North Sea may have taken advantage of the sporadic presence of the large cetaceans and killed them. Recent studies have found evidence of sperm whale utilisation in this area from the period spanning AD 400 – 1600, though this has been interpreted as remains of stranded individuals by the author (van den Hurk 2020: 12). However, opportunistic procurement of sperm whales in nearshore waters around the Hebrides could have occurred in the manner indicated by historic texts, and sperm whales have been identified at both Bornais and Cille Pheadair (Mulville 2002; Mulville and Powell 2018; Paterson 2018). These species are not typically associated with herring, and therefore are unlikely to have been viewed as the valuable 'Fish Drivers' recorded by Norse texts. It is of interest therefore that the bones of this species occur most frequently within the Norse deposits at Bornais, a pattern which could reflect a deliberate focus on species not associated with herring, and which may therefore have had fewer restrictions around hunting. The right whale has the second highest NISP in Norse deposits, and also has no known association with herring. This species is discussed further below (Section 6.2.2).

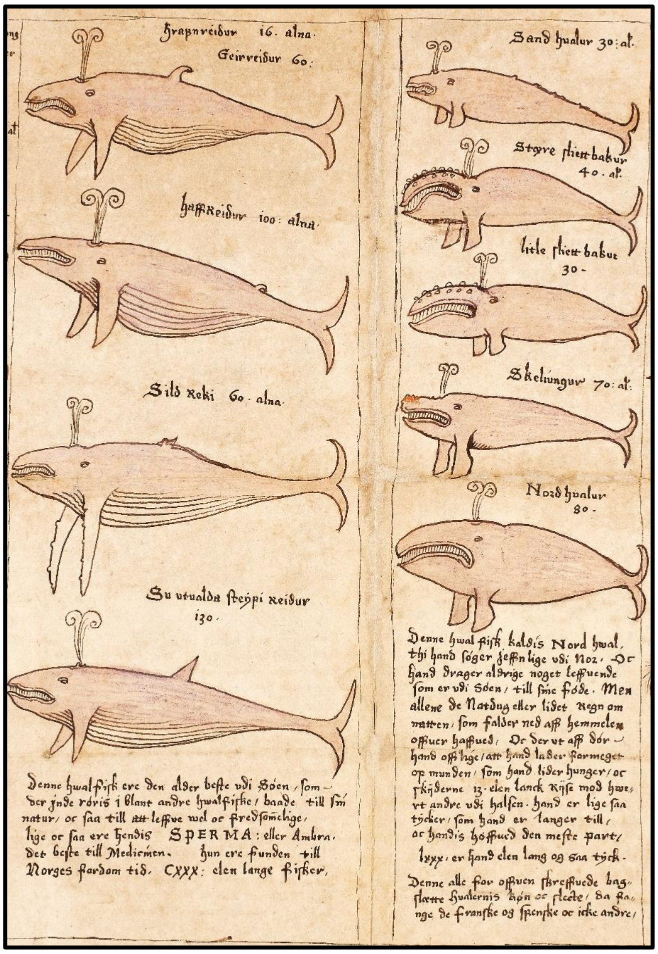

Figure 79 Cetacean species depicted in Jón Laerði Guðmundssyni's text, the Natural History of Iceland Source: https://nmsi.is/frettir/jon-laerdi-og-natturur-natturunnar/

The reyðr, a cetacean which features in a variety of Norse texts, has been interpreted as a rorqual (Szabo 2008: 183) and Lindquist (1993, 1994) suggests that the term is solely used for balaenopterids[22]. The reyðr appears in the King's Mirror in the description of '*The Marvels of the Icelandic Sea*' and was reportedly 'often caught by hunters because of its gentleness and quietness, and it is better to eat and smells better than any other of those fishes that we have now talked about, and that although it is regarded as well fat; it has no teeth either' (Lindquist 1994: 996-997; Szabo 2008: 183) indicating that species within the genus balaenoptera were hunted by the Norse Icelanders. Given that these species can sink once dead, and are very large and fast, Lindquist (1994) asserts that the method of procurement is likely to have been by wounding, drifting, stranding and recovery (here termed 'drift whaling') (Lindquist 1993: 28). In Iceland these species occur closer inshore

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[22] The term 'reiður' is clearly applied solely to balaenopterids in 17th-century illustrations by Jón Laerði Guðmundssyni (Figure 79), and today the 'reyðr' element is incorporated into the Icelandic names for the blue whale (Steypireyðr), fin whale (Langreyðr) and sei whale (Sandreyðr) only, supporting the application of the term reyðr to the genus Balaenoptera.

(Reid et al. 2003: 20) and such methods of procurement are therefore more likely to have been attempted successfully in Icelandic waters (though loss rates were still high (Lindquist 1997: 44)). Individuals straying inshore near the Hebrides could too have been opportunistically procured in this way and remains of balaenopterids are present at Cille Pheadair (Mulville 2002; Mulville and Powell 2018; Paterson 2018) as well as Bornais, however, such occurrences are rare and where such individuals were following herring shoals historical sources indicate that active procurement may have been avoided and suggesting that exploitation of stranded individuals may be more likely.

Ultimately it is not possible to distinguish opportunistic hunting of lone cetaceans from the exploitation of stranded ones using the zooarchaeological data. However, the evidence from Bornais does suggest that regular and systematic hunting of the large offshore species is unlikely, and at least some of the whales were probably procured through strandings, discussed further in Section 6.2.4, though there may have been opportunistic hunting of those species not thought of as 'fish drivers' when they occurred inshore.

6.2.2 LARGE INSHORE TAXA

As in the earlier periods, large inshore taxa are likely to have been encountered while the Norse were engaging in fishing activities. Interactions with species found in association with herring may have been particularly common, though as we have seen this may not necessarily have led to active procurement. Interactions may have been most common to the east of the Hebrides, and the seascapes around this side of South Uist provide opportunities for a range of procurement styles, including trapping, driving and drift whaling. Species and seascape therefore both allow for the active procurement of the right, gray and humpback whales. The following section reviews uses of cetacean bone at Bornais for further insights into procurement.

Utility and procurement

Unfortunately use of the bone of the large inshore species at Bornais does not provide any further insights into the potential for active procurement. Bones of all large species from both offshore and inshore environments are found primarily as unworked or worked fragments, or artefacts (Table 20), with little distinction apparent between the species from different environments, excepting the apparent preference for sperm whale bone discussed above.

However, the flesh of these species is represented at Bornais by a single humpback whale barnacle (Law 2021). This find, while small, provides the only indication of an otherwise invisible resource. This single barnacle indicates that the flesh of large inshore species was brought back to the site, and may either indicate the consumption of cetacean meat or the use of blubber. If used for consumption this would imply the need for a fresher specimen, which could point to active procurement, however, it is equally likely that the flesh could have been used for other purposes and thus use of a stranded individual is also possible.

Historical evidence and comparative sites

As discussed above and in Chapter 3, there are numerous historical texts indicating the active procurement of large inshore species and in particular the right whale from the Late Iron Age and Norse period. Further Norse texts including Ohthere's 9th century account, have also been suggested to represent exploitation of right whales in northern Norway (Clark 1947; Sjøvold 1974; Szabo 2008) though other species have also been proposed (Lindquist 1994; Valtonen 1988). The 11th century account of Spanish geographer al-Udhrī further demonstrates exploitation of a large cetacean off the coast of Ireland, which probably represents the right whale (Lindquist 1994: 930; Szabo 2008: 192), and the description indicates that mother and calf pairs may have been targeted on winter migrations (Lindquist 1994: 930). The capture of right whales is also indicated by the *De Animalibus* (Kitchell and Resnick 2018: 1667-1668). However, other Norse texts demonstrate different attitudes to balaenids and humpback whales and the *Kings Mirror* indicates both were feared for their propensity to wreck vessels (Szabo 2008: 186).

The evidence is therefore not straightforward. However, many sources indicate that active procurement of large inshore species is a possibility, though some may have chosen not to take up this activity due to the dangers (Szabo 2008: 186), a point specifically made in Ælfric's Colloquy (Harris 2003: 120-121). Right whales are not known to eat herring and are therefore not likely to have been considered a fish driver, adding further support to the potential for active procurement of this species. Other species, including the humpback and minke whale are known to prey on herring and may have been seen as fish drivers and avoided at certain times. The gray whale likewise feeds on herring spawn.

Interestingly, in contrast to Bornais none of the larger slow swimming coastal taxa (including balaenids, gray whale and humpback whale) were identified at Cille Pheadair, though minke whale was identified (Mulville and Powell 2018; Paterson 2018). However, it is possible that this apparent absence could relate to identification problems (no biomolecular methods have been applied to the Cille Pheadair assemblage yet), and examples of these species have been identified in Norse deposits from the Northern Isles and medieval sites elsewhere in Europe. Gray whale, for example, was identified at Jarlshof (Kitchener et al. 2021) and both gray whale and right whale has been identified from numerous sites bordering the Southern North Sea interpreted as possible evidence of whaling (van den Hurk 2020: 11-13).

Ultimately, as for large offshore species, it is not possible to prove whether active procurement of large inshore species took place in the Norse period at Bornais (Evans and Ingrem 2021: 327). The similarity of uses of both inshore and offshore species may suggest a similar mode of procurement (likely strandings in many cases) however, the species present, historical documents and presence of flesh on the site are all indicators that whaling is a possibility.

6.2.3 DELPHINOIDS

Remains of Delphinoids were present throughout the Norse periods (NISP 44). Killer whale and harbour porpoise are likely to have been encountered while the Norse were engaging in nearshore fishing activities, as may other the species which are reflected by generic identifications. Interactions with the harbour porpoise, which is known to feed on herring, were probably particularly common though it is possible that all species were actively procured. However, regular exploitation of Delphinoids is unlikely given the relatively low numbers of bones. The potential for active procurement is considered further below in light of utility and historical sources.

Utility and procurement

Delphinoid bones were identified throughout the Norse phases at Bornais. Meat utility is evident particularly within the Early Norse period and the pattern is thought to represent initial consumption of meat from smaller cetaceans during the years after the Norse settlement was established, with a shift away from this dietary resource in the Late Norse period as the herring fishery was well established (Sharples et al. 2016; see Chapter 3). As discussed earlier, meat utility can indicate the presence of fresh specimens more likely procured actively, and it is therefore likely that the Delphinoids from the early phases were caught by the inhabitants of Bornais in order to supplement the diet.

A shift in delphinoid use is apparent in the Late Norse period, and these species may have been valued more for their artefactual or oil utility than the meat they provided. These uses would not require fresh specimens and the remains include the killer whale bones. This suggests that hunting for this species need not have occurred. The historical evidence for delphinoid procurement is examined below.

Historical evidence

As discussed earlier historical accounts from the 8th century AD onward include references to exploitation of dolphins or porpoises (Szabo 2008; van den Hurk 2020), and active procurement around the UK coast is attested within the accounts of Bede (AD 731), the Annal's of Ulster (AD 828) and Ælfric's Colloquy (AD 1000), all of which are roughly contemporary with the Norse remains at Bornais. The Annals of Ulster refers to a great slaughter of porpoises by foreigners off the coast of Ireland, interpreted as a potential drive fishery for this species by the Norse (Colgrave et al. 1969; Raye 2016: 344; Szabo 2008: 109-110), while Ælfric's Colloquy suggests that fishermen caught porpoises or dolphins[23] alongside fish including herring and a range of other species. Herring are specifically mentioned providing a clear connection between exploitation of herring and Delphinoids (Harris 2003: 120- 121; Szabo 2008: 56-7), and Harvie-Brown and Buckley (1888: 38) writing in the 19th century indicated that harbour porpoise were occasionally caught in herring nets in the Hebrides (see Chapter 3). There are no indications that Delphinoids were considered to be 'fish drivers', and this term is solely applied to larger species. It is possible therefore that Delphinoids were caught alongside herring in the Norse period as in later periods. This is certainly likely for the harbour porpoise, which feeds on herring, and many of the other Delphinoids found on the site.

Norse texts indicate that killer whales may have been considered differently and there are no indications that they were actively hunted. Instead, descriptions of this species focus on its unique characteristics, and most (including *Kings Mirror* and Olaus Magnus' account) make specific mention of the teeth (Szabo 2008: 184-5, 201), discussed for their utility in the previous chapter.

Overall, it is likely that Delphinoid remains from the earlier Norse periods represent individuals which were actively caught, however, given the low numbers it is likely that catches were opportunistic or accidental, potentially occurring alongside the herring fishery. In the Late Norse period meat may not have been the primary driver for procurement and other uses came to the fore. This, coupled with the presence of species for which historical

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[23] The text notes that 'Herring and salmon, porpoises (note, the term 'sea-swine' is used and may refer to dolphins or porpoises) and sturgeon, oysters and crabs, mussels, winkles, cockles, plaice and flounder and lobster and many similar things' were caught (Harris 2003: 120- 121; Szabo 2008: 56-7).

sources do not indicate active procurement (i.e. the killer whale), suggests that exploitation of stranded individuals may be more likely in these cases.

6.2.4 DRIFT AND STRANDED WHALES: SEASCAPES AND STATUS

This section considers access and rights to cetaceans on the shoreline by the inhabitants of Bornais, using historical sources to examine archaeological evidence for cetacean acquisition on the Norse Hebridean coast.

The archaeological and historical evidence for methods of procurement reviewed above paints a complex picture which suggests that cetacean procurement by the Norse was likely highly opportunistic in nature and undertaken according to specific needs at certain times, and as has been shown, differentiating between opportunistic hunting and use of stranded cetaceans in archaeological contexts is difficult. However, it is not whaling which forms the focus for most Norse texts, instead exploitation of cetaceans found on the shoreline dominate legal codes and sagas alike (e.g. Szabo 2008). The focus on shoreline recovery is due to the importance of stranded whales but also because Norse hunting techniques did not generally include methods for landing whales, but instead relied on ocean currents and drive whaling to bring cetaceans to the shore (see Section 3 of this chapter; e.g. Szabo 2008: 250-252). Once cetaceans reached the shoreline they were subject to complex legal codes in the North Atlantic. Access to such cetaceans and ability to exert rights over them is the clear focus of Norse whaling literature (Szabo 2008), which shows that ability to obtain a whale was guided simultaneously by the seascape and presence of stranded cetaceans, and by the status of those who sought to exploit them. This access and ability to recover cetaceans is reviewed at Bornais. The seascape will be considered first, followed by social aspects of cetacean acquisition.

As discussed in Section 3 of this chapter, the west coast of Scotland has a high density of cetacean strandings (Coombs et al. 2019). South Uist in particular has a high proportion, and of 92 strandings recorded in the Hebrides for the period between 1913 – 2015, around one third of these were from the coast of South Uist, and specifically the west coast (NHM 2018). Bornais lies midway along this 20-mile-long stretch of coast, giving the Norse inhabitants of the site the ability to perceive and access a wide range of cetaceans (and other stranded materials), which may have been there by virtue of natural strandings or owing to other Norse methods of procurement. Evidence from the wider Norse world suggests that this access was not a chance occurrence, and proximity to good stranding locations was a factor in settlement locations (e.g. Szabo 2008: 232). The *Landnámabók* (concerning the Norse settlement of Iceland) specifically depicts one of the settlers (Thorolf) throwing pillars overboard so that they 'might come to land where the God (Thor) wished him to settle' (Ellwood 1898: 49) which apparently demonstrates a practical approach to ensuring settlement in an area where stranded material washes ashore.

Accessing and perceiving cetaceans on the shore was the first step in the process, ability to exert rights to the carcass was also an important part of acquisition in the Norse period. Norse texts indicate that access to cetacean remains was to some extent dictated by status (e.g. Szabo 2008; van den Hurk 2020). The relevance of Scandinavian legal codes to the Hebrides was discussed in Chapter 3, which demonstrated that the Norse Gulathing Law and later codes probably influenced elements of Scottish Law regarding cetaceans. This is of relevance for the current discussion as the Gulathing Law, and later Scots Law, contain stipulations which indicate that status influenced access to cetaceans, a theme also seen in other European laws (e.g. Gardiner 1997; van den Hurk 2020). These laws stipulate that higher status individuals had access to large species while those of lower status could only claim smaller species (Lindquist 1994: 606).

Bornais (mound 2) was the residence of a high-status family (Sharples 2021: 456) and may therefore have been able to exert rights over any cetaceans found on the shoreline. This is borne out within the zooarchaeological evidence which demonstrates that the site's inhabitants clearly had access to a range of large and small cetaceans, including the largest of all species: the blue whale (Table 38).

The distribution of cetacean species according to status can also be investigated on other sites. Cille Pheadair has been interpreted as the residence of an independent, middle status family and therefore provides a good opportunity to assess potential differences in the cetacean record according to status (Parker Pearson et al. 2018; Sharples 2020, 2021). While ZooMS analysis has not taken place on the Cille Pheadair material, the cetacean bone has been assessed morphologically and identifications above Order level were achieved in some cases (Mulville and Powell 2018; Paterson 2018; see Appendix 2 for a summary). The chronologies of the sites have been correlated by Sharples (2021: 449), and have been used in the comparative Table 38. Information up to the Middle Norse period is included as Cille Pheadair has no later phases.

Comparison of the data from Cille Pheadair demonstrated few differences overall, though a lower number of identifications were achieved at the latter site. The largest species were also identified on that site, and blue whale, sperm whale, beaked whale and killer whale were found on both sites (Mulville and Powell 2018; Paterson 2018). This could suggest either that status was not a factor in cetacean bone distribution during the Norse period on the Hebrides, or that the inhabitants of Cille Pheadair were sufficiently important to claim rights to even the largest whales. The latter is most likely as assessment of other remains from the site demonstrated that Cille Pheadair's inhabitants were socially empowered and well connected with access to wide ranging trade networks, similar to Bornais' inhabitants (Sharples 2021: 455-456). Assessment of material from a lower status site would enable further discussion of social aspects of access to cetaceans during the Norse period[24].

	Identifications	Bornais	Bornais	Cille Pheadair	Bornais	Cille Pheadair
		Late Iron Age	Early Norse	Phase 1-2	Middle Norse	Phase 3-7
Large	Large cetacean	▨	▨	░		░
	B. musculus		▨		▨	░
	B. physalus	▨			▨	
	B. acutorostrata					░
	Balaenopterinae					
	M. novaeangliae		▨			
	Balaenopteridae		▨	░	▨	░
	Balaenidae	▨	▨		▨	
	E. robustus	▨	▨		▨	
	Mysticeti	▨	▨		▨	
	Odontoceti	▨	▨		▨	
	P. macrocephalus	▨	▨		▨	░
	Large to Medium cetacean		▨			
	Medium cetacean					
	Ziphiidae	▨			▨	░
	O. orca				▨	░
	G. melas					░
	Delphininae				▨	
	Small Delphininae		▨			
	Delphinidae		▨		▨	
	P. phocoena		▨			
	Small delphinoid	▨				
	Delphinoidea		▨		▨	
Small	Small cetacean		▨		▨	░

Table 38 Comparison of the cetacean taxa identified at Bornais and Cille Pheadair (identifications after Mulville and Powell 2018; Paterson 2018)

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[24] ScARF also identify investigation of low status Late Norse sites as a priority (Hall and Price 2012: 20).

6.3 SUMMARY

The evidence for the nature of cetacean procurement in the Norse period is highly complex, and many different procurement strategies were applied at different times, in different areas and for different species. On South Uist, interactions with the herring fishery are likely, and the clearest connection may be seen in the exploitation of Delphinoids at Bornais which were probably actively procured during the Early Norse period as a dietary supplement, but by the Late Norse period, when the herring fishery was well established, active procurement of Delphinoids for meat may have been less important.

It is also possible that some of the larger species were hunted opportunistically, though most probably represent stranded individuals (Evans and Ingrem 2021: 327). It may be significant that those species represented by the highest quantities of bone are also those which are not known to associate with herring. These species are not likely to have been considered fish drivers, which would be of use in the herring fishery, and may therefore have been focused on for exploitation. However, the high NISP may relate to the degree of fragmentation rather than a focus on these species, and ultimately the MNI for each cetacean species identified is one. Though this is a pattern which would warrant further study as data from other Norse sites emerges.

While opportunistic hunting is a possibility, systematic and large-scale active procurement is unlikely. For larger species, given the focus on stranded whales within Norse texts it is likely that many of the cetaceans present on site represent the remains of stranded individuals and hunting methods may have also led to the presence of drifting whale carcasses. In this light the central location of Bornais along South Uist's west coast, an area with a rich strandings record, is of interest; this location would have provided access to a wide range of cetacean species, animals which Bornais' inhabitants clearly had the ability to exploit - a factor which may relate to their high status. This material would benefit from comparisons with other Norse assemblages and ongoing work associated with the NSF-funded project, *Assessing the Distribution and Variability of Marine Mammals through Archaeology, Ancient DNA, and History in the North Atlantic* is likely to provide important comparative well-studied material which is currently lacking.

7 CONCLUSION

Taxonomic identification is a vital step in the interpretation of procurement strategies. This chapter has demonstrated that interpretation of taxonomic data in light of contemporary use of the local seascape: determining interactions and interpreting the nature of these interactions with reference to the zooarchaeological evidence for cetacean utility, and drawing on other evidence from contemporary sites, historical and ethnographic sources, a picture of the likely methods of procurement can be developed.

However, the evidence for the nature of cetacean procurement at Cladh Hallan and Bornais proved to be complex. Ultimately as other studies have found (e.g. van den Hurk et al. 2021) it has not yet been possible to securely differentiate between exploitation of stranded individuals and active procurement in many cases. Quantification remains an issue and identification of the number of individual cetaceans of each species would aid understanding of likely modes of procurement. However, the identification of taxa undertaken as part of the current work has enabled recognition of times when active procurement is a possibility and exploitation of stranded cetaceans a probability. All species were probably procured through strandings in the Bronze Age. Active procurement may have been taking place for large inshore species during the Late Iron Age, and although extensive use of stranded individuals in the Norse period is likely, some could have been caught opportunistically on occasion (though differentiating between use of stranded whales and those opportunistically caught based on archaeological datasets remains a problem). Previously it was difficult to pose specific research questions as cetacean bone assemblages were not sufficiently well characterised. The analysis undertaken here allows for questions to be posed and directed toward certain elements of the assemblages which warrant further investigation. They also provide comparative material for the investigation of assemblages from other sites.

The examination of procurement also raised some bigger questions. Procurement may seem a key question to us today, and whaling is a divisive issue and with deep political and cultural divides between those who hunt whales and those who do not. However, both the zooarchaeological evidence and historical documents suggest that the divide may not have been so important within the past (e.g. Lindquist 1994; Szabo 2008). Cladh Hallan's inhabitants clearly treated stranded whales in a manner which indicated their significance; and Norse texts demonstrate focus on both hunted and stranded individuals, both provided opportunities to obtain key resources and both provided a stage for social relations to play out (e.g. Szabo 2008: 236). We must also remember that use of stranded whales was not necessarily passive, indeed there is specific historical evidence from the Norse period which shows that stranding spots were actively chosen as good settlement locations, and wider ethnographic evidence provides insights into other complex and non-physical methods which may have been employed to influence the strandings process (Lowenstein 1993; Whittle 2000). So, perhaps the focus should not be who went whaling and who did not, but rather how were whales valued in the past and what was the nature of human-cetacean relationships? The previous chapter considered some evidence for this at Cladh Hallan and Bornais, but we can only hope to address these questions in more detail with further analysis of zooarchaeological assemblages.

Chapter 9: Conclusion

1 INTRODUCTION

This chapter concludes the research set out within this thesis and outlines the contributions made to original knowledge in the areas of cetacean zooarchaeology and cetacean use and procurement in the Outer Hebrides. Directions for future research are also set out.

1.1 OVERVIEW OF CONTRIBUTION TO ORIGINAL KNOWLEDGE AND RESEARCH AIMS

The primary contributions to original knowledge set out within this thesis are focused on two key areas. These include methodological developments relating to the taxonomic identification of cetacean bone and the investigation of human-cetacean relationships through detailed analysis of cetacean bone use, deposition and procurement in the Outer Hebrides using methods developed within this thesis and existing methods. Contributions in these areas were the primary aims of this research.

The methodological development was principally concerned with taxonomic identification of cetacean vertebrae using morphometrics. This research has provided a method for identification, and comparative datasets which may be used by others to further research in cetacean zooarchaeology. The research also demonstrated how this method and data can be combined with existing biomolecular identification methods (ZooMS) to achieve greater precision in identifications. It has therefore taken steps toward addressing one of the major problems facing zooarchaeologists studying cetacean bone assemblages: that of taxonomic identification.

The second key area in which this thesis has contributed to original knowledge has been through the detailed analysis and taxonomic identification of two large cetacean bone assemblages deposited over a period of four thousand years. This analysis has included investigation of just under three thousand bone fragments and has achieved taxonomic identifications to above Order level on 25% of this material. These results have enabled detailed investigation of cetacean use, deposition and procurement and insights into human-cetacean relationships. They have also opened up many new questions and provide a framework for future investigation. In addition, the assemblages from Cladh Hallan and Bornais can now provide comparative datasets against which the results of other investigations can now be compared.

The conclusions of these two key areas are set out in further detail below, along with detailed outcomes in relation to the research objectives which were established in Chapter 2.

1.2 METHODOLOGICAL DEVELOPMENT AND APPLICATION

1.2.1 OBJECTIVE 1: CREATE A METHODOLOGY AND TOOLKIT FOR THE MORPHOMETRIC IDENTIFICATION OF CETACEAN BONE

The first objective was to develop a method and toolkit for morphometric identification of cetacean bone. This study focused specifically on cetacean vertebrae and the results of this work are principally set out Chapter 5 (supported by material within Appendices 3, 6 and 7). Through study of functional morphology and evolutionary biology (e.g. Buchholtz 2005; Buchholtz and Schur 2004; Slijper 1936, 1962) the research undertaken established osteological traits which can reliably be used for taxonomic identification of cetacean vertebrae from archaeological contexts. The data set out within this chapter also demonstrated that the vertebrae of the thirty-one cetacean species which inhabit the north-eastern Atlantic can be reliably identified using morphometric data for these osteological traits. Species-level identifications using this method and data have been shown to be possible for most of the thirty-one species included within this study, which range from the largest baleen whales to the smallest toothed whales.

1.2.2 OBJECTIVE 2: INVESTIGATE CETACEAN REMAINS ON MULTIPERIOD SITES TO TEST THE METHOD DEVELOPED UNDER OBJECTIVE 1, AND TO USE PROTEOMICS, TO IDENTIFY CETACEAN REMAINS FROM THESE SITES

The method was applied to the material from Cladh Hallan and Bornais and identifications were achieved with reference to the morphometric data. ZooMS was also applied to the assemblages following a sampling strategy which was designed to achieve the archaeological aims of the work. Further precision in identifications was also gained by use of the combined approach to identification which relied on the synergy between the two methods to achieve more precise identifications for many of the cetacean bone pieces from Cladh Hallan and Bornais.

The methods and data proved successful when applied to the archaeological material from Cladh Hallan and Bornais (Appendix 6) and resulted in direct identifications for a quarter of the assemblages. However, species-level identifications were not possible in all cases owing to several factors including breakage and loss of identifiable traits and limitations of the morphometric method when considering juveniles of certain species of small dolphin which occurred regularly within the archaeological assemblages. There are also a number of areas in which further work could hone the morphometric method, which are set out below.

1.2.3 FUTURE WORK

While the data presented covers one third of all species known worldwide, the method and toolkit could be further improved by inclusion of additional species and expanded to cover all elements within the cetacean skeleton. Statistical analysis would improve conclusions about cetacean identification, and in particular use of Linear Discriminant Analysis and Principal Component Analysis would demonstrate in a quantitative manner which taxa can be reliably differentiated. Use of population standard deviations would also be desirable to derive standard deviations for the range of dimensions for each vertebra which would be representative of the population for each species.

1.3 HUMAN-CETACEAN RELATIONSHIPS: CETACEAN BONE USE, DEPOSITION AND PROCUREMENT FROM PREHISTORY TO THE NORSE PERIOD

1.3.1 OBJECTIVE 3: DRAW TOGETHER THE RESULTS OF TAXONOMIC IDENTIFICATION WITH OTHER EVIDENCE FROM THE ASSEMBLAGES INCLUDING ELEMENTS, QUANTITIES AND BONE MODIFICATIONS TO ASSESS EVIDENCE FOR THE UTILITY OF CETACEAN REMAINS THROUGH SPACE AND TIME

This research has revealed complex patterns of cetacean use and deposition at Cladh Hallan and Bornais. At least ten different species were regularly exploited in the Hebrides, ranging from the largest animals on the planet: the blue whale, to the smallest cetaceans alive today: the porpoise.

Use and deposition were key areas of study and at both sites there is evidence that cetaceans were used for wide variety of resources, including flesh, bone and oil. There is also complex evidence for value which goes beyond functional utility. The distribution of cetacean resources may have played varied social roles on both sites, and the particular ways in which species were used reflect the complexity of human-animal-landscape interactions in the Hebridean past. While use is generally not species-specific there are broad differences in the ways large species and Delphinoids were used. Sperm whale is important on both sites. Not only does this species dominate both cetacean bone assemblages, it also appears to have held special significance. At Cladh Hallan this is borne out by a number of structured deposits which place emphasis on the head of this animal and may have drawn on the power of this unique species, a factor which is supported by the incorporation of another iconic species within structured deposits: the killer whale. At Bornais human-cetacean relationships followed wider trends and demonstrate localised responses to the west coast

Hebridean environment following the period of Norse settlement, and may in particular have drawn on the special meanings of the sperm whale in Norse society.

1.3.2 OBJECTIVE 4: INVESTIGATE CETACEAN PROCUREMENT STRATEGIES DRAWING ON SPECIES IDENTIFIED AND THEIR HABITATS, AND WIDER EVIDENCE FOR USE OF CONTEMPORARY SEASCAPES.

Procurement patterns were another key area of study, and evidence again proved to be complex. While determining the nature of procurement remains a problem general trends can be discerned when viewed in the light of wider contemporary evidence for marine exploitation and maritime activity and drawing on evidence from the uses of different species, and supporting evidence from historical, ethnographic and archaeological sources. Exploitation of stranded cetaceans most likely occurred at Cladh Hallan, though this exploitation need not represent a passive relationship. From the Late Iron Age onwards there are tantalising hints that large inshore species, such as the right, gray and humpback whales, may have been hunted at Bornais and contemporary sites, although use of stranded whales continued. In the Norse period there is further evidence for use of stranded whales, although opportunistic hunting of large species may have occurred, and for delphinoids this is particularly likely. A relationship with the herring fishery is also apparent, and historical sources provide evidence of the social complexities of cetacean acquisition which are borne out by the remains from Bornais.

1.3.3 OBJECTIVE 5: DRAW TOGETHER THE EVIDENCE TO INTERPRET THE NATURE OF HUMAN-CETACEAN RELATIONSHIPS ON THE OUTER HEBRIDES FROM THE BRONZE AGE TO THE NORSE PERIODS

Discussion of different facets of human-cetacean relationships have been woven throughout this thesis, evident in the way cetaceans were used, deposited and procured. Overall, the evidence demonstrates that human-cetacean relationships were extremely complex throughout the period of study. The inhabitants of Cladh Hallan and Bornais interacted with and exploited multiple species in a variety of ways which indicate familiarity with the physical properties of cetacean bone and in some cases suggest complex ecological knowledge. The evidence also suggests that cetaceans were entwined within the social lives of the islanders, and their remains represent, formed and expressed social relationships at different points in time. While many species were used and exploited, the sperm whale in particular held a special place in the Hebridean past and the relationship with this particular species may have been the focal point of human-cetacean relationships in the Bronze Age and Norse periods.

1.3.4 FUTURE WORK

While the conclusions above can be drawn from the research presented within this thesis, a series of areas highlighted by the current work would benefit from further investigation. These include:

- The social utility of cetacean remains and human-cetacean relationships in the Bronze Age. Sharing of cetacean resources in the Bronze Age and Early Iron Age is possible at Cladh Hallan and using aDNA it may be possible to investigate the number of individual cetaceans represented between the houses to further investigate these patterns (e.g. Evans et al. 2016). Use of cetacean bone on other comparable Bronze Age sites could also be fruitfully investigated to further explore apparent human-animal-landscape connections identified by Jones (1998) and further investigated here.
- The potential for active procurement of large inshore species in the Late Iron Age, including balaenids, gray whales and humpback whales. While the current assemblage included Late, and not Middle Iron Age material, a review of evidence from other Middle Iron Age sites indicates that this too may warrant further investigation. In particular, sites of these with large cetacean bone assemblages located in potentially good whaling locales may represent an ideal starting point for investigation.
- Potentially complex patterns of cetacean use and procurement in the Norse period would also benefit from further investigation on other contemporary sites and with reference to the extensive historical literature for the period. Evidence from across the Norse North Atlantic has the potential to provide insights into varied human-cetacean relationships during this period, and sites of high and lower status could be further investigated to compare evidence for varied levels of access to cetacean resources.

Analysis has also revealed some problems which require further work. Quantification remains a key problem and the number of cetaceans represented by the assemblages may be well beyond what we can currently identify with MNI counts based on quantifications of fragmentary remains. Another well- acknowledged problem is the uncertain role of cetacean flesh in past societies. While some evidence for soft tissues has been found on the sites (e.g. Law 2021) this evidence likely represents the tip-of-the-iceberg of what were likely important resources in the past. However, study of bone assemblages is not well-suited to the recognition of such remains. These issues may mask the real extent of cetacean acquisition and use in the past, and to surmount them we must look beyond the traditional zooarchaeological techniques and draw on multi-proxy approaches to detect cetaceans. In particular ancient DNA analysis has the potential to shed important light on quantification issues (e.g. Arndt 2011: 94; Evans et al. 2016; UHI n.d), while residue analyses may provide a way in to the currently 'invisible' resources of soft tissues (e.g. Heron et al. 2013) and stable isotope analyses have the potential to illuminate dietary trends and have been used to distinguish marine mammal consumption (Coltrain et al. 2004, 2016). Landscape and seascape studies could also be used to target analysis on particular sites where different procurement strategies could be investigated. This evidence should be drawn together with reanalysis of existing cetacean bone assemblages to shed new light on human-cetacean relationships in the past.

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Appendix 1: Cetaceans and habitats

1 INTRODUCTION

This appendix provides information on the cetacean species included within this thesis. Latin and common names, and sizes of the species are established first, followed by discussion of habitats and other characteristics which support the discussion in the main text.

2 CETACEAN SPECIES: NAMES AND SIZES

As established in Chapter 3, thirty-one species are included within this study. The Latin and common names of these species are included in Table 39, along with their average and maximum sizes. The species are arranged according to size.

Latin name	Common name	Size av. (m)	Max. (m)
Large (11m to 30m)			
Balaenoptera musculus	Blue whale	25	29.8
Balaenoptera physalus	Fin whale	21	24
Balaena mysticetus	Bowhead whale	15	19.8
Balaenoptera borealis	Sei whale	15	19.5
Physeter macrocephalus	Sperm whale	15	18.3
Eubalaena glacialis	Right whale	15	18.3
Megaptera novaeangliae	Humpback whale	14.6	17
Eschrichtius robustus	Gray whale	12.2	15
Medium (c. 3.5m to 11m)			
Balaenoptera acutorostrata	Minke whale	8	10.7
Hyperoodon ampullatus	Northern bottlenose whale	7.3	9.8
Orcinus orca	Killer whale/ Orca	7	9
Ziphius cavirostris	Cuvier's beaked whale	6.4	7
Mesoplodon europaeus	Gervais's beaked whale	-	6.7
Globicephalus melas	Long-finned pilot whale	4.8	6.3
Pseudorca crassidens	False Killer whale	4.6	6.0
Mesoplodon bidens	Sowerby's beaked whale	5.0	5.5
Mesoplodon mirus	True's beaked whale	5.0	5.3
Mesoplodon densirostris	Blainville's beaked whale	4.8	-
Delphinapterus leucas	Beluga whale	3.9	4.9
Monodon monocerus	Narwhal	4.0	4.7
Mesoplodon grayi	Gray's beaked whale	3.6	4.2
Small (c. 1m to 4m)			

Grampus griseus	Risso's dolphin	3.0	3.83
Tursiops truncatus	Bottlenose dolphin	3.0	3.8
Kogia breviceps	Pygmy sperm whale	3.0	3.5
Lagenorhynchus albirostris	White-beaked dolphin	2.75	3.1
Lagenorhynchus acutus	Atlantic white-sided dolphin	2.4	2.82
Peponocephala electra	Melon-headed whale	2.2	2.75
Lagenodelphis hosei	Fraser's dolphin	2.1	2.7
Delphinus delphis	Short-beaked common dolphin	2.1	2.7
Stenella coeruleoalba	Striped dolphin	2.4	2.65
Phocoena phocoena	Harbour porpoise	1.4	1.89

Table 39 Latin and common names for cetacean species within the study and sizes

These species range from are full-time residents to those passing through during their migrations. The habitats and behaviours all influence the likely nature and location of human-cetacean interactions in the past. Areas that are regularly used for feeding, breeding, raising calves and socialising, as well as, sometimes, migrating are all counted as 'critical habitat' (Hoyt 2005 cited in Clark et al. 2010: 13). The presence of critical habitat can indicate high numbers of a certain species, or the presence of a species over longer durations of time within a certain area. The nature of the critical habitat for each species also provides information on the nature of past potential interactions. For example, cetaceans which prey on certain fish species may have been encountered by human communities fishing for the same species. Areas for calving and nursing indicate the presence of juvenile cetaceans, which can be more easily caught and have been targeted by some hunting groups. Thus, identification of critical habitat allows insights into behaviours may have influenced human-cetacean interactions within the area.

Contemporary data on critical habitat is available for some species but climatic and other environmental changes, in addition to the large-scale impacts of commercial whaling have altered cetacean populations within Scottish waters. Thus, while studies of habitat and behaviour provide an insight into the species familiar to past Hebridean communities familiar, this picture remains incomplete as the impacts of hunting and environmental shifts are not fully understood.

The following section describes cetacean species and their habitats in Hebridean and adjacent waters, beginning with those which are most common today and moving on to rarer species. Other factors known to affect cetacean procurement are also considered, and the discussion is grouped into larger and smaller species as procurement strategies are known to differ between these groups (e.g. Lindquist 1994, 1997). This information primarily supports the discussion of procurement in Chapter 8.

3 COMMON SPECIES

3.1 HARBOUR PORPOISE

Today the harbour porpoise is the most common species in UK waters and critical habitat of this species has been identified in the seas around the Hebrides (Clark et al. 2010: 23- 24). The species occur year-round in inshore waters (Boyd and Boyd 1996) but are seen in particularly high numbers during summer months, coinciding with their breeding and calving season (NatureScot 2020b). Large numbers of calves, along with mother and calf pairs, recorded in the Minches and Sea of Hebrides suggest that calving may focus in these areas (*Ibid*) including the area to the east of South Uist. Harbour porpoise feed on a range of different species, though in Hebridean waters their primary diet consists of herring, sprat, whiting and sandeel (NatureScot 2020b).

3.2 SHORT-BEAKED COMMON DOLPHIN

Common dolphins are frequent in both inshore and offshore waters, and are increasingly common around the Hebrides, particularly within the Minch, Little Minch and Sea of Hebrides and offshore around areas of high seabed relief which likely correlate with high prey abundance (HWDT 2018: 40; Pollock et al. 2000: 68). Warming temperatures may be encouraging an increase in population size in the area, and the species may have been less abundant during cooler periods. In Hebridean waters they form groups of around 30 animals although in the summer months large pods made up of hundreds of individuals are known. The species are most abundant from April to October, but some animals may be year-round residents (HWDT 2018: 40). Calves have been identified and the Hebridean seas may be used for breeding and raising young (Clark et al. 2010: 36). This species preys on a variety of fish including herring and mackerel, and squid (HWDT 2018: 40).

3.3 WHITE-BEAKED DOLPHIN

The waters around the Hebrides, and in particularly the northern part of the Minch, also frequently play host to pods of white-beaked dolphins which prefer inshore waters under 200m in depth in this region. Calves have often been recorded during summer months, and the species are thought to be year-round residents, though there are suggestions that warming sea temperatures may be leading to a decrease in their numbers (Clark et al. 2010: 46). High numbers occur within Hebridean inshore waters during the summer, coinciding with spawning seasons for one of their prey species: the herring. White beaked dolphins also prey on a variety of other fish including gadoids (e.g. cod) and hake (Pollock et al. 2000: 66-67).

3.4 White-sided dolphin

The white-sided dolphin is abundant in offshore areas, particularly in waters over 1000m deep. However, the species may also undertake seasonal migrations and have been recorded in waters under 200m deep and in inshore areas during summer months (Pollock et al. 2000: 66). Surveys have recorded high numbers of calves during the summer period, and their presence in shallower and inshore waters may therefore indicate that calving occurs within these areas (Evans 1992), although this is unconfirmed (Pollock et al. 2000: 66). As with other delphinid species white-sided dolphins eat a variety of species including herring, cod and squid (HWDT n.d, c.).

3.5 Bottlenose dolphin

Bottlenose dolphins exist in two forms: an inshore/coastal form and offshore form. These populations exhibit genetic, molecular, osteological and morphological differences (Hoelzel et al. 1998; LeDuc and Curry 1998). The offshore form is less well understood, however, stranded individuals of this type may occur along Scotland's coastlines (Thompson et al. 2011: 87). The coastal form is present year-round in Hebridean waters, with a peak in numbers between July and October (Clark et al. 2010: 31). The coastal form present within Hebridean waters are split into two communities: the Inner Hebridean community and the outer Hebridean or the Sound of Barra community, focused within the waterway separating South Uist from Barra but also found in the waters around both islands (Van Geel 2016). This species is commonly sighted close to the shore, in bays and off headlands (HWDT 2018: 41). Analysis of stomach contents from Scottish bottlenose dolphins indicated a diet dominated by gadids (cod, saithe, whiting) along with other species including sea scorpion, mackerel, salmon, haddock and cephalopods (Santos et al. 2001).

3.6 Risso's dolphin

Risso's dolphins are also common in the around the inshore waters of the Outer Hebrides. In this area they tend to be found in locations with deeper water, such as off the north-eastern coast of Lewis, and south-eastern tip of the Hebrides which may be home to their prey species including squid, octopus and cuttlefish (HWDT 2018). The north-eastern coast of Lewis has been identified as a particular focus for this species who may use the area for breeding and nursing young. A resident population is thought to inhabit this area, who appear to move from deeper offshore waters where they spend May to July, to inshore and coastal waters in August and September, possibly following their prey in this region (Clark et al. 2010: 47) though some animals are present year-round inshore and offshore (Ibid; Pollock et al. 2000). An MPA around the north-eastern coast of Lewis is in place to protect the Risso's dolphin population in this area, along with sand eels (Clark 2014).

3.7 PILOT WHALES

Pilot whales are primarily deep-water species and tend to be found off the edge of the continental shelf in deeper waters to the west of Scotland, around Rockall Bank and Hatton Rockall Basin (Clark et al. 2010: 54) which may be important feeding grounds. Although they are infrequent in inshore waters, where they do occur they have been the focus for drive fisheries, which exist today in the Faroe Islands and are known historically on Orkney, Shetland, areas of mainland Scotland and the Hebrides (Baldwin 2008: 75). Their presence inshore has been connected with the seasonal presence of pelagic fish such as herring and mackerel, and salmon, though their favoured prey are squid (Baldwin 2008: 85).

3.8 KILLER WHALE

Killer whales are common both inshore and offshore. The killer whales of the region have been identified as a distinct ecotype, dubbed the West Coast Community. This group of whales are residents in UK waters, and range from Pembrokeshire to the Outer Hebrides, though are mainly present in Scottish waters (Carwardine 2020: 277). Recent studies have found high levels of chemicals within individuals of this group which may be connected to a failure of the group to breed, and the group may be dying out. Prior to such changes it is possible that populations of killer whales were larger. The diet of the West Coast Community is not well understood but they are known to have taken seals and harbour porpoises and may therefore represent marine mammal specialists. While the West Coast Community is the most commonly sighted group other killer whales may pass through Hebridean waters and may feed on other species such as herring and mackerel (Carwardine 2020: 277).

3.9 MINKE WHALES

Minke whales are common near the coasts of the Hebrides both in the Minch and around the Inner Hebrides. They occur inshore seasonally are and focused particularly within the Sea of Hebrides which has been designated as a MPA for the species (and basking sharks) (NatureScot 2020a), though they also occur on the Atlantic side of the islands (HWDT 2018: 15). Minke whales are thought to be a migratory species, and although the details of their movements are not fully understood, surveys indicate that they likely move from overwintering grounds to the south of the UK to cooler northern waters in summer. They are generally present within Hebridean waters from April/May to October (HWDT 2018: 30; Pollock et al. 2000). Within this area their smaller-scale movements are also seasonal and thought to relate principally to the presence of prey species, in particular sandeel and herring (Clark et al. 2010: 42).

4 LESS COMMON SPECIES: LARGE CETACEANS

Historical and commercial whaling has reduced the numbers of many of the larger species of cetacean to a fraction of their former abundance, materially affecting our understanding of what the seas surrounding the Hebrides may have looked like in the past. A major obstacle to the improvement of this understanding is conflicts between pre-whaling abundance estimates derived from different datasets. Shifting baselines, whereby a false baseline (normally relatively recent, and much altered from its 'natural state') is perceived and used for management of species is a clear issue (Pauly 1995). The, establishment of reliable pre-whaling population baselines represents an important issue both for conservation management and interpretation of cetacean bone from zooarchaeological assemblages.

Analysis of historical catch records provide one source of data, though the estimates based on these data sets tend to be much lower than abundance estimates based on genetic data, which can be up to 20 times greater than current population estimates for some species (Roman and Palumbi 2003). Studies of historical and genetic data have refined estimates over recent years, and are moving closer together, though there are still major discrepancies (Alter and Palumbi 2009; Reugg et al*.* 2013; Roman and Palumbi 2003; Smith and Reeves 2010). North Atlantic humpback whale populations for example are estimated at 20,000 – 46,000 based on population modelling taking into account historical catch data (Punt et al. 2006; Smith and Pike 2009) and *c*. 112,000 based on refined genetic studies (Reugg et al*.* 2013). Many of the earlier historical studies place estimates much lower, at between 20-30,0000, while older genetic estimates reach up to c. 240,000 (Roman and Palumbi 2003), though the latter are thought to be inaccurate (Reugg et al*.* 2013: 111).

From the documentary perspective, discrepancies may arise from inaccuracies in catch data, failure to report whales which were killed but not landed, and the amount of whales taken prior to detailed record keeping; while the genetic data, which is based on the identification of genetic variation which increases with population size, can be affected by migrations, fluctuations in population size, generation length, mutation rate and selection (Reugg et al.

2013; Roman and Palumbi 2003: 508). The timescales also differ. Historical catch data allows for calculation of abundance during specific points in time, while genetic evidence provides an average population size over the course of the species' evolutionary past without accounting for potential fluctuations of abundance in response to changes to environments such as during ice ages (Reugg et al. 2013: 112). Revision of any of the variables affecting the studies can substantially alter estimates. For example, generation length for humpback whales used by Reugg et al. (2012) ranged from 12 to 24 years. If other estimates were used (e.g. 18-31 years as modelled by Taylor et al. 2007) this would reduce the average population estimates from this genetic study to 81,000, bringing it closer to the estimates from population modelling (Punt et al. 2006), though still not in line.

These examples of possible abundance estimates for humpback whales also apply to other large species targeted during commercial whaling. The evidence serves to demonstrate the paucity of our understanding of past ocean ecosystems, which presents an issue when attempting to interpret cetacean remains found on archaeological sites. To address this issue, for larger species in particular, a greater focus on behaviour and habitat is necessary, rather a focus on the numbers of these species in Hebridean waters. However, it is very likely that current numbers are generally lower than pre-whaling abundance.

4.1 HUMPBACK WHALES

Humpback whales pass through Scottish waters on their seasonal migrations between cool summer feeding grounds and warm breeding and calving areas. They have been recorded around the Hebrides, both within the waters of the Minch and Sea of Hebrides, and off the west Atlantic coast of the islands (HWDT 2018: 54), though most sightings occur in deeper waters beyond the 1000m depth contour (Clark et al. 2010: 62; Pollock et al. 2000). They may stop off in coastal waters to feed (Stone et al. 1987), and their diet is focused on krill and small fish such as herring and mackerel (HWDT 2018: 55). As discussed above former population levels are unknown, though some studies suggest that due to the low number of historical stranding records and catches in Scottish waters the numbers of this species may never have been high within this area (O'Neil et al. 2019).

4.2 BLUE, FIN AND SEI WHALES

Blue, fin and sei whales are all classified as endangered. In general these species all occur in deep waters, west of the Hebrides at the edge of the continental shelf, and in deeper waters beyond.

Fin whales are an offshore species and are thought to use the continental shelf edge as a migration channel between feeding grounds to the north and breeding grounds to the south. Although migrations are seasonal research suggests that at least some individuals may be present in UK offshore waters year-round. The species are very rare in the Hebrides but may come further inshore in summer to feed (HWDT n.d.a,b) and recent reports indicate that occasional visitors do occur on the Hebridean shelf and inshore waters possibly following food sources (e.g. BBC 2018). Fin whales consume euphausiid prey (krill), along with other planktonic species and small schooling fish such as herring (Clark et al. 2010: 61; HWDT n.d. a).

Blue whales are also found in deep waters, and around the Hebrides most are sighted to the west of St Kilda in the Rockall Trough (Evans 2012). While most pass through this area on seasonal migrations some may stay year-round in offshore waters off the UK (Clark et al. 2010). Blue whales are extremely rare today and there are no known records of the species in inshore waters. They favour euphausiid prey (krill), although other planktonic species are also taken.

Sei whales tend to favour deep offshore waters, further west than other baleen whales (Clark et al. 2010: 62-63). This species favours copepods though they also take small schooling fish such as anchovies and mackerel (Clark et al. 2010: 61; HWDT n.d. a).

4.3 GRAY WHALE

Species such as the North Atlantic gray whale, once abundant, are now entirely extinct from the area. The exact cause of the extinction of the North Atlantic gray whale is not clear, though climatic and habitat changes may have played a role. Early whaling may too have depleted the gray whale's numbers (Mead and Mitchell 1984), as with other large cetaceans their numbers are thought to be greatly reduced compared with their historic levels due to early and modern commercial whaling, though specific pre-whaling population levels are unknown. Studies of the extant Pacific populations show that gray whales are bottom-feeders, a unique feeding style amongst cetaceans. This species feed in shallow muddy bays and lagoons for a variety of prey including mysids, amphipods, tubeworms and other species opportunistically targeted including red crabs, larvae and herring eggs (Reiley et al. 2008). Gray whales also breed in shallow bays typically situated in warm climates and undertake long migrations to northern feeding grounds (Ibid). Their migrations also tend to follow the coastline and thus it is likely that this species would have occurred in inshore waters of the Hebrides during the past.

4.4 RIGHT WHALE

Right whales were an early focus for commercial whaling. Prior to this exploitation they are thought to have had critical habitat within UK waters (Clark et al. 2010: 18). The species is now extremely rare in the northeast Atlantic, and may now be functionally extinct within the area. In general this species show a preference for coastal waters, and studies of surviving populations indicate they calve in coastal areas, and migrate following the coasts to cooler feeding ground (NOAA 2015: 11), though excursions into deeper waters are also recorded (NOAA 2015: 13). Their distribution in feeding areas appears to correlate with the distribution of their favoured prey, zooplankton (NOAA 2015: 18).

4.5 BOWHEAD WHALE

Other species are likely to have been present historically during periods of differing climatic conditions. The bowhead whale for example, which inhabits ice-edge areas, may have been a resident of Scottish waters during periods of greater ice cover in glacial phases of the Quaternary and evidence of their presence south of their current range has been found in other areas of Europe (Wiig et al. 2019).

4.6 SPERM WHALES

Sperm whales are currently classed as vulnerable. This species were also targeted by commercial whalers and while population estimates vary current populations are thought to be much lower than pre-whaling levels (e.g. Whitehead 2002).

Like the large baleen whales, sperm whales also favour deeper waters and are present year round in offshore waters around the UK. The highest numbers are reported around productive areas above the shelf edge in water depths of 1000m of greater (Clark et al. 2010: 55) and Rosemary Bank and Anton Dohrn seamounts (JNCC 2020). The species are rare in inshore Hebridean waters though small numbers are recorded each year (HWDT nd.b). Sperm whales prey on squid, octopus and fish (Pollock et al. 2000: 62).

4.7 BEAKED WHALES

Other species which have been recorded in the area include the enigmatic beaked whales. Due to their deep diving habits and offshore distribution relatively little is known about this group. The deep waters off the continental shelf (over 1000m in depth) to the west of Scotland, and waters to the west of the Hebrides in particular, are thought to have relatively high numbers of these species. Northern bottlenose whales and Sowerby's beaked whales are the most common species in these areas today, with other Mesoplodont cetaceans and Cuvier's beaked whales rarely sighted (Clark et al. 2010: 57). Although live sightings are very rare in nearshore areas, strandings are more common. An Unusual Mortality Event (UME) was recorded in 2018, with almost 100 beaked whales stranding, already in a state of decomposition, on the shores of Scotland and Ireland, with particularly high numbers in the Western Isles. This event primarily saw strandings of Cuvier's beaked whales, though Northern bottlenose whales and Sowerby's beaked whales were also recorded (Brownlow 2018). Strandings of these species are consistently reported throughout stranding records (Coombs et al. 2019).

5 OTHER LESS COMMON SPECIES

Many of the species, including the pygmy sperm whale, false killer whale, Fraser's dolphin, narwhal, beluga, melon-headed whale, Blainville's beaked whale, True's beaked whale, Gervais' beaked whale, Gray's beaked whale and striped dolphin are all rare. They are only occasionally reported in UK waters, though strandings are also known (Clark et al. 2010).

Appendix 2: Cetacean bone from sites on the Western Isles

1 INTRODUCTION

This appendix provides information on cetacean bone reported from sites on the Western Isles, with a focus on South Uist (excluding the material from Cladh Hallan and Bornais which is set out in greater detail in Appendix 4 and 5). The material is reported on chronologically. Original reports have been referred to and references included. Quantities are given where referred to within the original text (where quantities are not given this is recorded as ‘P’ = Present) as are taxonomic identifications. Where possible the cetacean bone has been divided into three categories (worked/artefacts; fragments; elements) to allow broad comparison with the material from Cladh Hallan and Bornais. Further notes provide additional information. Details from the Norse site of Drimore are included in greater detail than other sites as these results are not published and formed part of the author’s MA study (Evans 2011 unpublished).

Key to abbreviations. Type of Investigation column: Exc = Excavated; Sur = Surveyed; TT = Trial Trenched; TP = Test Pit; P = Published; PI = Interim report published; UP = Unpublished. Other abbreviations: MIA = Middle Iron Age; LIA = Late Iron Age; WH = Wheelhouse; W/A = Worked/ Artefact; F = Fragment; E = Element.

Site	Type of investigation	Phase	Date	Total	W/A	F	E	Notes	Species	Reference
Early Bronze Age (2500 – 1500 BC) to Middle Bronze Age (1550 – 1150 BC)										
Cill Donnain 1	Exc. P	Phase 1: Early to Middle Bronze Age		P				Cetacean bone fragments are noted on the site (EBA- LIA) but not quantified or phased.	Unidentified	Vickers et al. 2014: 161
Manish Strand, Ensay	Exc.	Early Bronze Age	c. 2000 BC	P				The presence of whale bone is noted in the report text, but not quantified.	Unidentified	Simpson et al. 2003: 182
Machair Mheadhanach (Sites 182-184 plus probable EBA sites at 177-9; 181; 185; 123-4).	Sur.	Early Bronze Age		1				Site 184: Finds and bone from rabbit burrows. Animal bone not reported on in detail but seven animal bones were noted including one possible cetacean.	Unidentified	Hamilton and Sharples 2012: 199
Northton	Exc. P.	Beaker: B VII	2140 - 1740 cal BC	2		2			Unidentified	Finlay 1984
		Beaker: B V/VI	1940 – 1680 cal BC	1		1			Unidentified	Finlay 1984
Sligeanach (Sites 17, 18 and 176)	Exc.	Early Bronze Age		5		5		Five pieces of cetacean bone reported, but fragments/elements/artefacts not quantified	Unidentified	Mulville and Madgwick 2012: 239
Udal	Exc.P.	Beaker EBA						No cetacean bone reported	-	Finlay 1984: 39
Late Bronze Age (1150 – 700/600 BC) to Early Iron Age (700/600- c.200 BC)										

Barvas	Exc. P	LBA		**1**		1		Fragment from a large cetacean	Large cetacean	Cowie and MacLeod Rivett 2010
Baleshare	Exc. P	Late Bronze Age to Early Iron Age		**P**				A few eroded pieces of whale bone have not been further identified.	Unidentified	Halsted 2003: 143
Cill Donnain	Exc. P	Phase 2: Late Bronze Age to Early Iron Age	8th-6th centuries BC	**P**				Cetacean bone fragments are noted on the site but not quantified of phased (Vickers et al. 2014: 161)	Unidentified	Vickers et al. 2014
Dun Bharabaht	Exc. PI			**1**	1			Report includes small finds. Animal bone report not yet available.	Unidentified	Harding and Dixon 2000
Hornish Point	Exc. P	Early to Mid Iron Age	Block 19 C14 dates: 2170+- 50 BP; 2285 +- 50 BP	**1**			1	Part of a cetacean vertebra found in (301)	Unidentified	James and McCullagh 2003
Northton	Exc. P.	Midden I	Late Bronze Age	**3**					1 x possible G. melas 1 x possible O. orca	Finlay 2006: 173-174
		Midden II		**1**					Balaenopterid	Finlay 2006: 173-174
Middle (c. 200 BC – AD 300) to Late Iron Age (c. AD 300 – AD 900)										
Sollas	Exc.	WH/A	MIA	**5**		5			1 x neural arch fragment from B. musculus (Finlay 1984: 309) Frags of ventral surface of caudal vertebra (poss B. musculus) (Finlay 1984: 310)	Finlay 1984
		Pre WH/B midden	1st and 2nd century AD	**45**	35	10			1 x radius/ unla from large cetacean (Finlay 1984: 322) 3 x fragments of the skull of a large cetacean	Campbell 1991 (worked bone and debris)

										Finlay 1984 (fragments);
		Period B wheelhouse	MIA	**11**	11				1 x earbone of T. Tursiops (Finlay 1984: 239)	Campbell 1991
		S2 souterrain cutting		**1**			1		1 x vertebral fragment from medium whale (Finlay 1984: 327)	Finlay 1984
Udal	Exc.	MIA Early WH	(wheelhouse levels may be 1st century AD; Finlay 1984: 33)	**7**		7			Unidentified	Finlay 1984
		Later WH/ squatter	(1st century AD; Finlay 1984: 33).	**5**		5			1xPossible pilot whale; 1x dolphin/ porpoise	Finlay 1984
Sligeanach (Site 27)	Exc.	MIA wheelhouse	Middle Iron Age	**1**			1		Unidentified	Mulville and Madgwick 2012: 240
Cnip	Exc.	1	? BC - AD 1	**8**	2	6			Unidentified	McCormick 2006 for fragments (identification on p172); Armit 2006 (for artefacts)
		2	AD 1 – AD 100	**69**	16	53			1 x phalanx of E. glacialis (probable)	
		3	AD 100 – AD 250	**25**	5	20			Unidentified	
Kilpheder (Site 64) Bruthach a Sithean or Bruthach Sitheanach	Exc.	Middle Iron Age - wheelhouse		**3+**	3			Artefacts include possible cetacean bone used as rough paving, vertebra of small whale used as a mallet(?) and perforated vertebra. Report discuses finds but not animal bone generally so elements/fragments uncertain.	Unidentified	Letherbridge 1952
Dun Vulan (Site 0)		Broch revetment wall	200 BC – 0 BC	**3**			3		Mulville (2002: 38) notes sperm whale, minke whale, bottlenose whale, bottlenose dolphin, small cetacean and medium cetacean	Mulville 1999; Mulville 2002
		Broch construction	150 – 0 BC	**1**	1					

		Below platform	c. 100 BC – AD 100	**4**		3	1		remains at Iron Age sites including Dun Vulan, Bornais, Pabbay, Mingulay and Sanday).	
		Wall Chamber	0 BC – AD 200	**16**	1	3	12			
		Midden	0 BC – AD 400	**10**	2	6	2			
		Covering of entrance passage	AD 200 – AD 400?	**1**	1					
		Building A	AD 200 – AD 400	**6**	1	3	2		Sperm whale used as cist capping (SF 1219) in building A (Mulville 1999: 269; 2002: 40)	
		Waterlogged deposits	AD 200 – AD 400	**15**	4	9	2		See above.	
		Over stone building	AD 200 – AD 800	**27**	1	13	13			
		East of stone building	? (LIA)	**6**		6				
		Building B	AD 400 – AD 600	**3**		3				
		Building C	AD 500 – AD 800	**2**	2					
Cill Donnain (Site 84 and 85)		Phase 3: Pre-wheelhouse, MIA	AD100- 300	?				Cetacean bone fragments are noted on the site but not quantified of phased (Vickers et al. 2014: 161). However, Mulville and Smith (2004: 50) indicate greater than 100 fragments from this site.	Unidentified	Mulville and Smith 2004; Vickers et al. 2014
		Phase 4: Construction and use of wheelhouse: MIA to LIA	Cal. AD 170 – 360 (95%)	**1+**	1+					
		Phase 5: Construction and use of wheelhouse: MIA to LIA		**2+**	2+					

		Phase 8: Modification and abandonment of wheelhouse. LIA		**1+**	1+					
		Phase 9: Midden overlaying wheelhouse: LIA with MIA material	Cal AD 58- 665 (68%)	**12 +**	12 +					
Bac Mhic Connain (BMC) and Foshigarry (F)		-	Middle to Late Iron Age (c. 200 BC – c.AD 800)	**152**	47 (13 + 34)	80 + (70 ;10 +)	25	BMC and Foshigarry have been combined as they are presented in a combined way in the most detailed available bone report (Hallén and O'Neil, 1994). Where data allows, numbers for each site are presented separately in brackets (BMC; F). The total count is likely to have been higher as Hallén and O'Neil (1994: 191) note that the assemblage from Foshigarry is incomplete and bones are thought to be missing. 70 fragments were recorded from BMC alone	1 x cervical vertebra of a Cuvier's beaked whale (GNB 59)	Hallén, 1994. Identification p. 198.
A'Cheardach Bheag (Site 110)	Exc.	WHI	Middle Iron Age	**18**		18		Finlay (1984: 85) reports that note must be taken of the quantities of burnt and unburnt whale bone fragments	1 x axis fragment from B. acutorostrata; 1 x vertebral fragment from H. ampullatus Burnt and unburnt frags (Finlay 1984: 369-70)	Finlay 1984
		WHI I	Middle Iron Age							
		Entrance								

		Furnace								
A'Cheardach Mhor (Site 117)		Phase I (wheelhouse occ)	c. AD 100-200	10	8	2			1 x vertebra fragment from a large whale (Finlay 1984: 348) 1 x whale vertebra (unidentified) from Phase I (Finlay 1984: 353)	Finlay 1984
		Phase IA (hearth, midden)	c. AD 100-200							
		Phase II (reused wheelhouse)		1		1				
		Phase III (squatter)	5th-7th C. AD	5	3		2		1 x fragment of whale skull (large whale) Finlay 1984: 359	
		Phase V	7th-8th C. AD	1	1				1x Atlas/axis +3VC of G. griseus 1 x radius/ulna fragment from large whale(Finlay 1984: 362)	
		Iron Age (phase uncertain)	Iron Age	1		1			Fragment of M. novaeangliae bone identified by ZooMS	Identifications in Buckley et al. 2014
				1		1			Fragment of M. novaeangliae bone identified by ZooMS	Identifications in Buckley et al. 2014
Bruach a Tuath			Middle to Late Iron Age	1		1			1 x vertebra of G. griseus (Finlay 1984: 386)	Finlay 1984
Bruach Ban			Middle to Late Iron Age?	3		3			1 x fragment of vertebral epiphysis from a large whale Skull and mandible fragments from a large whale (Finlay 1984: 384). E. glacialis is suggested on the basis of size	Finlay 1984

Galson, Lewis			Iron Age	**2**	2				1 x Balaenid 1 x Fin whale	Identifications in Buckley et al. 2014
Northton		Iron Age – likely later IA	IA II	**3**		3			3 x fragments Pilot whale/Killer whale size (Finlay 1984: 343)	Finlay 1984
		Iron Age– likely later IA	IA I	**1**		1			1 fragment Balaenopterid (Finlay 1984: 345)	Finlay 1984
Allasdale, Barra	Exc.	Middle to Late Iron Age		**3**	1	2		Report indicates three fragments of cetacean rib were found on a surface.	Unidentified	Wessex Archaeology 2008
Hornish Point (Site 158) and Baleshare				**P**					Unidentified	Mulville and Smith 2004: 50
Pabbay, Mingulay and Sandray		Iron age		**3**					Mulville (2002: 38) notes sperm whale, minke whale, bottlenose whale, bottlenose dolphin, small cetacean and medium cetacean remains at Iron Age sites including Dun Vulan, Bornais, Pabbay, Mingulay and Sanday).	Mulville 2002; Mulville and Smith 2004: 50
Dunan Ruadh (PY10) Pabbay		Middle Iron Age	1st – 3d century	**1**					1 x sperm whale vertebral epiphysis	Mulville and Ingrem 2000: 254-261.
		Late Iron Age	6th- 9th century	**11**					Unidentified	
Beirgh		Sub Phase 3	Late Iron Age	**3**					Unidentified	Thoms 2003
		Sub Phase 3a		**4**					Unidentified	
Udal	Exc.	Early WH Later WH XI-XIII	 -4th century AD LIA II c. AD 550-850	**18**		7 5 6			Unidentified	Cerón- Carrasco 2005; Finlay 1984; Serjeanston 2003
Norse (c. AD 800 – c. AD 1400)										
Bornais M3		DB (house)		**1**		1				Mulville 2005
		DD (house)		**10**		10			1x medium sized cetacean rib	

		DE (house)		3		3				
		FB (kiln/barn)		2		2				
		FD (Kiln/barn)		10		10				
		FE (Kiln/barn)		5		5			1 x vertebra from a large cetacean	
		FG (Kiln/barn)		5		5				

Drimore	Exc.	Norse		**12**	12			a. 1978.32.cf.[1] Thoracic vertebra from large cetacean a. 1978.32.cf.[2] Thoracic vertebra from cetacean a1978.32 ap. Worked fragment of whale bone, fashioned to a rounded tongue at one end Cleaver – Cetacean bone 'cleaver' a. 1978.32.ao Fragment of wedge shaped whale bone with two broken perforations a. 1978.32.aq[1] Complete caudal vertebrae, partially damaged around edges a. 1978.32.aq[2] Long cetacean bone object with striations a. 1978.32.aq[3] Worked cetacean bone a. 1978.32.aq[4] Small fragment of unworked cancellous whale bone a. 1978.32.aq[5] Cetacean bone partially rounded at both ends. a. 1978.32.aq[6] fragment of bone. Worked a. 1978.32.aq[7] Fragment of bone. Worked.	Large cetacean identified. No smaller fragments were present from this site and it is likely (given the nature, purpose and extent of the excavation, and difficulties encountered during excavation (see MacLaren 1974) that they were not collected if present).	Evans 2011 (unpublished MA thesis); MacLaren 1974
Cille Pheadair	Exc.	Phase 1		**3+**	3				Balaenopterid	Mulville and Powell 2018; Paterson 2018
		Phase 2		**3+**	3				Large cetacean	
		Phase 3		**2+**	2				O. orca G. melas	

		Phase 4		**10+**	10				Balaenopterid H. ampullatus B. acutorostrata Large cetacean Small cetacean	
		Phase 5		**7+**	7				Large cetacean	
		Phase 6		**8+**	8				P. macrocephalus B. musculus Large cetacean	
		Phase 7		**20+**	8	12			Large cetacean	
		Phase 8		**3+**	3				Unidentified	
		Phase 9		**2+**	2				Unidentified	
		U/S		**2+**	2				Unidentified	

Appendix 3: Supplementary information relating to the method and toolkit for the morphometric identification of cetacean vertebrae

1 INTRODUCTION

This appendix provides information which supports the method and toolkit for morphometric identification of cetacean vertebrae presented in Chapter 5. It provides background information, further detail and information on data used, to support discussions within that chapter.

It begins with an introduction to the history of relevant work on cetacean vertebral osteology to frame understanding of the sources drawn on by the method and toolkit for morphometric identifications set out within this thesis. The second section sets out key aspects of evolution and functional morphology which have a bearing on taxonomic identification. This section essentially provides further detail to the information presented in Chapter 5, and in particular gives insight into the osteological traits which are of use in taxonomic identification. The next section provides information on the data used for the comparative datasets and discussion of taxonomic differentiation set out in Chapter 5. The full list of 442 specimens referred to by this work is included within Section 13 of this Appendix.

The discussion then sets out data which demonstrates the effects of age on absolute and relative dimensions, providing support for the assertions in Chapter 5 which stated that while absolute dimensions alter with age for most species the relative dimensions of each vertebrae stay the same regardless of age and are therefore of use for taxonomic identification. The exception to this is species within the sub-family delphininae, which exhibit ontogenetic changes to relative dimensions of their vertebrae. Data which demonstrates these patterns is presented here.

2 CETACEAN VERTEBRAL OSTEOLOGY: HISTORY OF WORK

Studies of various aspects of cetacean anatomy are widespread, cropping up in the disciplines of marine biology and zoology, biomechanics, palaeontology, museum and conservation studies and archaeology but none provide a method for identification or detailed comparative datasets against which archaeological specimens can be identified. However, each discipline views bones from different perspectives focuses on different attributes, and all ultimately have the potential to contribute to our understanding of cetacean bone in the archaeological record. The specific work of key studies is reviewed here from a chronological perspective.

The history of investigation into cetacean biology begins with Classical authors, and Aristotle, writing in the 3rd century BC, made important early contributions to this field (Romero 2012). However, it was not until the 18th century that a more detailed understanding of the internal anatomy of cetaceans began to emerge (Hunter 1787), and the discipline of cetology did not make any large advances to understanding systematics and osteology until the 19th century (e.g. Cuvier 1823 ; de Lacépède 1804). Mainland Europe was the focus for these investigations during the first half of the 19th century, though by 1860 the focus had shifted to Britain (Slijper 1936). These studies were led by researchers such as Flower (1864a, b, 1868, 1871, 1878, 1883, 1885), Gray (1864, 1866, 1868, 1870), Eschricht, Reinhardt and Lilljeborg (1866), True (1904, 1910) and Van Beneden and Gervais (1880), based at the world's major museums and research institutions. Some of the earlier works cover the order Cetacea (Van Beneden and Gervais 1880; Beddard 1900; Eschricht et al. 1866; Fischer 1881; Flower 1864a; Gray 1864, 1866, 1868) while others focus on families (Lillie 1910; Flower 1878; True 1904, 1910) or individual species (see Table 40). The early works in particular are concerned with the classification of different species, and provide considerable detail to demonstrate the validity of certain species (True 1910). The majority of the studies focus on the skulls, though some also give detailed descriptions of the cervical vertebrae (e.g. Dwight 1871: 212). A few give detailed descriptions of the post-cervical vertebrae (e.g. Struthers 1889). This is less common, but where found these descriptions formed extremely useful sources for this thesis.

These studies are, however, treated cautiously. Although they were written by world-leading experts in cetacean osteology, they were penned before many cetacean species were firmly fixed, and the aim of many of the works was to properly classify cetaceans (e.g. True 1904, 1910). These publications represent a work in progress, providing discussion of what was known about cetacean osteology at the time, with each generally adding new specimens to the discussion. However, they cause confusion in places and include many different 'species', now known not to exist, and which had often been suggested on the basis of scant evidence. Many use different characteristics for erecting new species, leading to a proliferation of species (Allen 1908: 298). The authors were writing in a mire of confusion, which, despite attempts at clarification, has affected the reliability of some of the work in places. For example, Van Beneden and Gervais' (1880) major publication provided detailed illustrations along with descriptions, which form the basis for much discussion. However, in addition to erecting a large number of false species (Slijper 1936: 11), this text has mistakes in areas. The cetacean illustrated as 'Balaena biscayensis' (correlated with Eubalaena glacialis), for example, was later critiqued and thought to be composed of a series of different cetaceans of multiple species (Allen 1908). Later authors reviewing the earlier works have attempted to highlight some of these issues (Allen 1908), which aids readers today. However, over time their research and publications generated much of our present knowledge of whale species.

In the period before 1880 the works tended to focus on individual species, though there are some exceptions which included comparison between groups of species (e.g. Andrews 1914; Flower 1866; Gerstaecker 1887; Struthers 1889; True 1910). However, in the wake of Gegenbaur's work on comparative anatomy (e.g. Gegenbaur 1859), later studies increasingly took a comparative approach (Kükenthal 1893). Slijper's (1936) monographic treatment of the cetacean vertebral column, *Die Cetaceen Vergleichend-Anatomisch und Systematisch*, and his later works (e.g. 1962) typify this approach and form a seminal work for all research on the cetacean spine. Slijper focused on the comparative anatomy of the post-cranial skeleton and soft tissues to investigate phylogenetic relationships, addressing a gap in previous research which had tended to focus on the osteology of the skull, teeth and pectoral fin to address questions of phylogeny (Slijper 1936: 4). To do this he took a comparative approach and used dissections and skeletal material to investigate the evolution of cetaceans by comparing both extinct and living species with their terrestrial relatives. Slijper (1936) focused on the importance of nerves and other soft tissues to unpick cetacean anatomy and draw reliable comparisons between marine and terrestrial mammals, leading to an understanding of the evolution of osteological traits which can be used for reliable taxonomic differentiation in cetaceans.

Later studies have been heavily influenced by Slijper's (1936) work. Functional morphology has been studied by Long et. al. (1997) and by Emily Buchholtz' and her colleagues, who took this perspective to investigate the evolution of the cetacean spinal column (Buchholtz 2001; Buchholtz and Schur 2004). Others have investigated the relationship between vertebral morphology and habitat (e.g. Gillet et al. 2019; Viglino et al. 2014). Recent work by Gillet et al. (2019) demonstrated that the evolution of the osteo-morphology of cetacean spinal columns can be connected to their habitat, on a broad scale. Together, these studies demonstrated that cetaceans can be grouped according to their vertebral morphology.

While these works provide vital contributions and a framework for understanding the cetacean vertebral column, overall they tend to focus on similarities between cetacean species to identify taxonomic groupings, reflecting Slijper's aim to investigate cetacean phylogeny, although Buchholtz' work does indicate differences between some Delphinoid species and is therefore of particular relevance when considering species within that group. Other recent work has included publication of metrical data for a number of specimens by van den Hurk (2020), used to demonstrate identifications set out within his work.

Later works also include the studies published by the *Scientific Reports of the Whales Research Institute.* These studies often contain detailed discussion of osteology of particular species (e.g. Omura 1957, 1969, 1962, 1972), though they are typically not comparative in nature.

The current work has drawn on these studies to investigate differences between all species within the study area, as well as differences present at higher taxonomic levels. A brief interim statement on this work was published in 2018 (Evans and Mulville 2018).

3 EVOLUTION, FUNCTIONAL MORPHOLOGY AND CETACEAN BONE IDENTIFICATION

The identification methodology developed within this thesis has focused on traits which are known to relate to the evolution or function morphology of cetaceans and this section introduces these areas of study. This is to ensure that traits used for identification are not the result of individual variation, but rather relate to reliable differences which have evolved between different taxonomic groups, from species to sub orders. This is particularly important in light of relatively small sample sizes available for recording. The following sections sets out detail drawn upon in Chapter 5 (Step 1) and provides additional information to what is set out within that chapter.

3.1 AQUATIC LOCOMOTION

Unlike terrestrial mammals and other marine mammals such as seals, cetaceans do not use their limbs as the main source of propulsion (Boszczyk et al. 2001; Moran et al. 2015). Instead, locomotion is achieved by undulations along the spine. These undulations are primarily generated by the epaxial and hypaxial muscle groups which work to produce the upstrokes and downstrokes which ultimately propel the animals through the water (Buchholtz and Schur 2004: 394; Carrillo et al. 2014). The vertebrae in the posterior thoracic, lumbar and caudal regions provide attachment sites for these muscles, and allow for this movement to take place. Consequently, the vertebrae in these regions have formed the focus for modifications which aid locomotion. These modifications are interconnected, and include elongation of the spine, changes to flexibility and modifications to musculature with corresponding osteological traits which affect the vertebral centra, processes and key muscle attachment sites such as metapophyses. These modifications allow for differentiation with terrestrial and other marine mammals, but have also resulted in differences between cetacean families, and in some cases species.

Slijper (1936: 325) identified elongation of the spine as the first locomotory adaptation which evolved amongst cetaceans. Elongation of the spine allowed for the reduction of the width and height of the abdominal cavity and facilitated the development of the streamlined bodies which typify modern cetaceans, allowing an improvement in swimming abilities (Slijper 1936: 325, 1962: 105). Elongation has been achieved in different ways among different cetacean families and species. The 'lumbarisation' of sacral vertebrae has occurred within all species and sacral vertebrae are now no longer evident within cetacean osteology (Buchholtz et al. 2005). However, some species achieved additional elongation by an increase in the length of the individual vertebrae themselves and a reduction of the number of ribs (thereby increasing the area of the spine involved in locomotion), while in other groups elongation of the spine was achieved by an increase in the number of vertebrae, which often, paradoxically, went hand in hand with a decrease in the length of each individual vertebra (Slijper 1936: 325). Key osteological characteristics which demonstrate these adaptations include the number of vertebrae in a specimen's spine, the number of ribs, and individual centrum lengths. Other features are also influenced by elongation of the spine, including the location of key arteries and associated foramen or grooves (Slijper 1936 chapter 12). The former two characteristics (number of ribs and vertebrae) are not normally measurable on archaeological sites with assemblage composed of disarticulated remains. However, they may be of use in identifying articulated specimens, typical of shoreline butchery sites. Centrum lengths and arterial foramen can be recorded on articulated or disarticulated remains alike, and the former have been used in the identification of cetacean bone found on archaeological sites (e.g. Evans and Mulville 2018; van den Hurk 2020a, b).

Different swimming styles which reflect differences in spinal flexibility have also emerged amongst cetacean species. Flexibility is influenced by the way in which elongation has been achieved in addition to a range of other factors including centrum and process characteristics as well as musculature. The key swimming styles relate to whether movements are achieved evenly along the post-thoracic spine (unimodal) or whether they are focused at key points (bimodal) (Buchholtz and Schur 2004; Slijper 1936: 248-254, 1961: 90) (Figure 80).

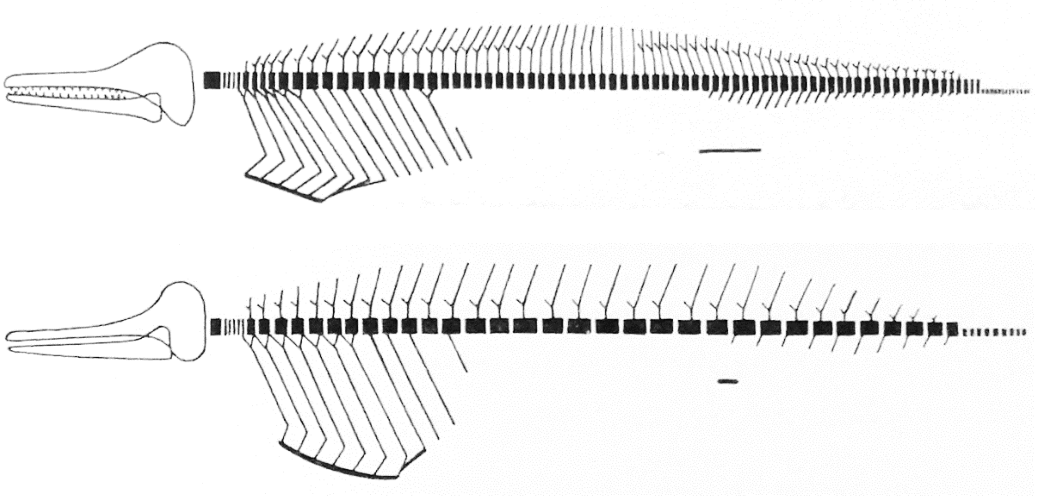

Figure 80 Schematic representations of bimodal and unimodal torsos, showing L. albirostris (top, bimodal) and M. bidens (bottom, unimodal). Illustrations from Slijper (1936: 425, 429).

The epaxial and hypaxial muscles which produce the undulations of the spine can run the length of the body and have insertions to the vertebrae along their length (in particular at the top of the neural process and on the metapophyses), which are associated with modifications to these vertebrae when compared with those of terrestrial mammals (Buchholtz and Schur 2004: 393; Slijper 1961: 90). The modifications include elongated neural and transverse processes particularly within the lumbar region, which increases the mechanical advantage of these powerful axial muscles (Pabst et al. 1999: 30; Slijper 1962). Longer spinous and transverse processes allow the muscle attachments to be located further away from the point of rotation (the vertebral column), gaining greater mechanical advantage for the lever formed by the muscle attachment working on the process. The elongation of these processes is seen in terrestrial animals with strong lumbar muscles (Flower 1885: 56).

In addition to the differences between cetaceans and terrestrial mammals, these elements of vertebral anatomy also display differences between cetaceans. Specific muscles within the epaxial group in particular (especially the longissimus and multifidus muscles; Figure 18) have developed very differently among different cetacean families, and this is associated with differences in neural process and metapophysis characteristics. Differences between the dominant muscle within the group, and the points of origin and insertion of the muscles influence osteological differences between taxonomic groups. In particular the neural process and neural spine height, height of metapophyses, height of the neural arch and neural arch inclination and neural spine inclination are all influenced by the anatomy of this musculature, and therefore are all useful in identifications (Buchholtz 2001: 179; Slijper

1936: 437; Viglino et al. 2014: 272). The orientation of the neural process has been found to be primarily influenced by the pull of the epaxial muscles and tendons which insert on to them (Slijper 1936: 410). Changes to that musculature between species are therefore associated with osteological differences. Neural process inclination can be uniformly posterior along the length of the spine in some species, though in others the inclination of the neural arch and neural spine is altered in some regions and anticlinal vertebrae are present (reflecting a reversal of the direction of the neural process toward an anterior inclination), and a synclinal point can also be identified further down the spine, reflecting a switch back to neural processes which have a posterior inclination. Differences between the neural processes and metapophyses also relate to whether the process represents the origin or insertion of the muscle, which again differs between species (Slijper 1936: 410). Similar factors also influence the transverse processes, affecting transverse process length and breadth, and some studies have found transverse process inclination to have a phylogenetic signal (Viglino et al. 2014: 272).

Differences in centrum length and centrum face curvature, and the number of vertebrae, which tend to be factors associated with the elongation of the spine, also influence flexibility (Buchholtz 2001: 179; Buchholtz and Schur 2004: 384; Slijper 1936: 415). This relationship is complex and although short centrum lengths with flat centrum faces and long processes can reduce flexibility, large numbers of short centra can increase flexibility through the accompanying large number of elastic intervertebral discs. Longer centrum lengths with curved centrum faces and short processes can allow for mobility, though long centra with flat faces inhibit overall flexibility (Buchholtz and Schur 2004: 385). Non osteological traits such as intervertebral disc length and composition, musculature and ligaments also influence flexibility, though these tissues typically do not survive in archaeological contexts and as such are not considered further here (Buchholtz and Schur 2004: 384). Other features of the centra also appear to be related to taxonomic identity, including the overall shape, such as discoidal, spool shaped (e.g. Buchholtz and Schur 2004) or barrel shaped.

These factors all affect the mobility of different areas of the spine. Long neural and transverse processes, coupled with short centrum lengths, produce areas of relative inflexibility, while longer centrum lengths coupled with shorter processes (which in some cases are inclined away from one another at particularly mobile locations), indicate regions of greater flexibility. Areas of greater and lesser flexibility are generally found in species with bimodal torsos, while those with unimodal torsos tend to have more uniform flexibility along the length of the spine, and are typically associated with longer centrum lengths and neural processes which have the same posterior inclination along the length of the vertebral column (Figure 80). Metapophysis height and development also varies, depending on the relative development of the multifidus and longissimus muscles, which have a different anatomy and are differently developed between cetacean species. Some species have raised metapophyses, which provide a mechanical advantage to the muscles which insert on them, while others have very low metapophyses. In some species this is coupled with elongated neural processes which form attachment sites for muscle fibres which take precedence over tendons inserting onto metapophyses in those species. Regionalised metapophysis loss is also evident in some species of delphinid (Buchholtz and Schur 2004: 386), indicating the suppression of the longissimus systems, and differences in the shape of the metapophyses are also taxonomic indicators (Slijper 1936: 414). These are just some examples of the variations and functional implications of vertebral morphology between species, involving the key features which show family, genus or species-specific variation. Cetacean vertebral morphology varies only slightly in some cases, and species occur within a spectrum of these changes. Many features of vertebral morphology are interconnected and so consideration of multiple features is desirable for reliable identification, particularly when discerning between closely related species.

In summary, there are a number of characteristics which relate to aquatic locomotion and which have evolved differently among cetacean species, and therefore aid identification (Buchholtz and Schur 2004; Slijper 1936; Viglino et al. 2014). These include:

- Number of vertebrae;
- Number of ribs;
- Centrum length;
- Location of arterial foramen;
- Neural process and neural spine height;
- Height and form of metapophyses;
- Height of the neural arch;
- Neural arch inclination and neural spine inclination; and
- Transverse process breadth, length and inclination.

The modifications have occurred primarily within the posterior thoracic, lumbar and caudal regions, and therefore aid identification in these parts of the spine. Fusion or extreme shortening of the cervical vertebrae along the cranio-caudal axis is also a feature of many cetaceans, causing rigidity in the neck thereby stabilising the head, aiding movement through the water (Slijper 1962: 105). This is also an indicator of taxonomic identity, although the degree of fusion is more variable within species and so is not focused on here.

3.2 BREATHING

In the thoracic region modifications have increased both the area and flexibility of the cetacean thorax compared with terrestrial animals (Slijper 1939: 378-9). The increased flexibility allows the ribcage to undergo compression during diving. Variations in size and flexibility relate to the location of transverse processes relative to the centrum and the nature of rib articulations within the thoracic region (Slijper 1939: 378-9). The breadth of the neural arch also varies between families, particularly within the anterior thoracic region, and bears a relationship with transverse process location.

It was thought that the thorax of deep diving species was likely to be more flexible than that of shallow divers, however, although there are differences in lung size, differences in osteological flexibility between these groups does not exist (Piscitelli et al. 2010). Instead differences in the joints between the vertebrae and ribs have been found to correlate with families. In the thoracic region the following characteristics are key indicator of taxonomic identity:

- Nature of rib articulations;
- Location of the transverse processes relative to the centrum; and
- Breadth of the neural arch.

The information set out above has formed the basis for the list of osteological traits of use in taxonomic identification which is set out within Step 1 in Chapter 5.

4 DATA

The following section provides details on the data which formed the basis for the method for cetacean vertebral identification set out in Chapter 5, and for the comparative data included within that chapter and Appendix 7. Information on methods for including data collection, data handling and data cleaning are also set out here.

While the studies in cetacean phylogeny, comparative anatomy and functional morphology provide a framework for understanding taxonomic differences (e.g. Slijper 1936), those published have primarily sought to investigate phylogenetic relationships or functions, and therefore while species -specific differences are highlighted in places is not the focus of the work. Additionally, none of the existing studies are able to provide a dataset against which archaeological material can be compared for identification purposes. For this reason, species-specific data relating to features which represent adaptations to aquatic locomotion and breathing, as outlined above, were gathered as part of this thesis. This data included measurements of key dimensions and information on morphological characteristics. Other measurements were also collected following standard zooarchaeological conventions (von den Driesch 1976) to ensure comparable results and in order that any other indicators of species identity, used amongst non-cetacean species, could be identified. See Chapter 5 for a full list of measurements collected. This data was collected for all of the 31 species included within the current study.

Data were gathered from a number of specimens of each individual species, in order that these patterns could be investigated within species and to determine the range of dimensions for each individual species.

4.1 SPECIMENS

Information has been obtained in three ways: direct measurements of museum specimens and recording of morphological data, data from existing metrical data sets and general descriptions. A full list of all specimens included within this study is set out in Section 13 of this appendix.

4.1.1 DIRECT MEASUREMENTS AND DATA RECORDED BY THE CURRENT STUDY

Information set out above has been collated from cetacean specimens held by institutions across the UK and Scandinavia. These include the British Museum of Natural History (London, Wandsworth Research Centre and Natural History Museum, Kensington), the Museum of Scotland, (Edinburgh, Granton Research Centre), the University Museum (Norway, Bergen), the Icelandic Institute of Natural History (Iceland, Reykjavik), Húsavík Whale Museum (Iceland, Húsavík) and Cardiff University (Wales, Cardiff). Studies by the author of private collections held by individuals in Shetland, including those of Neil Anderson, have also been included within this guide, as have earlier measurements taken by Dr Jacqui Mulville and colleagues at the Museum of Scotland and the British Museum of Natural History. Data collection trips to the University Museum (Norway, Bergen), the Icelandic Institute of Natural History (Iceland, Reykjavik), and Húsavík Whale Museum

(Iceland, Húsavík) were funded by the European Cooperation of Science and Technology (E-COST) Oceans Past Platform.

Measurements of 97 specimens held by these institutions have been taken during the production of this research, and additional specimens have undergone visual assessment with the aim of recording features of the bone (typically undertaken when a specimen was articulated on display, and therefore not accessible to take measurements). Distinct features of the spine and the morphology of the vertebrae were also studied, noted and photographed. These included the number of ribs and vertebrae, the location of arterial foramen, the nature of rib articulations, location of the transverse processes relative to the centrum, the location and form of metapophyses, and the form of the centrum including whether the ventral aspect has an exaggerated keel, or rounded barrel shaped profile, or 'waisting' (spool shaped). Photographs were taken to demonstrate features and comparisons between species, as well as variations between specimens of the same species.

4.1.2 EXISTING METRICAL DATASETS

Data from other studies has also been incorporated within the dataset. In particular Gillet's et al. (2019) study provided measurement data on an additional 105 specimens of species under study here, while measurement data on an additional 58 specimens was also collected from a range of other historic studies (see Section 13 for references for each specimen). Dr John Rochester's detailed information and datasets which include measurements and photographs of cetacean vertebrae, obtained online (Rochester n.d.), is also an important resource and includes a range of species. Many of these works include basic measurements of some elements, in particular crania and occasionally vertebrae. All published measurements for the vertebrae of different species has been collated as part of this thesis.

4.1.3 GENERAL DESCRIPTIONS

In addition, although many early studies do not contain measurements, they do often provide descriptions of vertebral osteology, which have been used to inform understanding of morphological characteristics. Slijper's (1936) work also formed a major source for this research. Slijper's descriptions are based on a large number of specimens spread across many European institutions (Slijper 1936:6), and in general have not been enumerated here. His descriptions have, however, fed into the descriptions set out within, and as such the dataset included here is supported by Slijper's (1936) observations of additional individuals.

Recent publications on the anatomy of dolphins and whales have also provided useful sources (Cozzi et al. 2017; Huggenberger et al. 2019).

4.2 DATA DETAILS

In total the dataset set out here is based on measurements, photographs, illustrations, descriptions and studies of 442 specimens, including all species within the study area. This includes measurements of 260 specimens representing 31 species (around one third of all cetacean species in existence). All specimens referred to have been included within Section 13, which also sets out the data collected for each specimen, references and other information (where known) including the repository at which the specimen is held, the catch/strand location, vertebral fusion, age, sex, length and whether the specimen is partial or complete (Gillet *pers. comm*. 2020). The number of specimens from each family is detailed in Chapter 5. Those with a higher number of species within the study area per family (such as the Delphinidae) are represented by higher numbers of specimens.

Age is a key variable with the potential to influence identifications and is discussed in more detail below (Section 5.1). The age of specimens included within the current dataset range from very young individuals in which epiphyses were absent or completely unfused (juvenile), to older specimens with epiphyses present though fused or partially fused in some areas of the spine, though visible suture lines remain (sub-adult), to physically mature specimens with epiphyses fully fused (adult) (definitions of maturity following Slijper 1936: 63 and van Waerebeek, n.d.: 228-230). While efforts were made to include specimens of a range of ages, from juvenile to physically mature, it has not been possible to systematically measure specimens from all age groups and inclusion of specimens of different ages within reference collections is inconsistent. Additionally, neonatal specimens do not form part of the dataset. As such the variation between the absolute sizes of adult and young specimens is likely to be even larger than that demonstrated by the discussion below.

4.3 DATA LIMITATIONS

Initial data collection for this study included one representative vertebra per region. Following the recognition of amount of variation within a single region this was increased to every other vertebra for the whole spine. Other authors have also collected measurements for each vertebra (e.g. Gillet et al. 2019). For this reason the dataset does not contain the same number of measurements for each vertebra, and some vertebrae are represented by only a small number of measurements.

While many of the measurements recorded by this study are comparable to those published in other studies there is some inconsistency between previous authors in the way particular measurements have been collected, recorded or described. Specifically, the neural process height is variably measured in a vertical line from the tip of the process to the dorsal aspect of the centrum (e.g. Carrillo 2014), or at an angle following the axis of the neural spine (e.g. Gillet et al. 2019). The measurement recorded by this thesis was the vertical height from the distal tip of the neural spine to the centrum, as used by Carrillo (2014) (see Chapter 5). However, other data is presented where it aids identification (e.g. Gillet et al. 2019). Where other measurements have been used specific reference has been made to how the measurement was collected.

Other limitations affect particular regions of the spine. Frequently the small posterior caudal vertebrae including the fluke vertebrae are lost and thus do not form part of most datasets (Buchholtz and Schur 2004: 387; Gillet et al. 2019). For this reason, some studies such as Gillet et al. (2019) consistently excluded the posterior caudal and fluke region from data collection. This area is therefore poorly represented within the dataset. This has the effect of reducing the potential range of measurements available. This is the case for M. grayi for example, in which measurements of the posterior most caudal vertebrae are missing entirely.

Collection of measurements reflecting the breadth of the neural arch were also problematic where sections of the spine, or the whole spine, was articulated. This measurement was taken where possible.

5 VARIABLES AFFECTING TAXONOMIC IDENTIFICATION

Step 2 in Chapter 5 states that a series of factors can be used to guide taxonomic identification. These include:

- Determination of the precise position along the spine;
- Recording of absolute measurements (as set out by Evans and Mulville 2018);
- Calculation of relative dimensions;
- Comparison with reference datasets (set out below); and
- Analysis of bone morphology

The information to support most of these areas is set out within that Chapter. However, the following section provides further information to demonstrate ontogenetic changes to relative dimensions observed within some species.

5.1 THE INFLUENCE OF AGE ON ABSOLUTE AND RELATIVE DIMENSIONS

Age is a key factor which influences the size of a vertebra, and therefore requires consideration when undertaking identifications. This section considers the influence of age on absolute and relative dimensions.

Immature specimens are often an important part of zooarchaeological assemblages, including at Bornais and Cladh Hallan and therefore the methodology required to analyse this material needs to cover both immature and mature cetaceans. While other studies have set out identifications for immature specimens (Szabo 2008: 173-174; van den Hurk 2020) which rely in part on the size of the vertebrae, there has typically been no discussion of the differences between immature and adult specimens which influence size (Buchholtz et al*.* 2005) and therefore have the potential to influence identification.

Skeletal maturity is gauged by the fusion of vertebral discs to centra. Fusion of the epiphyseal plates and vertebral centra begins to occur when growth (along the longitudinal axis) ceases as the animal reaches physical maturity, but this growth can continue well into sexual maturity in some species (Moran et al*.* 2015). The rates of fusion for cetaceans are not fully known, and in some very old individuals fusion may not be fully complete (R. Sabin *pers. comm* 2019) indicating that physical maturity may be very late in some species. Studies have found that compete fusion along the entire spine is relatively rare in *P. phocoena* and many specimens retain unfused epiphyses long after sexual maturity, and some may never achieve fusion. While this is the case with *P. phocoena*, complete fusion is much more common in delphinids (Galatius 2005).

Buchholtz (et al. 2005) investigated ontogenetic changes in the spine of *L. acutus*. Their study considered centrum length, centrum width, centrum height and neural process height and found that all change with age, though some areas of the spine saw greater changes. The largest changes in absolute size were observed in the neural process, which doubled in length between immature and mature specimens, as did centrum length (though absolute increase was lower, due to the smaller size of the centra compared with the neural process). Neural process inclination was also studied, however this was found to be constant between adult and immature specimens (Buchholtz et al. 2005: 424), in contrast to Slijper's (1936: 410) observations which found that although neural spine inclination is generally the same in immature and mature specimens (i.e. anterior/posterior), the angle of inclination becomes more pronounced with age.

Ontogenetic changes to centrum length were investigated within the current dataset[25]. The figure below demonstrates the size variation in centrum length evident between immature and adult specimens of *Z. caviostris.* The data, which includes five immature specimens, demonstrates that the absolute size of the centrum length in adult specimens can be more than twice as great as in immature specimens (Figure 81). The total body length for one of the immature specimens is known, and was recorded at 12/13ft in the original publication (3.6/3.9m) (True 1910). The average length of this species at birth is between 2.3m and 2.8m, and the average lengths for adult specimens are between 5.3m and 6m though the maximum body length recorded for this species is 8.4m (Carwardine 2020: 183). The specimen recorded at 3.6/3.9m has centrum length values which occur around the centre of the dataset, suggesting that some of the smaller immature specimens may represent very young calves. However, it is highly likely that the ranges for younger specimens of other species are under-represented within this dataset, as it was not possible to systematically record very young individuals of each species. If this is assumed it is likely that overlap between species, which is already high based on the data collected, would be even greater if all age groups were included for all species.

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[25] It was not possible to investigate ontogenetic changes to all parameters due to data limitations, as set out within Chapter 5.

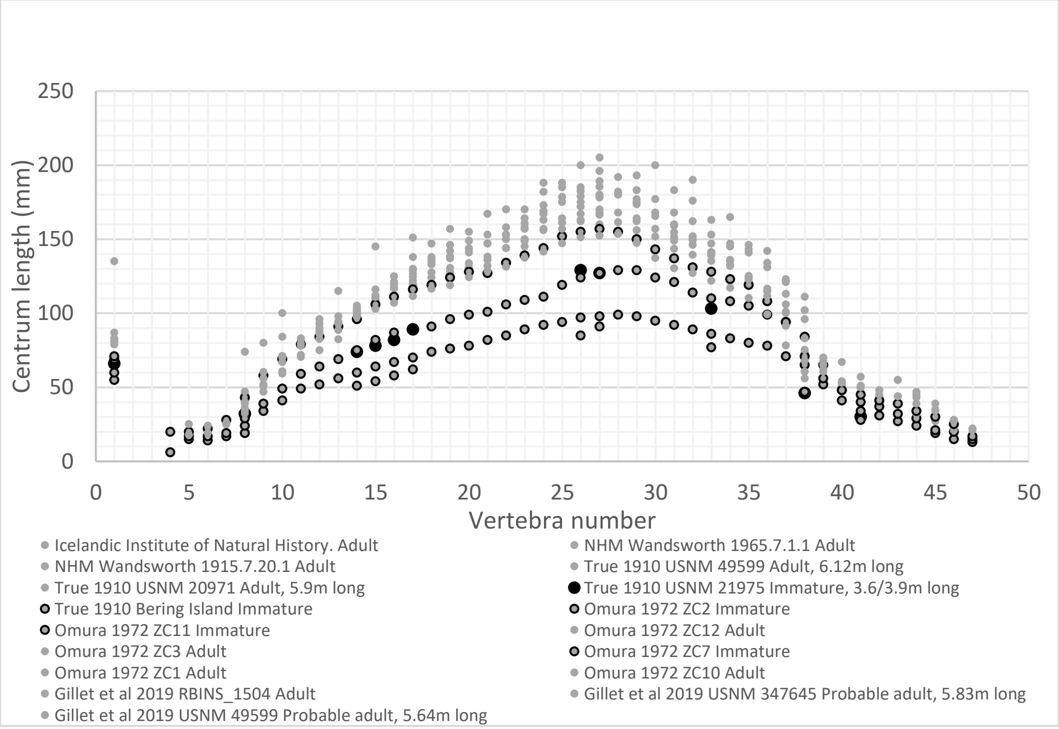

Figure 81 Centrum lengths of 17 specimens of Z. caviostris showing increase in absolute centrum lengths with age

Differences are greatest in the mid spine region (posterior thoracic to anterior caudal), reflecting the pattern found by Buchholtz et. al. (2005: 422). The size difference between young and adult specimens of the same species depicted in Figure 81 is large, allowing for greater overlap with other species and therefore blurring the boundaries for species discrimination. This demonstrates the need for an approach which goes beyond the absolute size of a bone, to take into account other factors.

As set out in Chapter 5, consideration of the relative proportions is often a key focus for studies guiding the identification of bone (e.g. Hillson 2009; Prehn et al. n.d), and has been used by number of authors to investigate the spine of terrestrial mammals and cetaceans alike (Bucholtz 2001; Buchholtz and Schur 2004; Carillo et al. 2014; Evans and Mulville 2018; Slijper 1936: 355). However, the majority of researchers considering cetacean bone represent the relative dimensions through graphs which chart multiple absolute dimensions (e.g. Slijper 1936: 434- 439; van de Hurk 2021), which therefore to some extent suffer the limitations set out within this section, as regards age. However, reliance on absolute measurements can be avoided by calculation of the ratios of certain aspects of the bone (see Chapter 5).

Previous studies have tended to focus on the use of ratios in adult animals (e.g. Buchholtz 2001, 2007) or have not explicitly considered potential differences between adults and sub-adults (Buchholtz and Schur 2004). However, ontogenetic change was investigated by Buchholtz et al. (2005). Though the focus of this study was on absolute measurements, inferences were drawn about the changes to relative proportions (Buchholtz 2005: 426). Buchholtz et al. (2005: 426) found that although the same basic morphology is retained regardless of age, 'during ontogeny variable growth among vertebral parameters and among column regions produce changes in body proportions'. These conclusions were drawn in relation to data from *Lagenorhynchus acutus.* Ontogenetic change to relative dimensions were investigated within the current dataset.

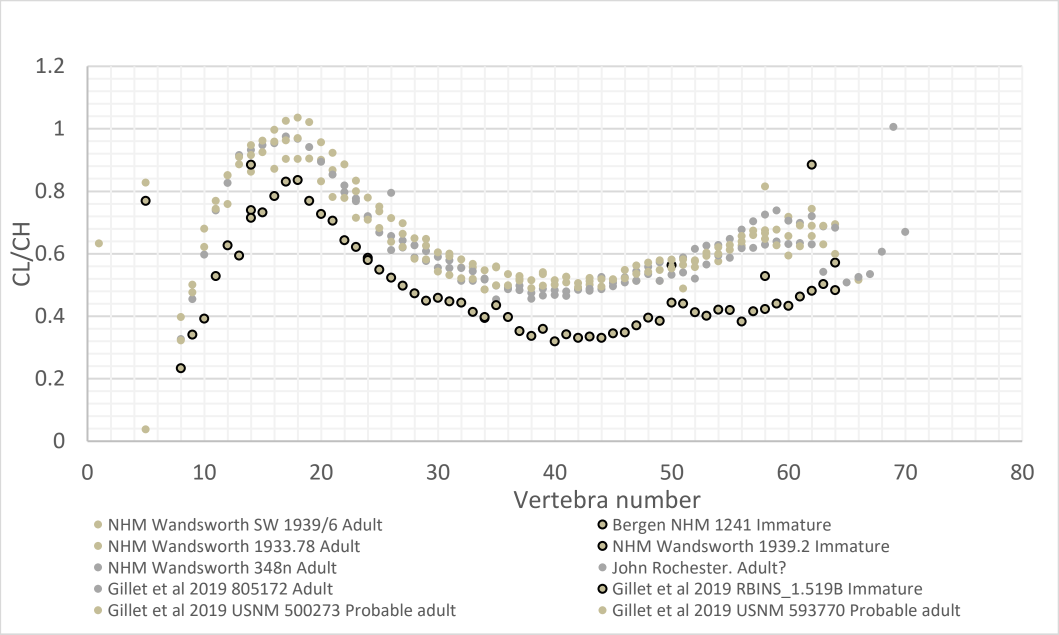

Figure 82 CL/CH Ratio in 10 immature and adult specimens of D. delphis.

Figure 82 shows the centrum length to height ratios for vertebrae of ten specimens of *D. delphis*. As predicted by Buchholtz' et al. (2005) data, there are differences between immature and adult values, and lumbar and caudal vertebrae were found to have greater differences than thoracic vertebrae. *L. acutus*, and other members of the Delphininae sub-family, which includes *D. delphis*, are known to have highly specialised vertebral morphology. As such, these patterns were also investigated amongst other taxonomic groups to determine whether all showed such ontogenetic differences, or whether this was specific to Delphininae.

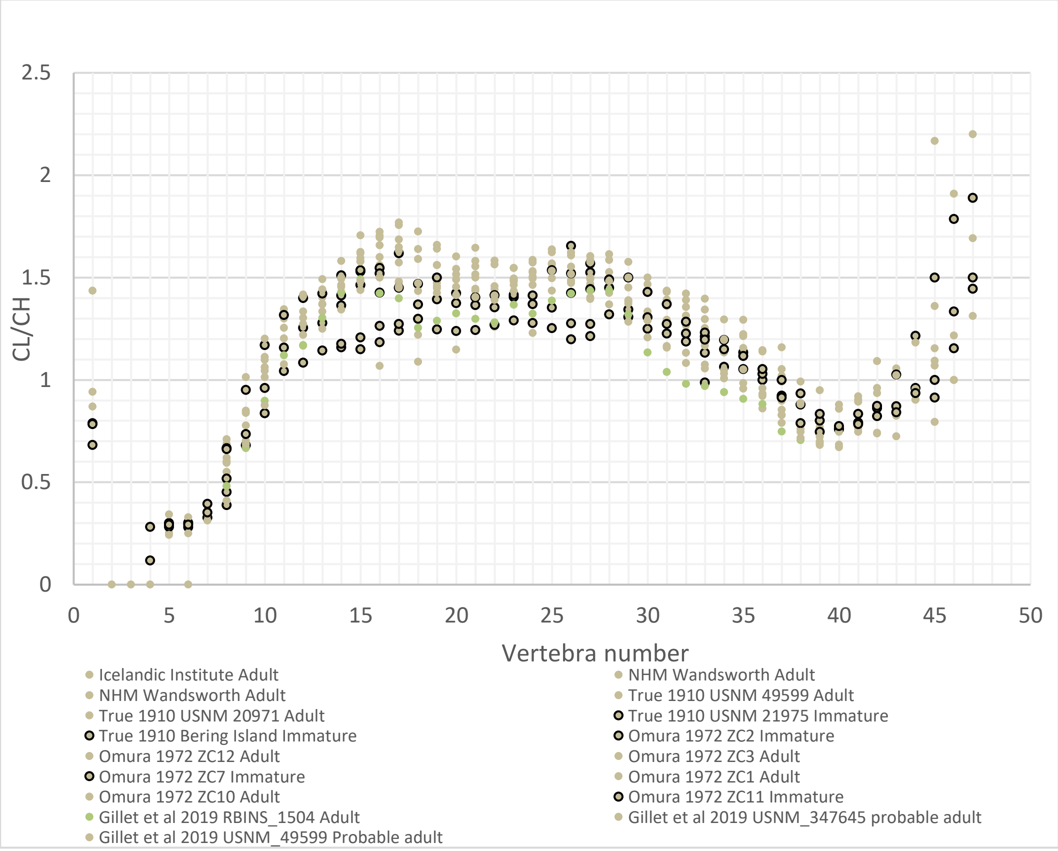

Figure 83 CL/CH Ratio in 17 young and adult specimens of Z. caviostris.

Figure 83 depicts the centrum length to height ratios for vertebrae of seventeen specimens of *Z. caviostris,* representing the Ziphiidae family. The specimens are the same as those depicted in Figure 81 which demonstrated the large variation in centrum lengths between adult and immature specimens[26]. Despite this, Figure 83 shows that the centrum length to height ratios all fall within the range represented by adult individuals demonstrating that there is no difference between adults and immature specimens when considering relative CL/CH in this species. This was also found to be true for specimens of *B. musculus* (Figure 84).

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[26] Note, the ratio of CL/CH is altered when epiphyses are absent

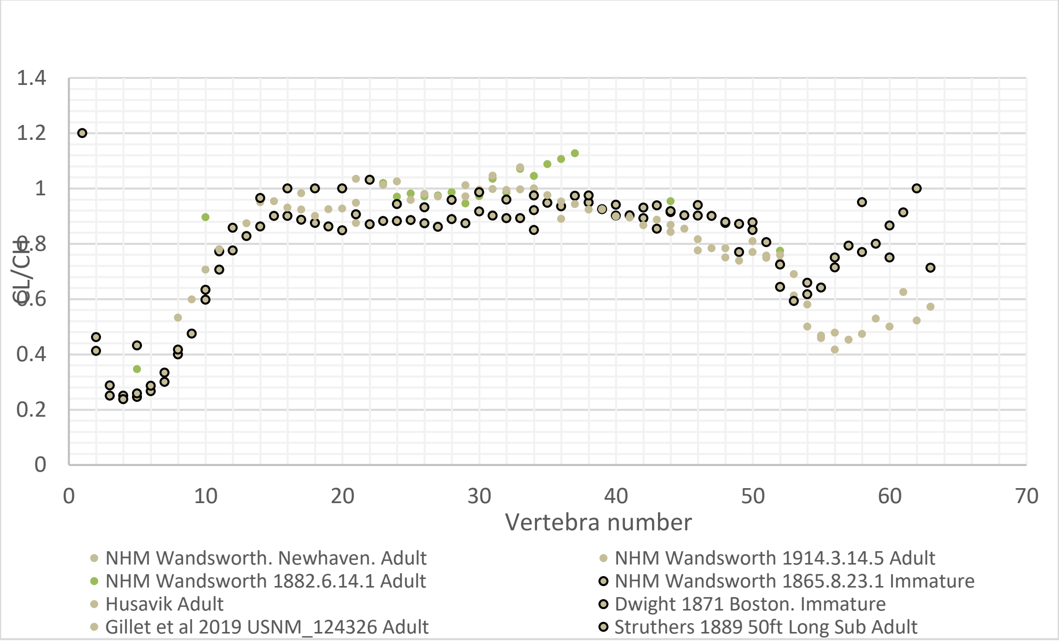

Figure 84 CL/CH Ratio in 8 immature and mature specimens of B. musculus

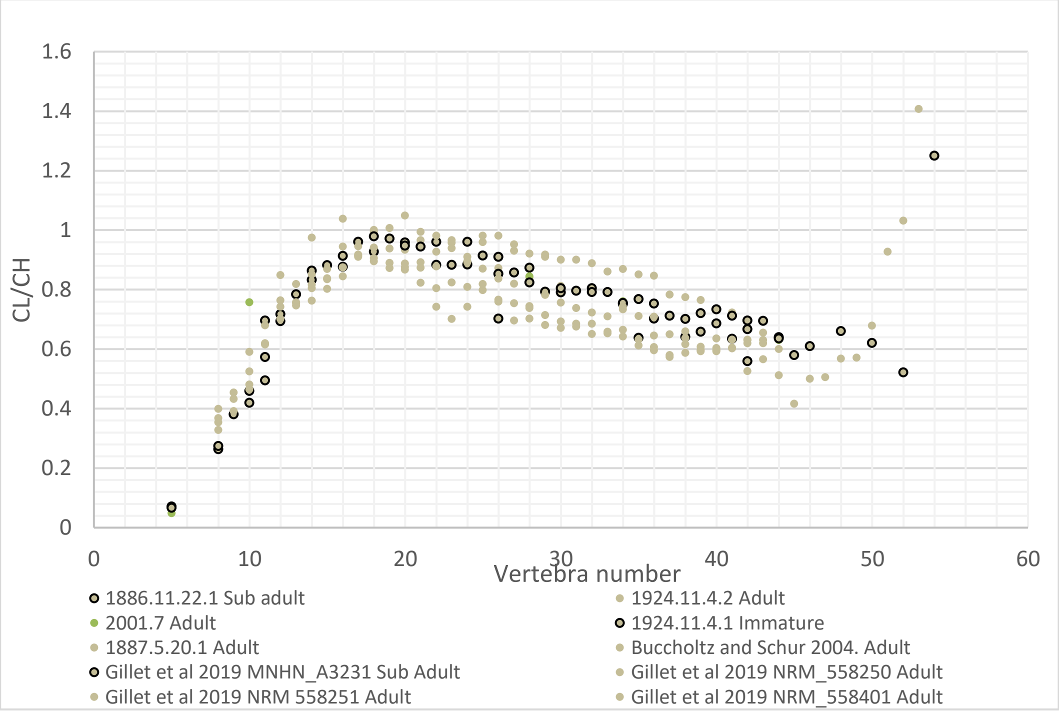

Figure 85 CL/CH Ratio in nine immature and adult specimens of O. orca

Figure 85 depicts the centrum length to height ratios for vertebrae of nine specimens of *O. orca*. This species lies within the same family as *L. acutus* and *D. delphis* (Delphinidae), but within a different sub family (Orcininae). Despite the apparent close taxonomic relationship, this species does not show the difference between CL/CH at different ontogenetic stages.

Ontogenetic changes were also investigated in other relative dimensions. Relative dimensions of the neural process height and centrum length were calculated for immature and mature specimens representing a range of species. As with other features, ontogenetic change is evident within specimens of the Delphininae sub-family (Buchholtz et al. 2005: 423), while in other species the range for immature specimens concurs with that of mature specimens (Figure 86- 88).

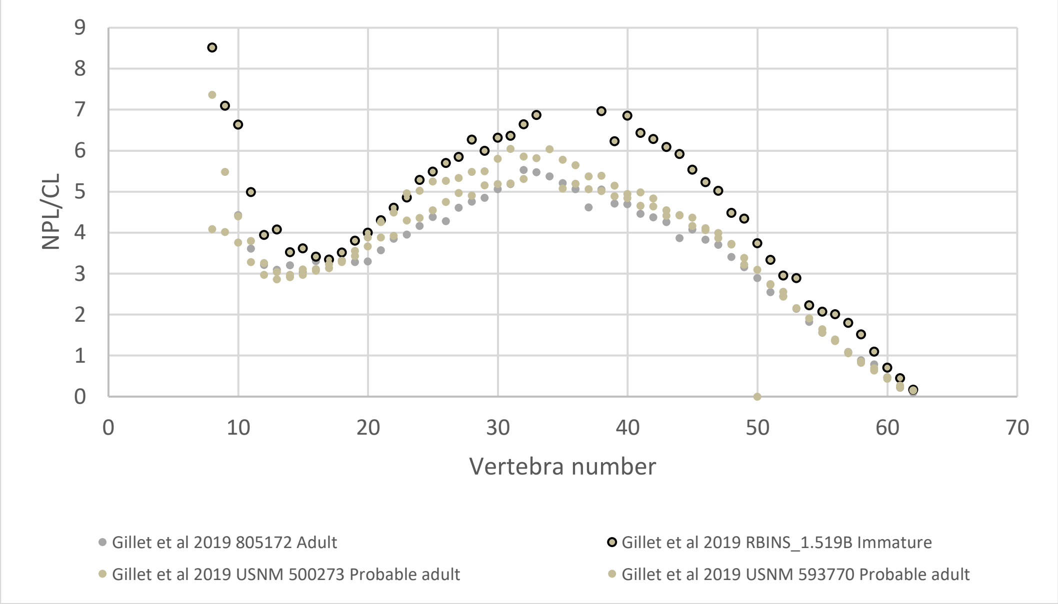

Figure 86 NPH/CL ratio in immature and mature specimens of D. delphis

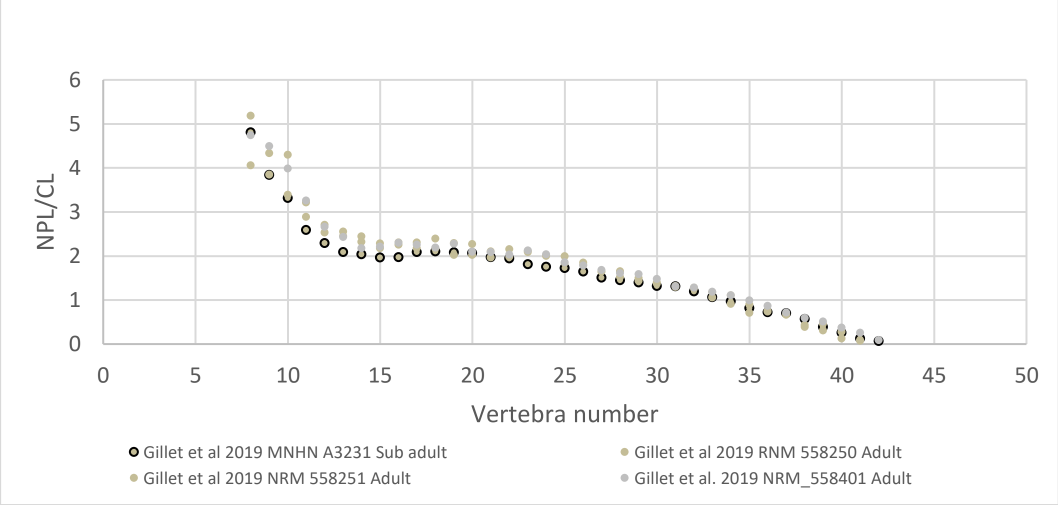

Figure 87 NPH/CL ratio in immature and mature specimens of O. orca

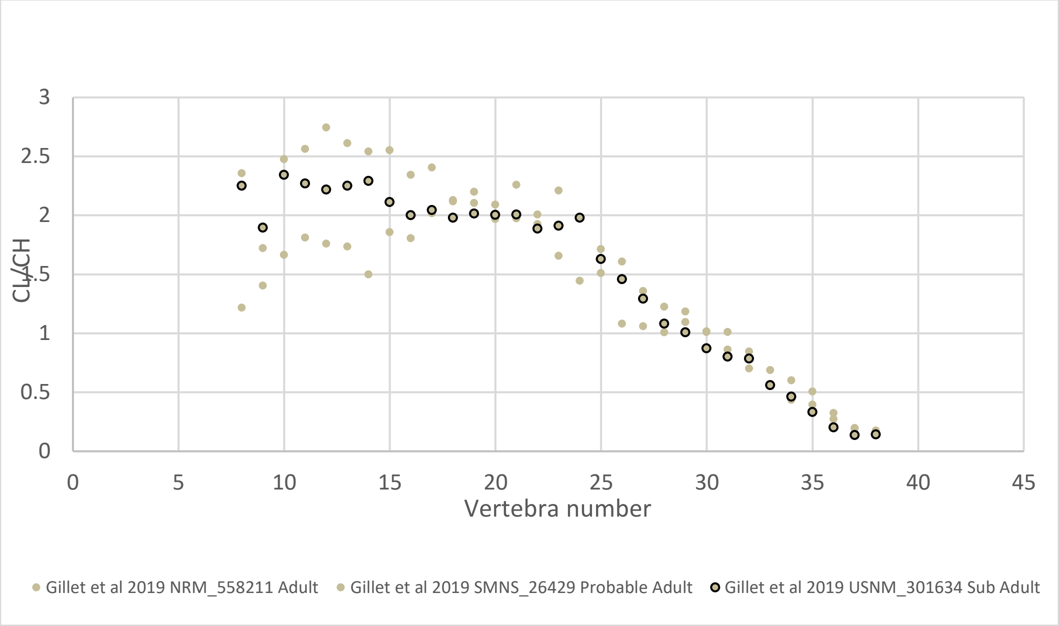

Figure 88 NPH/CL ratio in immature and mature specimens of P. macrocephalus

Consideration of ontogenetic change in a range of different taxonomic groups demonstrates that, with the exception of the Delphininae sub-family, while absolute measurements tend to increase with age until the time of physical maturity among all species, the overall shape of the bones represented by relative size is largely constant regardless of age. This reduces the effects of age as a variable, and demonstrates the overall suitability of ratios for investigation of zooarchaeological assemblages containing both immature and mature cetacean vertebrae.

6 SPECIMENS

Table 40 sets out a list of the specimens referred to within this study. These specimens provide the basis for the information set out within Chapter 5 and the data collated in Appendix 7. The table provides basic details about the specimen including sex and length (where known) and records made. Where evidence was from a secondary source the source is given (in the reference column). The 'Type of Record' column refers to what data was recorded and used. Most are self-explanatory. 'Measurements' refers to measurements recorded for specimens (by this and other studies, and used within the reference dataset); 'Visual assessment' refers to bones which were assessed and morphological features recorded but no measurements were taken (this is typically on articulated specimens or those out of reach); 'description' refers to reference to descriptions given in other sources. 'All' refers to recording and use of all data (i.e. measurements, photographs, visual assessment, description etc).

Species	Reference	Specimen	Type of record	Repository	Catch/Strand Location	Fusion	Age	Spine partial or complete	Sex	Length
B. musculus	This study	Presented by mssrs J. H. Bull and c. 18.x.24 (no number)	All	NHM Wandsworth	Newhaven	Fully fused	Adult	Single thoracic vertebra		
	This study	1914.3.14.5	All	NHM Wandsworth	South Georgia	Fully fused	Adult	Partial	Female	
	This study	1882.6.14.1	All	NHM Wandsworth		Fully fused	Adult	Near complete		
	This study	1865.8.23.1	All	NHM Wandsworth			Sub adult			
	This study	No. number	All	Husavik, Iceland		Fully fused	Adult	Complete		
	This study	Hope' Articulated display	Visual assessment	NHM Kensington		Fully fused	Adult	Complete		
	Gillet et al. 2019	USNM_124326	Measurements	Smithsonian	Newfoundland, North Atlantic	Fused	Adult		Male	22.76m
	Struthers 1871		Description		Off Aberdeen	Most fused	Sub-adult to Adult	Near complete		19.5m
	Struthers 1889	Nairn, 1884	All		Nairn, 1884		Sub adult	Complete		50 ft
	Struthers 1872	Peterhead, 1871	All		Peterhead, 1871			Measurements of cervical vertebrae only		64ft
	Struthers 1872	Stornoway, 1871	All		Stornoway, 1871			Measurements of cervical vertebrae only		60ft 6in
	Struthers 1872	Wick, 1869	All		Wick, 1869			Measurements of cervical vertebrae only		65ft 6 in
	Struthers 1872	Norway	All		Norway			Measurements of cervical vertebrae only		
	Dwight 1871		All	Boston NHM		Most unfused	Immature	Complete	Female	14.6m

	Delange 1886		Description		Langrune beach, Luc-sur-Mer		Immature or subadult	Near complete	Male	20m
	Lilljeborg 1866		All	Bergen Museum			Adult	Complete	Male	
	Lilljeborg 1866		All		Greenland		Immature		Male	
	True 1904		All	Ocean City						
	Van Beneden and Gervais 1880		Illustration					Cervical vertebrae only		
	Van Beneden and Gervais 1880		Illustration					Complete		
B. physalus	This study	1848.10.12.20; 793c	All	NHM Wandsworth		Fully fused	Adult	Near complete		
	This study	1885.6.30.4	All	NHM Wandsworth		Fully fused	Adult			
	This study	790c	All	NHM Wandsworth		Not fused	Immature			
	This study	Articulated display	Visual assessment	Stavanger Museum		Not fused	Sub-adult	Near complete		
	Gillet et al. 2019	NRM_558431	Measurements	Stockholm Museum			Probable sub-adult			
	Gillet et al. 2019	NRM_558434	Measurements	Stockholm Museum	South Georgia and the South Sandwich Islands		Adult			
	Huggenberger et al. 2019	Number not given	Photographs	Museum of Natural History of Milan, Italy				Cervical and anterior thoracic vertebrae		
	Murie 1865		All			Fully fused	Adult			60ft
	Museo di Storia Naturale del Mediterraneo	Annie	Visual assessment of 3D model	Museo di Storia Naturale del Mediterraneo (MUSMED)	Piombino					19m+

	(MUSMED) Sketchfab									
	Van Beneden and Gervais 1880		Illustrations					Selection of vertebrae, including cervical, thoracic, lumbar and caudal examples illustrated		
	Carrillo 2014	MZB 83–3084	All	Natural History Museum, Barcelona	Girona, Spain	Fully fused	Adult	Complete		
B. borealis	This study	1888.10.25.1	All	NHM Wandsworth			Sub adult		Male	
	This study	No number	All	NMS Granton			Sub adult			
	Andrews 1916		All	American Museum of Natural History			Sub adult			13.5m
	Gillet et al. 2019	NRM_558432	Measurements	Norway			Adult			
	Gillet et al. 2019	USNM_236680	Measurements	Smithsonian			Adult		Male	13.50m
	Lilljeborg 1866		All	Bergen Museum			Adult			
	Flower 1883		Description		River Crouch, Essex		Sub-adult		Male	8.8m
	Schulte 1916		Description				Foetus			
	Turner 1882	No number	Description	Purchased for Edinburgh University Anatomical Museum	Firth of Forth	Not fused	Sub-adult	Complete		c.38ft
	Van Beneden and Gervais 1880		Illustration					Selection of vertebrae, including cervical, thoracic, lumbar		

								and caudal examples illustrated		
	Van Beneden and Gervais 1880		Illustration					Selection of vertebrae, including cervical, thoracic, lumbar and caudal examples illustrated		
	Van Beneden and Gervais 1880		Description and Illustration			Partial fusion	Sub-adult	Selection of vertebrae, including cervical, thoracic, lumbar and caudal examples illustrated		
B. acutorostrata	This study	1956.36.23	All	NMS Granton			Adult		Female	
	This study	1913.9.26.1	All	NHM Wandsworth			Adult		Male	
	This study		All	Mu Ness, Shetland			Adult			
	This study	Articulated display	Visual assessment	Stavanger Museum		Not fused	Sub-adult	Complete		
	This study	Articulated display	Visual assessment	NMS Edinburgh		Fully fused	Adult	Complete		
	This study	No number	Visual assessment	Private collection of Neil Anderson, Shetland.		Not fused	Sub adult	Single vertebra		
	Flower 1864	No number	Description		Cromer, England	Fully fused	Adult		Male	25ft
	Gillet et al. 2019	USNM_49775	Measurements	Smithsonian	Massachussetts, North Atlantic		Probable adult			

	Gillet et al. 2019	NRM_558397	Measurements	Stockholm Museum	Bohuslän, Sweden		Adult			
	Omura 1957	18ft	All	Ayukawa Whale Museum			Immature	Near complete	Male	5.4m (18ft)
	Omura 1957	25 ft	All	National Science Museum in Tokyo.		Most unfused	Sub-adult	Near complete	Male	7.62 (25ft)
	Van Beneden and Gervais 1880		Illustrations					Complete		
	Watson and Fordyce 1993	Whale 1	Description and Illustration		New Zealand	Not fused	Immature		Female	
	Watson and Fordyce 1993	Whale 2	Description and Illustration		New Zealand	Not fused	Immature		Female	
M. novaeangliae	This study	1464a	All	NHM Wandsworth		Fully fused	Adult	Partial		
	This study	1829a.	All	NHM Wandsworth	San Francisco, California	Fully fused	Adult	Partial		
	This study	792b	All	NHM Wandsworth			Sub adult	Partial		
	This study	No number	All	Icelandic NHM		Unfused, discs not present	Immature	Partial		
	Gillet et al. 2019	NRM_558433	Measurements	Stockholm Museum	Norway		Adult			
	Gillet et al. 2019	SAM_ZM02288	Measurements		Table Bay, Western Cape, South Africa		Probable adult			
	Groch et al. 2012	122	Descriptions and photographs				Adult	Complete	Male	13.7m
	Groch et al. 2012	238	Descriptions and photographs				Adult	Partial	Male	14.3m

	Groch et al. 2012	242	Descriptions and photographs				Adult	Partial	Male	15.42m
	Groch et al. 2012	333	Descriptions and photographs				Sub adult	Partial		9.18m
	Groch et al. 2012	334	Descriptions and photographs				Uknown	Partial		
	Groch et al. 2012	382	Descriptions and photographs				Immature			9.0m
	Groch et al. 2012	391	Descriptions and photographs				Immature			11.0m
	Lilljeborg 1866		All							
	Rochester	No number	Photographs			Unfused	Immature			
	Struthers 1889		All	Firth of Tay			Immature	Complete	Male	40ft
	True 1904	Type specimen (Megaptera bellicosa)	Description (general) and Photographs		West Indies					
	True 1904	21492	Description (general)	USNM	Cape Cod, Mass.					
	True 1904	16252	Description (general)		Provincetown, Mass.		Immature		Female	
	True 1904	269	Description (general)	Brussels Museum	Greenland					
	Van Beneden and Gervais 1880		Illustration			Fused	Adult	Complete		

	Van Beneden and Gervais 1880		Illustration			Unfused	Immature	Selection of vertebrae, including cervical, thoracic, lumbar and caudal examples illustrated		
E. robustus	This study	Articulated display	Visual assessment	NHM Kensington		Fully fused	Adult			
	Lilljeborg 1866		All							
	Gillet et al. 2019	USNM_593558	All	Smithsonian			Probable adult			
	Nakamura and Kato 2014	M-804A	All				Adult		Female	12.79m
	Nakamura and Kato 2014	KPM-NF1001969	All			Discs likley absent	Immature		Male	8m
	Nakamura and Kato 2014	AMP-R9	All				Immature		Female	9.5m
	Nakamura and Kato 2014	NZM-159	All				Immature			7.7m
	Nakamura and Kato 2014	M-804B	All				Immature		Female	7.75m
	Andrews 1914		All							
B. mysticetus	This study	Articulated display	Visual assessment	NHM Kensington		Partial fusion	Sub-adult	Complete		
	Eschricht and Reinhardt 1866	44 1/2 ft	All				Adult?	Partial	Male	44 1/2 ft
	Eschricht and Reinhardt 1866	47 1/2 ft	Description and Illustration	Zootomical-Physiological Museum			Near adult	Complete	Male	47 1/2 ft

	Eschricht and Reinhardt 1866	22 1/3ft	Description				Sub-adult		Female	22 1/3ft
	Eschricht and Reinhardt 1866	Foetus	Description				Foetus	Complete	Female	8 1/2ft
	Van Beneden and Gervais 1880		Illustration			Fused but fusion lines still evident		Selection of vertebrae, including cervical, thoracic, lumbar and caudal examples illustrated		
	Van Beneden and Gervais 1880		Description			Partial fusion	Sub adult			
E. glacialis	This study	2010.346 (Thames whale)	All	NHM Wandsworth			Adult	Partial		
	This study	1911.5.31.1	All	NHM Wandsworth			Immature			
	This study	Articulated display	Visual assessment	NHM Kensington		Partial fusion	Sub adult	Complete		
	This study	Monkton Nature Reserve specimen	Visual assessment	Monkton Nature Reserve, Kent		Fused		Cervical vertebrae only		
	Andrews 1908		Description and photographs		Amagansett, Long Island, New York		Adult	Complete	Female	56ft 7 inches
	Andrews 1908		Description and photographs		Wainscott, Long Island, New York		Sub-adult	Complete	Female	c. 40ft
	Lilljeborg 1866		All				Immature			
	Gasco 1878		All		Taranto, Italy	Unfused	Immature		Female	12m

	Gillet et al. 2019	USNM_593893	Measurements	Smithsonian	Delaware, United States, North Atlantic		Probable adult		Male	45.2ft
	Gillet et al. 2019	NRM_558389	Measurements	Stockholm Museum	South Georgia and the South Sandwich Islands		Adult			
	Gillet et al. 2019	NRM_558386	Measurements	Stockholm Museum			Adult			
	Holder 1883 (recorded by G. E. Manigault)			City College Museum	Charleston, South Carolina		Sub-adult	Near complete	Male	
	Graells 1889		Description, Measurements and Illustration		Guetaria, Spain					10.46m
	True 1910	23077	Description	National Museum (Smithsonian?)	Long Island, USA					
	True 1910	Type specimen	Photographs	Philidelphia academy of natural sciences			Adult			
	Van Beneden and Gervais 1880		Illustration			Unfused	Immature	Selection of vertebrae, including cervical, thoracic and lumbar examples illustrated		
E. japonica	Omura et al. 1969	61A	All				Adult?			
	Omura et al. 1969	61B	All							
	Omura 1958	56A								
	Omura 1958	56B								

P. macrocephalus	This study	Moby	All	NMS Granton		Fully fused	Adult		Male	
	This study	2009.1568	Visual assessment and photographs	NHM Wandsworth		Unfused	Immature			
	This study	1978.2558	All	NHM Wandsworth		Unfused	Immature			
	This study	Articulated display	Visual assessment	Private collection (Vaila, Shetland)	Vaila, Shetland	Unfused	Immature			42ft
	This study	Articulated display	Visual assessment and photographs	NHM Kensington		Fully fused (probable)	Probable adult			
	Flower 1868		All	Museum of the Royal College of Surgeons	Tasmania	Partial fusion	Sub-adult	Near complete	Male	14.6m
	Flower 1868		All	British Museum of Natural History	Thurso, Caithness	Fully fused	Adult		Male	
	Flower 1868		All	Burton, Yorkshire	Yorkshire	Fully fused	Adult		Male	
	Gillet et al. 2019	NRM_558211	Measurements	Stockholm Museum			Adult			
	Gillet et al. 2019	SMNS_26429	Measurements				Probable adult			
	Gillet et al. 2019	USNM_301634	Measurements	Smithsonian		Thoracic epiphyses not fully fused	Sub-adult			
	James and Soundararajan 1981		All	Museum of the Mandapam, Regional Centre Marin© Fisheries Institute	Krusadiai Island, Indian Ocean		Immature		Male	8.1m

	Omura et al. 1962		All		Japan	Partial fusion	Sub-adult		Male	46ft
	Pouchet and Beauregard 1889	1886-602	All	Paris		Fully fused	Adult	Complete	Female	8.75m
	Pouchet and Beauregard 1889	No. 5681	All	Paris		Most unfused	Immature	Incomplete	Male	13.3m
	Slijper 1936									
	Van Beneden and Gervais 1880		Illustrations					Cervical vertebrae only		
	Van Beneden and Gervais 1880		Illustrations					Cervical vertebrae only		
	Van Beneden and Gervais 1880		Illustrations					Complete		
	Wall 1851		Description							
K. breviceps	This study	1891.10.13.1	All	NHM Wandsworth	Sri Lanka	Fully fused	Adult			
	This study	1981.109	All	NHM Wandsworth		Fused	Adult			
	This study	1873.6.25.1	All	NHM Wandsworth		Fused	Adult			
	This study	1952-8-28-2	All	NHM Wandsworth		Not fused	Immature			
	This study	73.6.25.2 and 1474.C	All	NHM Wandsworth		Fused	Adult			
	Benham 1902	Purakanui Specimen	Description	Dunedin, New Zealand	Purakanui, New Zealand	Not fused	Immature		Male	2.7m
	Van Beneden and Gervais 1880		Illustration				Adult			

	Gillet et al. 2019	PEM_N1862	Measurements	Port Elizabeth Museum	Keurboomstrand		Adult		Female	3.2m
	Gillet et al. 2019	PEM_N989	Measurements	Port Elizabeth Museum	Seaview, west of Port Elizabeth		Immature			
	Gillet et al. 2019	SMNS_7618	Measurements	Stuttgart			Probable adult			
	Gillet et al. 2019	USNM_572932	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Male	3.1m
	Gillet et al. 2019	USNM_504737	Measurements	Smithsonian	Virginia, United States, North Atlantic		Probable adult		Male	3.28m
	Wall 1851		Description	Australian Museum	Maroubra Beach, Australia			Near complete		c. 9ft
H. ampullatus	This study	1992.42	All	NHM Wandsworth		Fused	Adult			
	This study	1978.2560; SW 1938/25	Visual assessment	NHM Wandsworth	Keadby, Lincolnshire	Unfused	Immature			
	This study	1899.11.6.1	All	NHM Wandsworth		Fused	Adult			
	This study	1860.12.2.2	All	NHM Wandsworth		Fused	Adult			
	This study	1845.7.41	All	NHM Wandsworth		Fused	Adult			
	This study	Thames whale in casing	Visual assessment	NHM Wandsworth		Unfused	Immature			
	This study	2001.166	All	NMS Granton		Fused	Adult		Female	
	This study	No number	All	Husavik, Iceland		Fused	Adult			
	True 1910	14499	Description	National Museum (Smithsonian?)	Norway			Partial		
	Gerstaecker 1887		All		Hiddensöe, Baltic Coast, Germany		Unknown but size indicates adult	Near complete		

	Gillet et al. 2019	RBINS_1503	All				Sub-adult			
	Gillet et al. 2019	NRM_558402	All	Stockholm Museum	Uppland, Sweden		Adult		Female	
	Van Beneden and Gervais 1880		Illustration				Foetus/ very young	Complete		
	Van Beneden and Gervais 1880		Illustration				Adult	Complete		
Z. caviostris	This study	1965.7.1.1	All	NHM Wandsworth		Fused	Adult	Partial		
	This study	1915.7.20.1	All	NHM Wandsworth		Fused	Adult			
	This study	No number	All	Icelandic NHM		Fused	Adult	Thoracic sequence incomplete and whole spine incomplete. Some vertebrae missing from within the sequence		
	This study	Display	Description and photographs	Museu da Baleia da Madeira	Madera	Fused	Adult	Two lumbar and one caudal vertebrae		
	This study		Visual assessment	Neil Anderson Private Collection		Fused	Adult	Single vertebra (caudal)		
	Haast 1876		Description, Measurements and Illustration	Cantebury Museum, New Zealand	New Zealand	Fused	Adult		Female	26ft
	Rommel et al. 2006	504094	Illustrations	Smithsonian						
	True 1910	No. 49599.	All	National Museum (Smithsonian?)	Newport	Fused	Adult		Male	20ft 1 inch

	True 1910	No. 20971.	All	National Museum (Smithsonian?)	Barnegat City	Fused	Adult		Female	19ft 4 inches
	True 1910	No. 21975.	All	National Museum (Smithsonian?)	Charleston	Unfused	Immature		Female	12/13ft
	True 1910	No. 22875,	All	National Museum (Smithsonian?)	Bering Island	Unfused	Immature	Incomplete		
	Gillet et al. 2019	RBINS_1504	Measurements				Adult			
	Gillet et al. 2019	USNM_347645	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Female	5.83m
	Gillet et al. 2019	USNM_49599	Measurements	Smithsonian	Rhode Island, United States, North Atlantic		Probable adult		Male	5.64m
	Omura 1972	ZC2	Measurements				Immature			
	Omura 1972	ZC11	Measurements				Immature			
	Omura 1972	ZC7	Measurements				Immature			
	Omura 1972	ZC12	Measurements	Whales Research Institute	Japan	Fused	Adult		Male?	
	Omura 1972	ZC3	Measurements	Whales Research Institute	Japan	Fused	Adult		Female ?	
	Omura 1972	ZC1	Measurements	Whales Research Institute	Japan	Fused	Adult		Female ?	
	Omura 1972	ZC10	Measurements	Whales Research Institute	Japan	Fused	Adult		Female ?	
M. europeaus	This study	1956.7.17.1	All	NHM Wandsworth		Fused	Adult			
	This study	1953.10.6.1	All	NHM Wandsworth		Fused	Adult	Partial		
	True 1910	No. 23346,	All	USNM	Atlantic City	Unfused	Immature		Male	12.5ft
	Raven 1937		Description		Long Island, USA				Female	4.67m

	Gillet et al. 2019	USNM_593439	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Male	4.43m
	Gillet et al. 2019	USNM_572952	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Female	4.26m
	Gillet et al. 2019	USNM_550824	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Female	4.57m
	Gervais 1855; Van Beneden and Gervais 1880	Nos. A.2120 and 7737	Illustration of skull	Muse´e d'Histoire Naturelle de Caen, France,	Found floating in the English Channel			Skull only (body was not recovered)		
M. bidens	This study	No number	All	Icelandic NHM		Fused	Adult	Complete		
	This study	S.W. 1928: 4/ 1964.6.3.5.	All	NHM Wandsworth		Fused	Adult	Complete		
	This study	1964.6.3.4; SW 1940-9	All	NHM Wandsworth		Fused	Adult	Complete		
	Turner 1882		All		Shetland, UK	Fused	Adult	Near complete	Male	14ft
	True 1910		Description		Landenaes					
	True 1910		Description		Faeo					
	True 1910		Description		Udsire					
	Gillet et al. 2019	USNM_594220	Measurements	Smithsonian			Probable adult		Female	
	Gillet et al. 2019	NRM_558398	Measurements	Stockholm Museum	Bohuslän, Sweden		Adult			
	Gillet et al. 2019	MNHN_A14519	Measurements				Adult			
	J. Rochester (Flickr, n.d)		Measurements				Sub adult to adult (fusion			

							lines still visible)			
	Van Beneden and Gervais 1880		Illustration					Complete		
	Sowerby 1804; reported in Waller 2015; Gray 1846	No. 06998	Illustrations and description	Oxford University Museum of Natural History,	Moray Firth, Scotland			Partial skull only		
M. mirus	This study	1920-5-20-1	All	NHM Wandsworth		Fused	Adult			
	Raven 1937	No. 90053	Description and photographs	American Museum of Natural History	Long Island, USA	Fused	Adult		Female	4.87m
	Gillet et al. 2019	USNM_504724	Measurements	Smithsonian	Maryland, United States, North Atlantic	Closed, sutures visible	Adult		Male	4.56m
	Gillet et al. 2019	USNM_504612	Measurements	Smithsonian	New Jersey, North Atlantic		Probable adult		Female	4.83m
	Gillet et al. 2019	SAM_ZM36844	Measurements		Struis Baai, Cape Peninsula		Probable adult		Female	4.55m
	True 1913	USNM 175019	Description and photographs	Smithsonian	Beaufort Harbour, North Carolina, United States, North Atlantic		Adult	Skull, mandible, tail and pectoral fin only	Female	4.88m
M. densirostris	This study	No number	All	Icelandic NHM		Unfused	Immature	Partial (part of thoracic, lumbar and caudal regions absent)		

	Raven 1942	No. 139931	Measurements (CL only), description, photographs	American Museum of Natural History	Nova Scotia		Adult		Male	14ft 5 inches
	Andrews 1914	Not numbered in publication	Description	Academy of Natural Sciences of Philidelphia	Corson's Inlet, New Jersey		Adult			14ft 5 inches
	True 1910		Description	Boston NHM	Annisquam, Massachusetts,		Immature	Partial, cervical and thoracic vertebrae	Female	12ft 2in
	Gillet et al. 2019	USNM_550951	Measurements	Smithsonian	South Africa		Adult		Female	
	Gillet et al. 2019	USNM_550754	Measurements	Smithsonian	New York, United States, North Atlantic	Fused	Adult		Male	4.2m
	Gillet et al. 2019	USNM_504217	Measurements	Smithsonian	North Carolina, United States, North Atlantic	Epiphyses fused, sutures visible	Adult		Female	3.97m
	de Blainville (1817)	CAC: A.3552	Description	Laboratoire d’Anatomie Compare´e du Muse´um National d’Histoire Naturelle,				Skull fragment		
M. grayi	Flower 1878		Description and photographs	Museum of the Royal College of Surgeons	Saltwater Creek, New Zealand	Unfused	Immature	Near complete (terminal caudal veretbra may be missing)	Male	13ft 8inches
	Flower 1878		Description		Lyall Bay	Fully fused	Adult	Near complete (terminal caudal		15ft 6 inches

								veretbra may be missing)		
	Gillet et al. 2019	PEM_N0021	Measurements		Cape Recife, Algoa Bay	Fused	Adult		Male	4.72m
	Van Beneden and Gervais 1880		Illustration					Complete		
	von Haast 1876		Description and illustrations	Canterbury Museum, Christchurch and Otago Museum, Dunedin, New Zealand				Three partial skulls		
D. leucas	This study	1952.10.30.1	All	NHM Wandsworth		Fused	Adult	Incomplete (some vertebrae from within the sequence missing)		
	This study	1933.10.13.4	All	NHM Wandsworth		Fused	Adult	Partial		
	This study	367a	All	NHM Wandsworth		Near complete fusion	Sub adult			
	This study	1952.10.30.2	All	NHM Wandsworth		Fused	Adult			
	Barclay and Neill 1816		Description		Firth of Forth		Adult		Male	13ft 4 inches
	Gillet et al. 2019	USNM_571021	Measurements	Smithsonian	Washington, Maine, North Atlantic		Probable adult		Male	3.99m
	Gillet et al. 2019	RBINS_1508	Measurements				Adult			

	Gillet et al. 2019	MNHN_A3246	Measurements				Probably sub-adult			
	Gillet et al. 2019	NRM_558404	Measurements	Stockholm Museum	Spitsbergen, Svalbard and Jan Mayen		Adult			
	Van Beneden and Gervais 1880		Illustration				Adult	Complete		
	Van Beneden and Gervais 1880		Illustration				Foetus	Complete		
	Wyman 1863		Description		Gulf of St Lawrence			Cervical vertebrae only described	Male	
M. monocerus	This study	1952.10.30.3	All	NHM Wandsworth		Fused	Adult			
	This study	1885.2.20.1; 369e	All	NHM Wandsworth		Fused	Adult			
	This study	1887.9.8.1/ 1937.10.30.1	All	NHM Wandsworth		Fused	Adult			
	This study	1949.11.2.1	All	NHM Wandsworth		Fused	Adult			
	This study	No number	All	Iceland NHM		Fused	Adult			
	Gillet et al. 2019	USNM_594407	Measurements	Smithsonian			Probable adult?			
	Gillet et al. 2019	NRM_558407	Measurements	Stockholm Museum	Svalbard, Norway		Adult		Male	
	Gillet et al. 2019	MNHN_A3235	Measurements				Adult			
	Van Beneden and Gervais 1880		Illustration				Adult	Complete		
	Van Beneden and Gervais 1880		Illustration				Foetus	Complete		

	Van Beneden and Gervais 1880		Illustration				Adult	Cervical vertebrae only		
P. crassidens	This study	1936.6.23.1	All	NHM Wandsworth		Fused	Adult			
	This study	1961.6.14.2	All	NHM Wandsworth	Dornoch Firth, Scotland	Fused	Adult		Female	
	This study	1961.6.14.89	All	NHM Wandsworth	Dornoch Firth, Scotland	Fused	Adult			
	This study	1961.6.14.78	All	NHM Wandsworth	Dornoch Firth, Scotland	Fused	Adult			
	This study	1961.6.14.90	All	NHM Wandsworth	Dornoch Firth, Scotland	Fused	Adult			
	This study	1992.244	All	NHM Wandsworth		Fused	Adult			
	This study	1961.6.14.22/ B22c	All	NHM Wandsworth	Dornoch Firth, Scotland	Fused	Adult			
	Gillet et al. 2019	QM_J14210	Measurements				Adult			
	Gillet et al. 2019	NRM_558405	Measurements	Stockholm Museum	Dornoch Firth, Scotland		Adult			
	Gillet et al. 2019	NRM_558271	Measurements	Stockholm Museum	Dornoch Firth, Scotland		Adult		Female	
	Gillet et al. 2019	SMNS_7617	Measurements				Probable adult			
	Reinhardt 1866		Description		Asnaes, Sealand, Denmark	Fused	Adult	Partial, cervical vertebrae	Female	
	Reinhardt 1866		Description		Refsnaes, Sealand, Denmark	Not fused	Sub-adult (?)	Near complete		14ft
	Reinhardt 1866		Description		Middlefart, Funen, Denmark	Fused	Adult	Near complete	Male	

	Slijper 1939	2236	Description and Illustration	Leiden Museum	Dornoch Firth, Scotland		Adult	Near complete	Female	
	Slijper 1939	5.7.23.1	Description and Illustration	NHM London	Travancore		Immature		Male	
	Slijper 1939	2393	Description	Leiden Museum						
	Slijper 1939	2340		Leiden Museum						
	Van Beneden and Gervais 1880		Illustration					Cervical vertebrae		
	Van Beneden and Gervais 1880		Illustration					Cervical vertebrae and caudal vertebra		
O. orca	This study	1924.11.4.2	All	NHM Wandsworth	South Shetland	Fused	Adult			
	This study	1887.5.20.1	All	NHM Wandsworth	Bildoen Island, Norway	Fused	Adult		Male	
	This study	2001.7	All	NMS Granton		Fused	Adult		Male	
	This study	1886.11.22.1	All	NHM Wandsworth		Fused	Adult		Female	
	This study	1924.11.4.1	All	NHM Wandsworth	South Shetland		Immature?			
	Buchholtz and Schur 2004		All			Fused	Adult			
	Gillet et al. 2019	NRM_558250	Measurements	Stockholm Museum			Adult			
	Gillet et al. 2019	NRM_558251	Measurements	Stockholm Museum	Finnmark, Norway		Adult			
	Gillet et al. 2019	NMR_558401	Measurements	Stockholm Museum	Bohuslän, Sweden		adult			
	Gillet et al. 2019	MNHN_A3231	Measurements			Some epiphyses not totally fused (especially	Probably sub-adult			

						in the anterior cuadal region)				
	Van Beneden and Gervais 1880		Illustration			Fused	Adult	Complete		
	Online 3D model www.ptmsc.org .boneatlas	Hope	Illustrations		Washington	Fused	Adult		Female	
G. melas	This study	1952.10.30.5	All	NHM Wandsworth		Fused	Adult			
	This study	1952.10.30.6	All	NHM Wandsworth		Fused	Adult			
	This study	1997.116.42	All	NMS Granton		Fused	Adult		Female	
	This study	1912.10.27.1 (B42A)	All	NHM Wandsworth		Partial fusion	Sub adult			
	This study	1911.7.3.1/SW1911 a	All	NHM Wandsworth		Partial fusion	Sub adult			
	This study	1868.1.30.1; case 7Bb	All	NHM Wandsworth		Partial fusion	Sub adult		Female	
	This study	1932.1	All	NHM Wandsworth		No fusion	Immature			
	This study	1948.3.4.1	All	NHM Wandsworth		Fused	Adult			
	Sweeny et al. 2005	NUVC 2157	Photographs	Northeastern University in Boston,	Cape Cod Bay, Mssachusetts	Fused	Adult	Caudal vertebra only	Female	
	Sweeny et al. 2005	NUVC 4247	Photographs	Northeastern University in Boston,	Cape Cod Bay, Mssachusetts		Adult	Lumbar and caudal vertebra only	Female	

	Sweeny et al. 2005	NUVC 2345	Photographs	Northeastern University in Boston,	Cape Cod Bay, Mssachusetts	Fused	Adult	Thoracic vertebra only	Male	
	Gillet et al. 2019	NRM_558264	Measurements	Stockholm Museum			Adult			
	Gillet et al. 2019	USNM_21118	Measurements	Smithsonian	Tasmania, South Pacific		Probable adult			
	Van Beneden and Gervais 1880		Illustration			Fused	Adult	Complete skeleton and Selection of cervical vertebrae, thoracic, lumbar and caudal vertebrae		
G. griseus	This study	1920.12.16.1	All	NHM Wandsworth		Partial fusion	Sub adult			
	This study	1872.1.11.1 and 1573a and a53c	All	NHM Wandsworth		Fused	Adult			
	This study	SW.1928.22 and b52a	All	NHM Wandsworth		Fused	Adult			
	Flower 1871		Description	British Museum of Natural History	Eddystone Lighthouse, Plymouth		Adult		Female	
	Gillet et al. 2019	MNHN_A3248	Measurements				Adult			
	Gillet et al. 2019	PEM_N117	Measurements		Sardina Bay, west of Port Elizabeth	Discs may be absent	Immature		Female	2.56m
	Gillet et al. 2019	USNM_347613	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Male	3.01m

	Gillet et al. 2019	USNM_504328	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Sub-adult/adult		Male	2.91m
	J. Rochester (Flickr, n.d)	NMS.Z.2011.41.9	Measurements	NMS			Adult			
	Slijper 1936	Le. 12-5-1924	Schematic					Complete		
	Van Beneden and Gervais 1880		Illustration					Cervical vertebrae		
	Van Beneden and Gervais 1880		Illustration				Probable adult	Complete skeleton and Selection of cervical vertebrae, thoracic, lumbar and caudal vertebrae		
T. truncatus	This study	1993.36.5	All	NMS Granton		Fused	Adult		Male	
	This study	1994.13.33	All	NMS Granton		Fused	Adult		Female	
	This study	1866.8.7.1	All	NHM Wandsworth		Fused	Adult		Male	
	This study	1951.11.26.2	All	NHM Wandsworth		Fused	Adult			
	This study	66.8.7.2/ 353e	All	NHM Wandsworth		Fused	Adult	Complete		
	This study	Articulated display	Photographs	Ramsgate Maritime Museum	River Medway, Gillingham.	Fused	Adult	Near complete		
	Buchholtz and Schur 2001		All							
	Cozzi et al. 2017		Photographs and description			Most unfused	Juvenile			

	Gillet et al. 2019	USNM_572831	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Female	2.46m
	Gillet et al. 2019	USNM_571388	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Female	2.85m
	Gillet et al. 2019	USNM_550852	Measurements	Smithsonian	North Carolina, United States, North Atlantic	Fused	Adult		Male	2.48m
	Gillet et al. 2019	USNM_550422	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Male	2.79m
	Gillet et al. 2019	USNM_550364	Measurements	Smithsonian	North Carolina, United States, North Atlantic	Fused	Adult		Female	2.58m
	Gillet et al. 2019	USNM_550225	Measurements	Smithsonian	North Carolina, United States, North Atlantic	Fused	Adult		Female	2.58m
	Gillet et al. 2019 and Rommel 1990	USNM_504906	Measurements (Gillet et al. 2019) and Description (Rommel 1990)	Smithsonian	South Carolina, United States, North Atlantic		Probable adult		Male	2.88m
	Gillet et al. 2019 and Rommel 1990	USNM_504726	Measurements (Gillet et al. 2019) and Description (Rommel 1990)	Smithsonian	South Carolina, United States, North Atlantic	Fused	Adult		Male	2.98m

	Gillet et al. 2019 and Rommel 1990	USNM_504618	Measurements (Gillet et al. 2019) and Description (Rommel 1990)	Smithsonian	Canada, North Atlantic		Probable adult		Female	2.8m
	Gillet et al. 2019	USNM_484529	Measurements	Smithsonian	South Carolina, United States, North Atlantic	Epiphyses fused, sutures invisible	Adult		Female	2.43m
	Gillet et al. 2019	SAM_ZM35678	Measurements		Italy, Adriatic Coast		Probable adult			
	Rommel 1990	22034	Description	Smithsonian					Female	
	Rommel 1990	396165	Description	Smithsonian					Male	3.03m
	Rommel 1990	500863	Description	Smithsonian					Male	2.61m
	Rommel 1990	504326	Description	Smithsonian					Female	2.8m
	Rommel 1990	504766	Description	Smithsonian					Male	3.09m
	Rommel 1990	550109	Description	Smithsonian					Female	2.2m
	Rommel 1990	550375	Description	Smithsonian					Male	3.1m
	Slijper 1936	Le 1758	Schematic					Complete		
	Slijper 1936	Le 1998	Photograph					Complete		
	Van Beneden and Gervais 1880		Illustration					Complete		
P. electra	This study and Dawbin et al. 1970	1959.7.9.2	All	NHM Wandsworth		Unfused	Immature			
	Dawbin et al. 1970	1965.6.2.1	Description	NHM Wandsworth		Unfused	Newborn			

	Dawbin et al. 1970	W.A.M. 4798	Description			Fused	Adult	Illustration of thoracic vertebrae		
	Best et al. 1981	ZM 38245	Description	South African Museum			Adult	Complete	Male	2.48m
	Bryden et al. 1977									
	Gillet et al. 2019	SAM_ZM38245	Measurements		Hout Bay, Cape Peninsula, South Africa		Probable adult		Male	2.48m
	Gillet et al. 2019	USNM_593941	Measurements	Smithsonian			Probable adult		Male	2.47m
	Gillet et al. 2019	USNM_593799	Measurements	Smithsonian			Probable adult		Male	2.46m
	Gillet et al. 2019	USNM_550399	Measurements	Smithsonian	Maryland, United States, North Atlantic		Probable adult		Female	2.46m
	Nakajima and Nikiwashi 1965		Measurements		Hiratsuka Beach, Sagami Bay, Japan	Fully fused	Adult		Male	2.60m
D. delphis	This study	348n	All	NHM Wandsworth						
	This study	1241	All	Bergen NHM		Unfused	Immature			
	This study	1933.78	All			Fused	Adult		Female	
	This study	1939.2	All	NHM Wandsworth	Cornwall	Unfused	Immature			
	This study	SW 1939/6	All	NHM Wandsworth		Fused	Adult			
	Gillet et al. 2019	USNM_593770	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Female	1.79m

	Gillet et al. 2019	USNM_500273	Measurements	Smithsonian	Baja California, Mexico, North Pacific		Probable adult			2.07m
	Gillet et al. 2019	RBINS_1.519B	Measurements			Uncertain if discs are present. Removed from CL/CH charts	Juvenile or subadult			
	Gillet et al. 2019	NRM_805172	Measurements	Stockholm Museum	Bohuslän, Sweden		Adult		Female	
	Huggenberger et al. 2018	Photographs	Description	Museum of Natural History of Milan, Italy				T4,L4 and Ca4 only		
	Martinez and Stockin 2013		Photographs		Torbay, New Zealand	Unfused	Immature		Male	
	J. Rochester (Flickr, n.d)		Measurements				Sub-adult			
	Slijper 1936	Le 1653	Schematic					Complete		
	Van Beneden and Gervais 1880		Illustration					Cervical vertebrae only		
	Van Beneden and Gervais 1880		Illustration					Complete		
S. coeruleoalba	This study	No number	All	Icelandic NHM		Unfused	Immature			
	Gillet et al. 2019	USNM_504384	Measurements	Smithsonian	North Pacific		Probable adult		Male	2.08m
	Gillet et al. 2019	USNM_504350	Measurements	Smithsonian			Probable adult			

	Gillet et al. 2020	PEM_N289	Measurements		Coega River Mouth, Algoa Bay		Adult		Male	2.44
	Haruka and Nobuyuki 1990		Measurements				Adult			
L. hosei	Gillet et al. 2019	USNM_571619	Measurements	Smithsonian			Probable adult		Female	
	Gillet et al. 2019	PEM_N827	Measurements		Port Edward		Probable adult		Female	2.26
	Gillet et al. 2019	PEM_N395	Measurements		Isipingo Beach		Adult		Male	2.59
	Lucero et al. 2009	MLP 2.IV.02.2	Description		La Plata River, Argentina		Sub-adult	Incomplete	Female	
	Lucero et al. 2009	MLP 30.XII.02.30	Description		La Plata River, Argentina		Sub-adult	Incomplete	Female	
	Lucero et al. 2009	MACN 21480	Description				Sub-adult	Complete	Male	
	Miyazaki and Wada 1978	TK451	Measurements and description	Ocean Research Institute, Universtity of Tokyo		Partial fusion	Immature		Female	2.31m
	Miyazaki and Wada 1978	TK452	Measurements and description	Ocean Research Institute, Universtity of Tokyo		Partial fusion	Immature		Male	1.83m
L. acutus	This study	1920.6.28.1	All	NHM Wandsworth		Unfused	Immature		Male	
	This study	1917.9.5.1	All	NHM Wandsworth		Fused	Adult			
	Gillet et al. 2019 and Buchholtz et al. 2005	USNM_504153	Measurements and description	Smithsonian	Washington, Maine, North Atlantic	Epiphyses closed, sutures visible	Adult	Incomplete	Male	2.61m
	Gillet et al. 2019	USNM_504154	Measurements	Smithsonian	Washington, Maine, North Atlantic	Epiphyses closed,	Adult		Female	2.34m

						sutures visible				
	Gillet et al. 2019	USNM_504164	Measurements	Smithsonian		Epiphyses closed, sutures visible	Adult		Female	2.19m
	Buchholtz et al. 2005	MCZ 60939	Illustrations					Complete	Male	
	Buchholtz et al. 2005	USNM 571828	Description	Smithsonian				Complete	Female	
	Buchholtz et al. 2005	NUVC 2694	Description	Northeastern University				Incomplete	Female	
	Buchholtz et al. 2005	USNM 22934	Description	Smithsonian				Incomplete	Male	
	Buchholtz et al. 2005	USNM 504082	Description	Smithsonian				Complete	Male	
	Buchholtz et al. 2005	NUVC1968	Description	Northeastern University				Complete	Female	
	Buchholtz et al. 2005	NUVC2702	Description	Northeastern University				Incomplete	Male	
	Buchholtz et al. 2005	MCZ62383	Description	Museum of Comparative Zoology				Incomplete	Female	
	Buchholtz et al. 2005	NUVC 2461	Description	Northeastern University				Incomplete		
	Buchholtz et al. 2005	MCZ 62377	Description	Museum of Comparative Zoology				Complete	Female	
	Buchholtz et al. 2005	NUVC 2701	Description	Northeastern University				Incomplete	Male	

	Buchholtz et al. 2005	NUVC 2712	Description	Northeastern University				Complete	Female	
	Buchholtz et al. 2005	MCZ 62382	Description	Museum of Comparative Zoology				Incomplete	Female	
	Buchholtz et al. 2005	NUVC 2706	Description	Northeastern University				Incomplete		
	Buchholtz et al. 2005	USNM 22942	Description	Smithsonian				Incomplete		
	Buchholtz et al. 2005	NUVC 2715	Description	Northeastern University				Incomplete	Female	
	Buchholtz et al. 2005	AMNH 143513	Description	American Museum of Natural History				Complete		
	Buchholtz et al. 2005	USNM 484922	Description	Smithsonian				Complete	Female	
	Buchholtz et al. 2005	NUVC 2707	Description	Northeastern University				Incomplete	Female	
	Buchholtz et al. 2005	NUVC 4167	Description	Northeastern University				Incomplete	Female	
	Buchholtz et al. 2005	USNM 504754	Description	Smithsonian				Complete	Female	
	Buchholtz et al. 2005	MCZ 62380	Description	Museum of Comparative Zoology				Complete	Male	
	Buchholtz et al. 2005	MCZ 60939	Description	Museum of Comparative Zoology				Complete	Male	
	Buchholtz et al. 2005	MCZ 61008	Description	Museum of Comparative Zoology				Complete	Male	

	Buchholtz et al. 2005	NUVC 2696	Description	Northeastern University				Incomplete	Male	
	Buchholtz et al. 2005	NUVC 2711	Description	Northeastern University				Incomplete		
	Buchholtz et al. 2005	USNM 571391	Description	Smithsonian				Complete		
	Buchholtz et al. 2005	MCZ 62384	Description	Museum of Comparative Zoology				Complete	Male	
	Buchholtz et al. 2005	MCZ62379	Description	Museum of Comparative Zoology				Complete	Male	
	Van Beneden and Gervais 1880		Description					Selection of vertebrae illustrated including cervical, thoracic, lumbar and caudal		
	Buchholtz and Schur 2004		Measurements							
L. albirostris	This study	916 d, B48b.	All	NHM Wandsworth		Fused	Adullt			
	This study	1992.84	All	NHM Wandsworth		Fused	Adullt			
	This study	Articulated display	Photographs and description	NHM Wandsworth	South Coast, England	Unfused	Immature		Female	
	This study	BM689	All	Bergen NHM		Partial fusion	Sub-adult			
	This study	696	All	Bergen NHM						
	Gillet et al. 2019	NRM_20065395	Measurements	Stockholm Museum	Halland, Sweden		Adult			

	Gillet et al. 2019	SMNS_7591	Measurements		North Sea		Probable adult			
	Gillet et al. 2019	USNM_550208	Measurements	Smithsonian	Massachussetts, North Atlantic		Probable adult		Female	2.38m
	Kompanje 1999	RMNH 21046	Photographs	National Museum of Natural History, Leiden	Kijkduin, Netherlands		Adult	Lumbar and caudal vertebra only	Female	
	Slijper 1936	Le 824	Schematic					Complete		
	Slijper 1936	Le 1827	Photograph					Lumbar and caudal		
	John Rochester, Flickr		Measurements				Sub-adult			
	Buchholtz and Schur 2001		Measurements							
P. phocoena	This study	1989.23.2	Measurements and description	NMS Granton		Fused	Adult		Female	
	This study	1982.35	Measurements and description	NMS Granton		Fused	Adult		Male	
	This study	1934 / 32 (SW)	Measurements	NHM Wandsworth		Fused	Adult			
	This study	B 1780	Measurements and description	Bergen NHM		Fused	Adult		Female	
	This study	No number	Measurements and description	Cardiff University		Fused	Adult			
	Gillet et al. 2019	RM_20065226	Measurements							
	Gillet et al. 2019	NRM_558322	Measurements	Stockholm Museum	Småland, Sweden		Adult			

	Gillet et al. 2019	NRM_805026	Measurements	Stockholm Museum	Bohuslän, Sweden		Adult		Male	
	Gillet et al. 2019	NRM_815072	Measurements	Stockholm Museum	Bohuslän, Sweden		Adult		Male	
	Gillet et al. 2019	NRM_835011	Measurements	Stockholm Museum	Bohuslän, Sweden		Adult		Male	
	Gillet et al. 2019	NRM_845002	Measurements	Stockholm Museum	Halland, Sweden		Adult		Male	
	Gillet et al. 2019	NRM_855083	Measurements	Stockholm Museum	Bohuslän, Sweden		Adult		Female	
	Gillet et al. 2019	NRM_855196	Measurements	Stockholm Museum	Skåne, Sweden		Adult		Female	
	Gillet et al. 2019	NRM_865044	Measurements	Stockholm Museum	Blekinge, Sweden		Adult		Female	
	Gillet et al. 2019	NRM_875045	Measurements	Stockholm Museum	Skåne, Sweden		Adult		Female	
	Gillet et al. 2019	NRM_875216	Measurements	Stockholm Museum	Halland, Sweden		Adult		Male	
	Gillet et al. 2019	NRM_895156	Measurements	Stockholm Museum	Skåne, Sweden		Adult		Female	
	Gillet et al. 2019	USNM_550312	Measurements	Smithsonian	North Carolina, United States, North Atlantic		Probable adult		Female	1.58m
	Gillet et al. 2019	USNM_571709	Measurements	Smithsonian	United States, North Atlantic		Probable adult		Male	1.6m
	Kastelein et al. 1997	Study Animal 2	Photograph	Natural History Museum, Leiden			Adult			
	Van Waerebeek	Reg 1530	Measurements	Brussels Natural History Museum	River Nete, Belgium		Adult		Male	
	Van Waerebeek	Reg 1529	Measurements	Brussels Natural History Museum	Brittany, France		Adult		Female	
	Van Waerebeek	Reg 1529	Measurements	Brussels Natural History Museum	Near Antwerp		Adult		Female	
	Van Waerebeek	14517	Measurements	Institute for Taxonomic Zoology,	Schiermonnikoog, Wadden Sea		Adult		Male	

				University of Amsterdam						
	Van Waerebeek	4794	Measurements	Institute for Taxonomic Zoology, University of Amsterdam	South of Doggerbank		Adult		Female	
	Van Waerebeek	RN 2606	Measurements	Zoological Museum, Rijksuniversitiet, Gent	Poss. Belgian Coast		Adult			
	Van Beneden and Gervais 1880		Illustration				Probable adult	Complete		
	Van Beneden and Gervais 1880		Illustration				Foetus	Complete		
	Tensmuir 1986		Measurements							

Table 40 Specimens included within this study

Appendix 4: Cetacean bone register for Cladh Hallan

See spreadsheet titled: Appendix 4_Cetacean Bone Register_Cladh Hallan

Appendix 5: Cetacean bone register for Bornais

See spreadsheet titled: Appendix 5_Cetacean Bone Register_Bornais

Appendix 6: Detailed results of morphometric analysis to the Cladh Hallan and Bornais assemblages

1 INTRODUCTION

The results of the application of the methodology for morphometric identification of cetacean vertebrae to the assemblages from Cladh Hallan and Bornais are set out within this appendix. Detailed discussion and evidence is set out where vertebrae have been suitable for such analysis. This includes vertebrae which are fused and sufficiently complete for the method set out within Chapter 5 to be applied. Identifications can be gauged with reference to the data set out in Chapter 5 and Appendix 7 even where bones are unfused or incomplete, though identifications are typically to higher taxonomic levels where this is the case. Identification of other vertebrae is set out within this appendix.

Basic details of each vertebra are noted first including identification of the region and precise position of the spine. The dimensions are then reported on and relative dimensions calculated, following the method set out in Chapter 5. This is followed by discussion on identification using comparisons with the morphometric data discussed in Chapter 5 and Appendix 3, and presented in full in Appendix 7.

2 CLADH HALLAN

The following sections give details of vertebrae from Cladh Hallan.

2.1 VERTEBRA (CONTEXT 1447; SF 4265)

The bone is identified as a caudal vertebra and is fused on both faces. The top of vertebra (dorsal aspect) is missing. However, the centrum height (CH) is still greater than centrum width (CW) indicating it is a pre-fluke caudal vertebra. The presence of arterial foramen and lack of transverse processes supports a position in the lower caudal but pre-fluke region. The absence of transverse processes allows the position to be relatively closely defined as the few vertebrae in the immediately pre-fluke region.

Table 41 provides details of the dimensions. As the dorsal aspect is missing it is not possible to tell whether a neural process was present. However, even without the complete CH the CL/CH is 0.5 and with a greater original CH this would be lower. Centrum width and length form the complete dimensions and so have been used as a basis for identification here.

Dimension	Measurement
Centrum Length	26 mm
Centrum Width	50 mm
Centrum Height	50* mm
CL/CW	0.52

Table 41 Measurements for vertebra (1447; SF 4265)

The general size of the vertebra indicates it is from a delphinoid, and thus comparisons are made with delphinoid species. The location of first fluke vertebra is marked with a dashed line in the following figures to aid comparison.

2.1.1 COMPARISONS WITH ORCININAE

The pre-fluke caudal vertebrae of both *G. melas* and *P. crassidens* have a greater CL/CW ratio (c. 0.7 and above) than the archaeological specimen and can therefore be ruled out (Figure 89 and 91). While the immediate pre-fluke vertebrae of *O. orca* have CL/CW ratios of around 0.5 (Figure 89) the absolute measurements are much larger than the archaeological specimen (CW around 100mm; Figure 92). Those of *G. melas* are also larger. The vertebra is therefore not likely to be from a member of the Orcininae family.

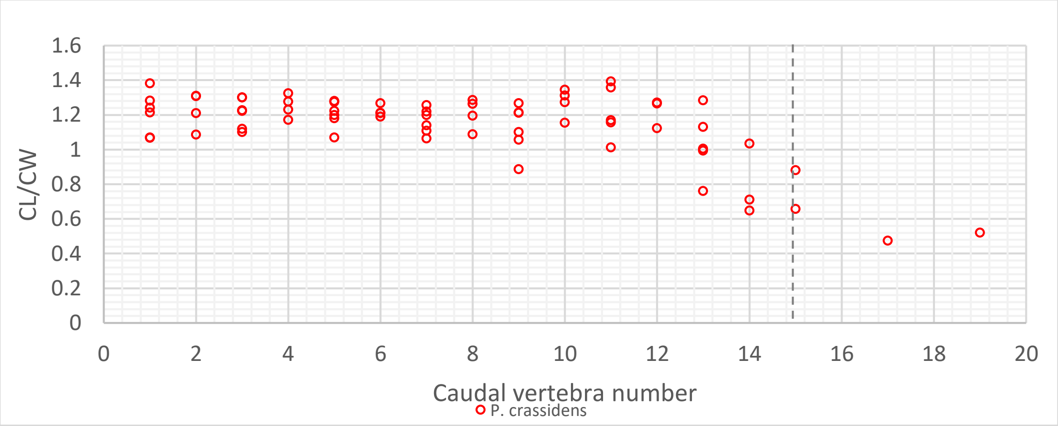

Figure 89 CL/CW in caudal vertebrae of adult specimens of P. crassidens

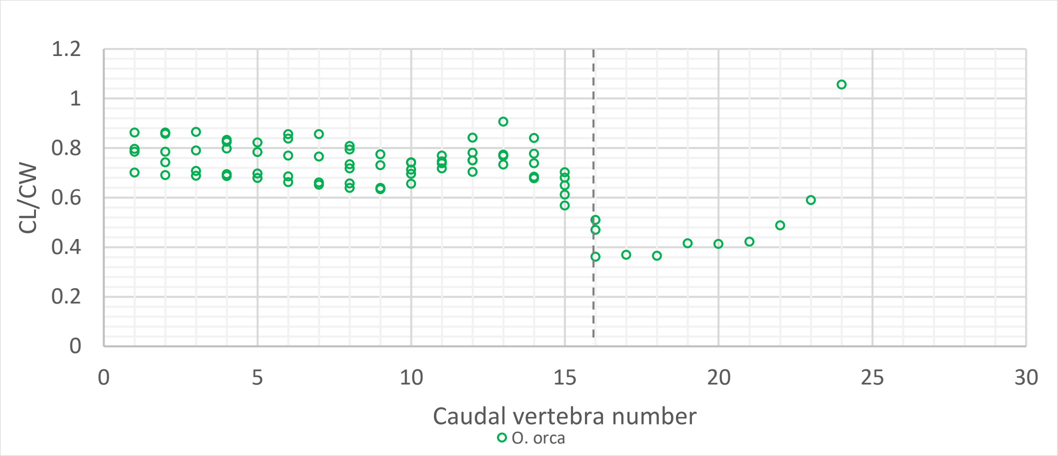

Figure 90 CL/CW in caudal vertebrae of adult specimens of O. orca

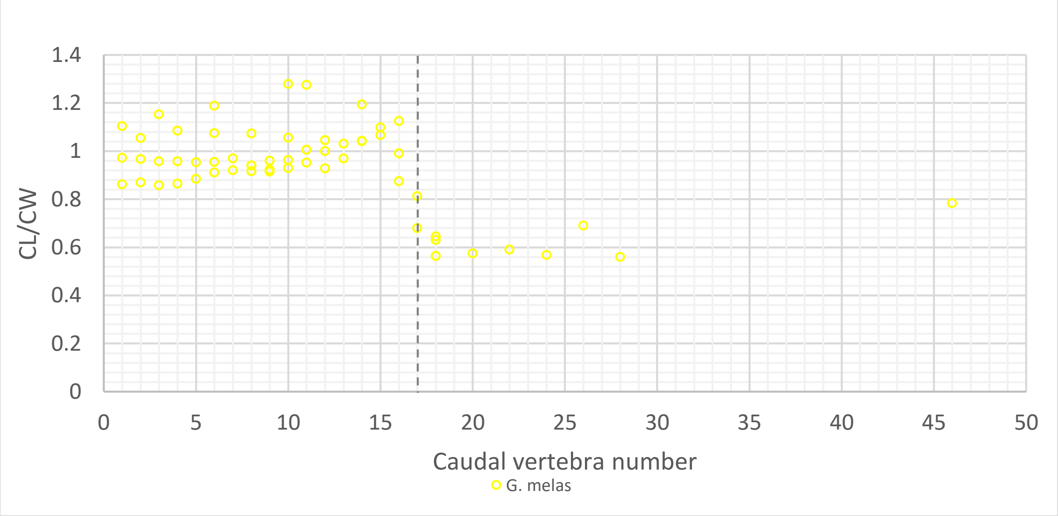

Figure 91 CL/CW in caudal vertebrae of adult specimens of G. melas

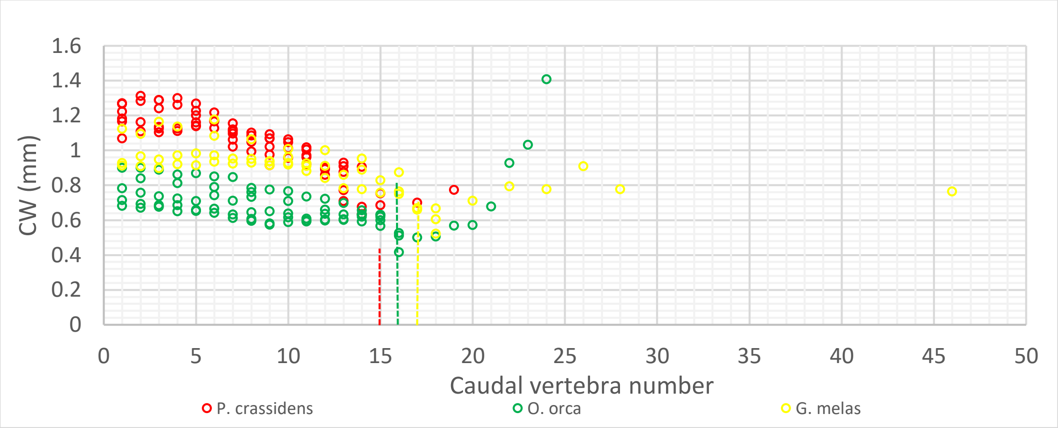

Figure 92 CW in caudal vertebrae of adult Orcininae

2.1.2 COMPARISONS WITH DELPHININAE AND PHOCOENIDAE

The absence of transverse processes demonstrates the vertebrae is in the pre-fluke caudal region. The final transverse processes are located at around Ca 16 in *G. griseus* and Ca 12-13 in *T. truncatus,* while the first fluke vertebra occurs around Ca 21-23 in the former, and Ca 17-19 in the latter. Within this region of the spine both *G. griseus* and *T. truncatus* are characterised by vertebrae with a greater CL/CW ratio (generally 0.7 and greater) than exhibited by the archaeological specimen (Figure 93 and 94).

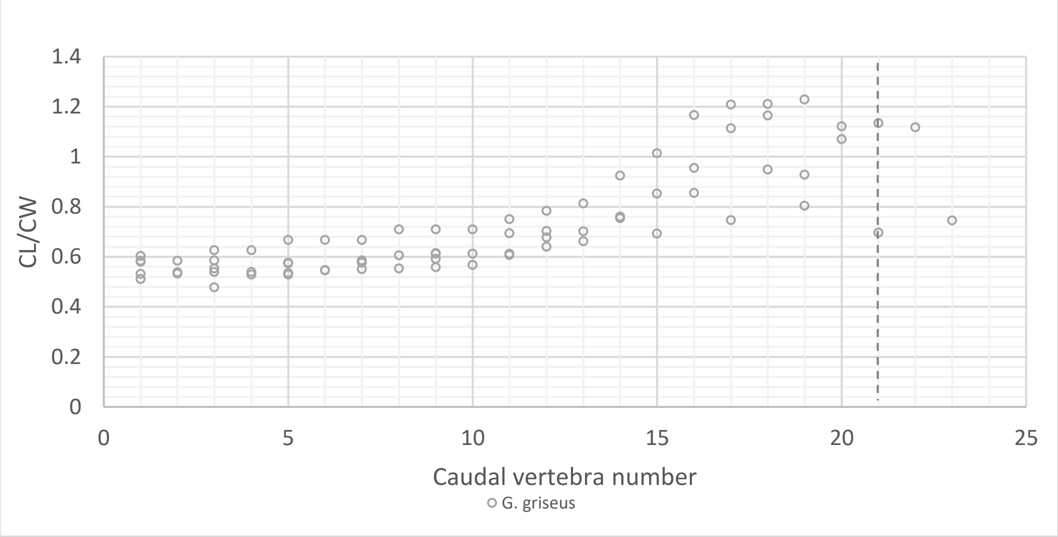

Figure 93 CL/CW in caudal vertebrae of adult specimens of G. griseus

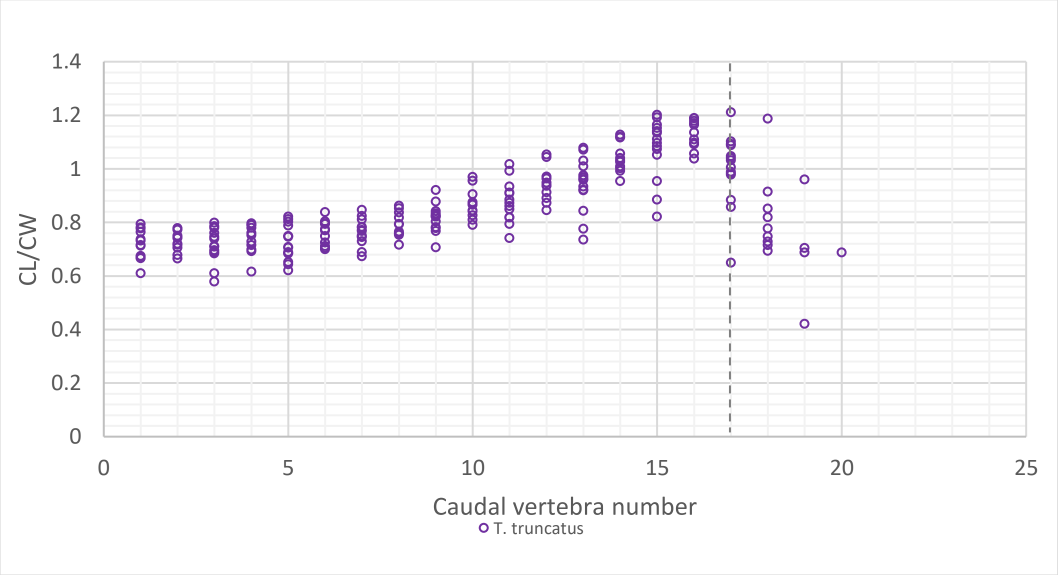

Figure 94 CL/CW in caudal vertebrae of adult specimens of T. truncatus

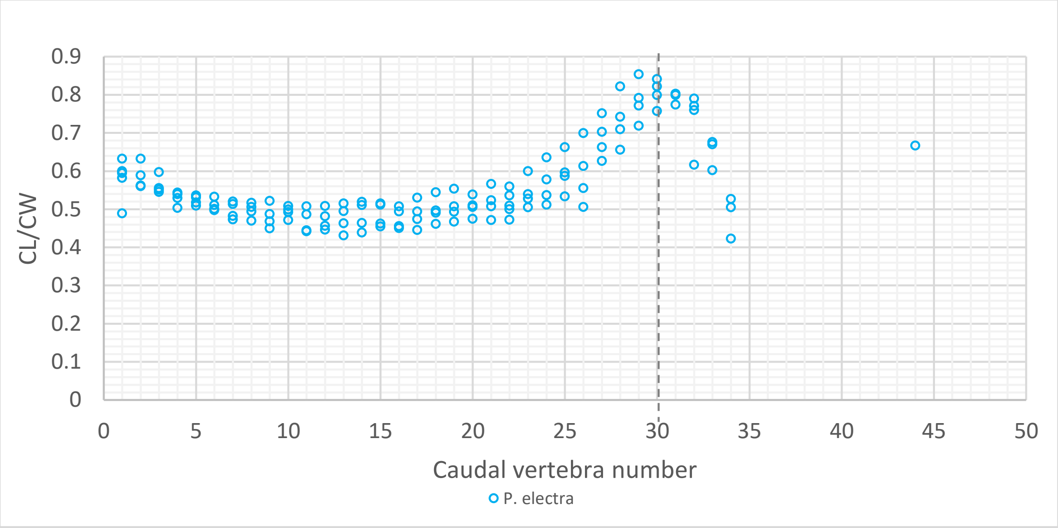

Figure 95 CL/CW in caudal vertebrae of adult specimens of P. electra

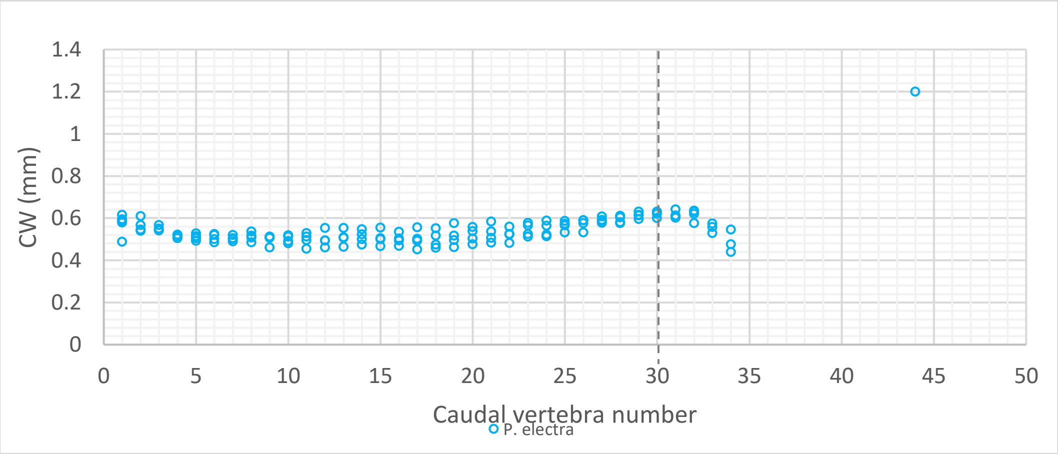

Figure 96 CL/CW in caudal vertebrae of adult specimens of P. electra

The first fluke vertebra occurs at around Ca 30 in *P. electra*, while the last transverse processes appear around vertebra Ca 22. Within the early part of this range (c. Ca 23-26) CL/CW ratios are similar to those of the archaeological specimen (Figures 95 – 96). Absolute centrum dimensions are generally slightly smaller than the archaeological specimen within this region, from around c. 45mm -40mm, though with one specimen demonstrating a CW of 50mm at Ca 26. Ratios and absolute measurements therefore make this species a possibility. However, the morphology of the bones differs. Haemal arches are more strongly developed in *P. electra* than the archaeological specimen and although centrum height is incomplete in the archaeological specimen the general height to width ratio is greater in *P. electra* indicating that the archaeological specimen does not derive from this species.

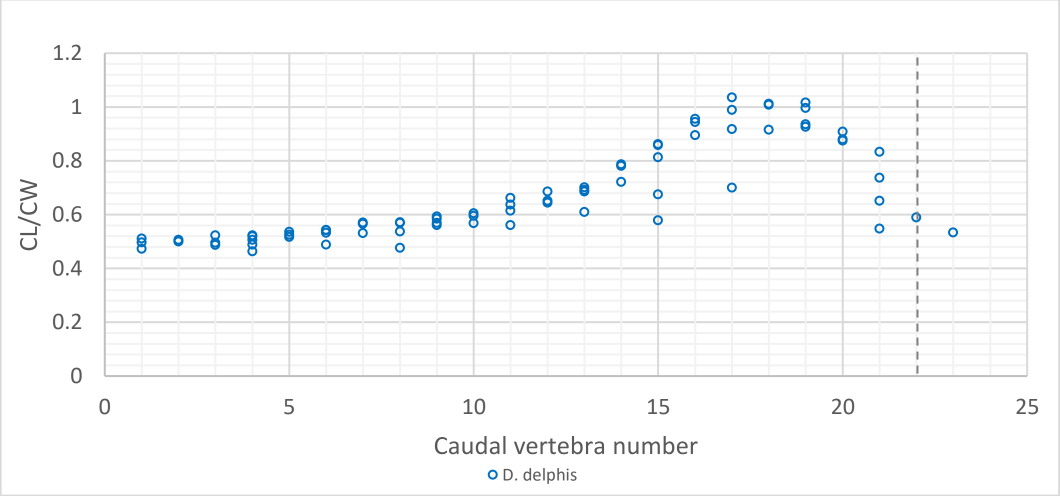

Figure 97 CL/CW in caudal vertebrae of adult specimens of D. delphis

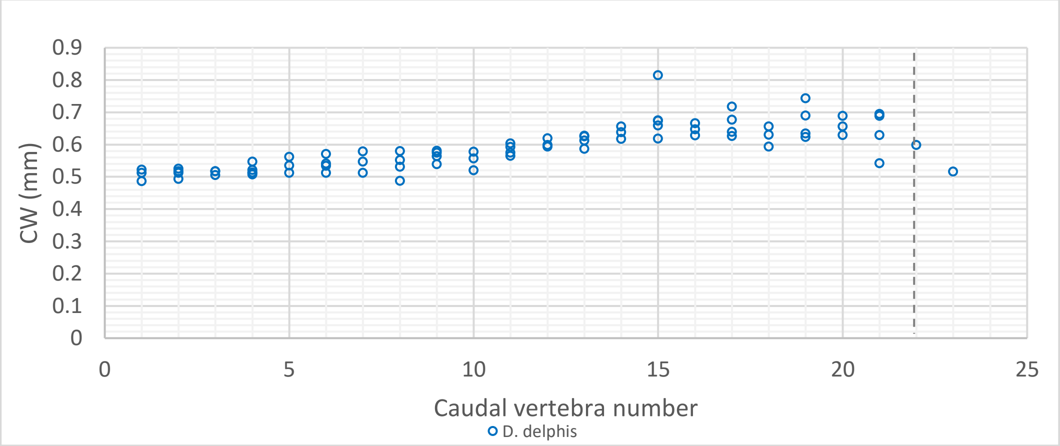

Figure 98 CW in caudal vertebrae of adult D. delphis

The first fluke vertebra occurs at around Ca 22-24 in *D. delphis* while the last transverse processes appear around vertebra Ca 17. CL/CW ratios within this range are generally greater than in the archaeological specimen, with the exception of the last pre-fluke caudal vertebrae (c. Ca 21) (Figure 97 – 98). In this vertebra CL/CW ratios reach c. 0.5. However, absolute measurements demonstrate that centrum widths are much smaller than in the archaeological specimen in this area (c. 30mm and below), indicating that the vertebra is not likely to be from *D. delphis.*

The location of the first fluke vertebra and last transverse process are not recorded for *S. coreuleoalba*. However, consideration of the CL/CW profiles in comparison with those from other delphininae demonstrates that this species, like others from the same sub-family, exhibits a rise and fall in CL/CW which in others is located in the pre-fluke caudal vertebrae. This area includes the last transverse processes in other delphinines. The area on the figures (Figures 99 - 100) which likely includes the region between the last transverse processes and first fluke vertebrae is outlined within the following figures. Within this area CL/CW is greater than 0.6, and absolute centrum width is c. 40 – 25mm. The ratios and absolute measurements therefore indicate that an identification of *S. coeruleoalba* is unlikely.

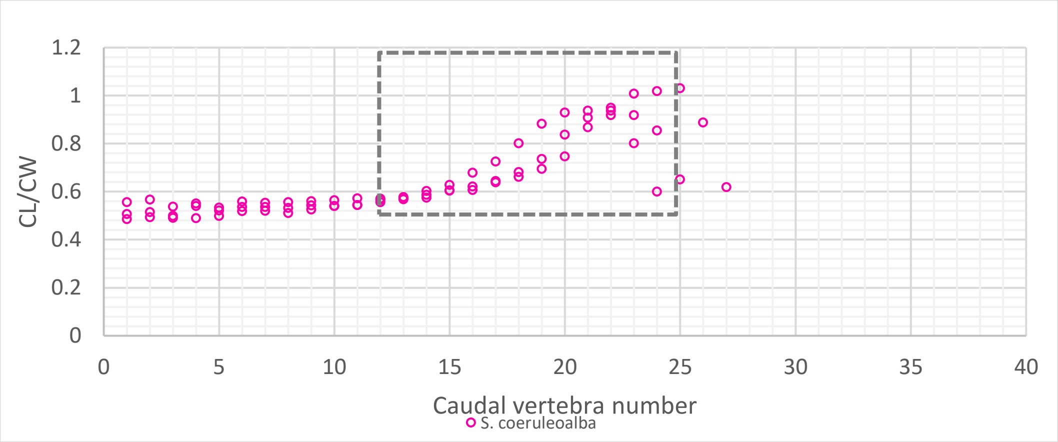

Figure 99 CL/CW in caudal vertebrae of adult specimens of S. coeruleoalba

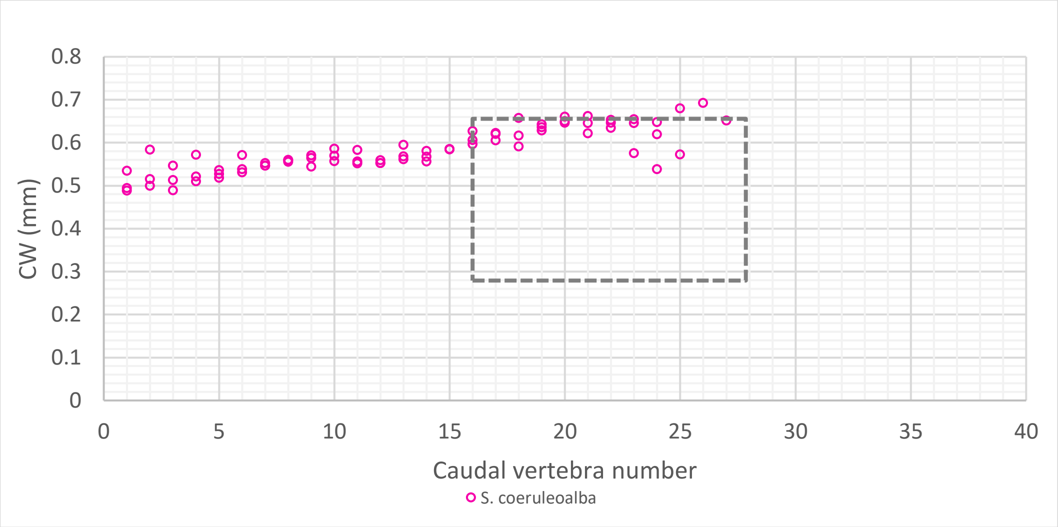

Figure 100 CW in caudal vertebrae of adult S. coeruleoalba

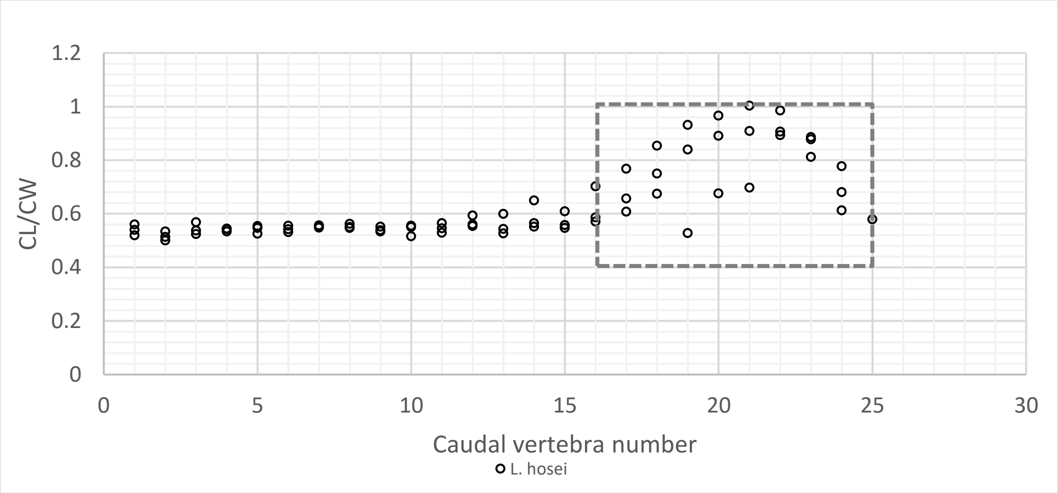

Figure 101 CL/CW in caudal vertebrae of adult specimens of L. hosei

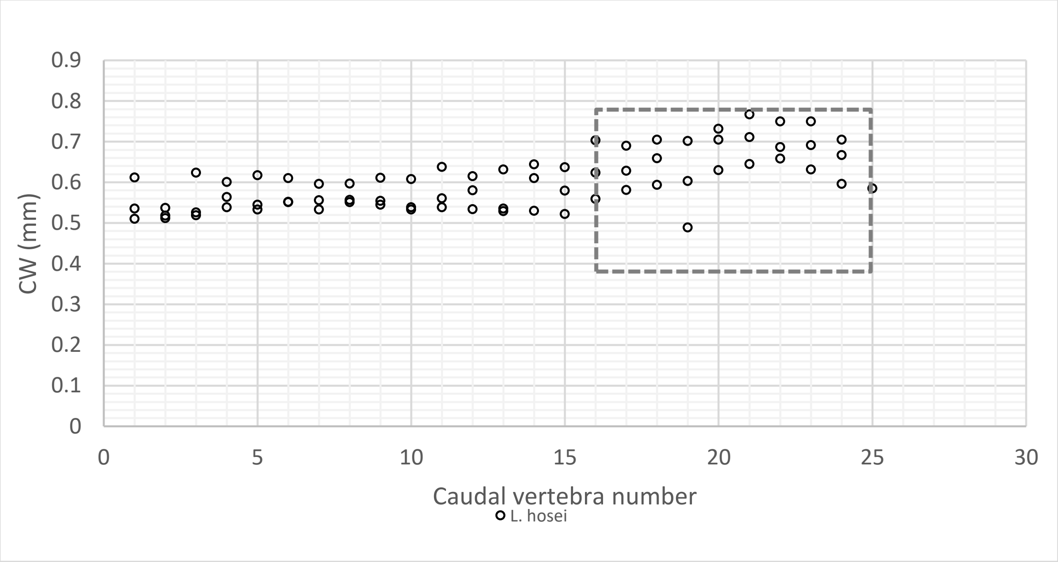

Figure 102 CW in caudal vertebrae of adult L. hosei

As with *S. coeruleoalba* the first fluke vertebra and last transverse process are not recorded for *L. hosei* and the region between the last transverse processes and first fluke vertebrae has been identified in the same manner as for the former species here (Figure 101 – 102). While the CL/CW ratios and the absolute centrum widths both have values which fall within the range recorded within the archaeological specimen they do not occur on the same vertebrae: vertebrae with CL/CW of c. 0.5 have a CW of less than 50, indicating that this species is unlikely. Additionally, CL/CW of 0.5 is at the lowest end of the range for this species and as 0.52 is an over-estimate of the CL/CW of the archaeological specimen this further demonstrates that an identification of *L. hosei* is unlikely.

As with *S. coeruleoalba* and *L. hosei* the last transverse process is not recorded for *L. acutus* and the region between the last transverse processes and first fluke vertebrae has been identified in the same manner as for the former species here (Figure 103 – 104). The CL/CW ratios and the absolute centrum widths both have values which fall within the range recorded within the archaeological specimen and this species is therefore a possibility.

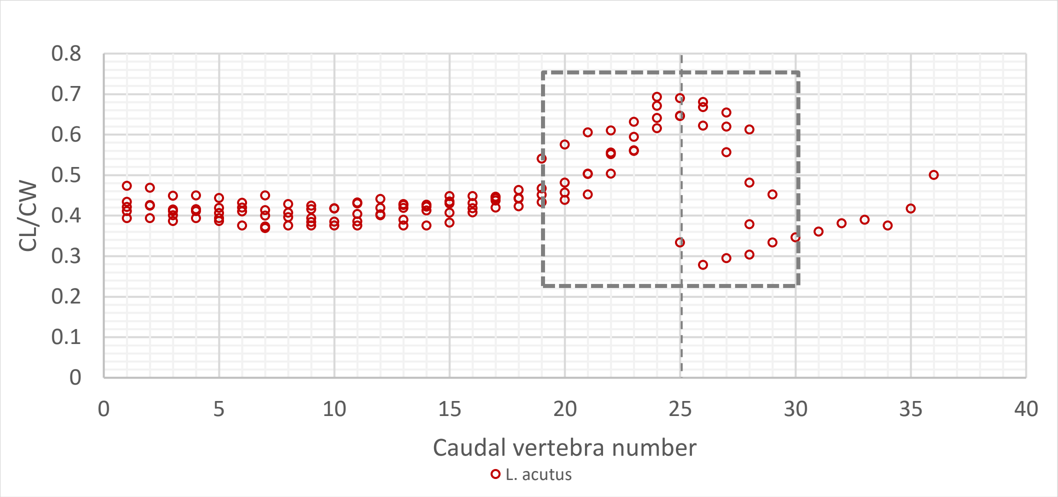

Figure 103 CL/CW in caudal vertebrae of adult specimens of L. acutus

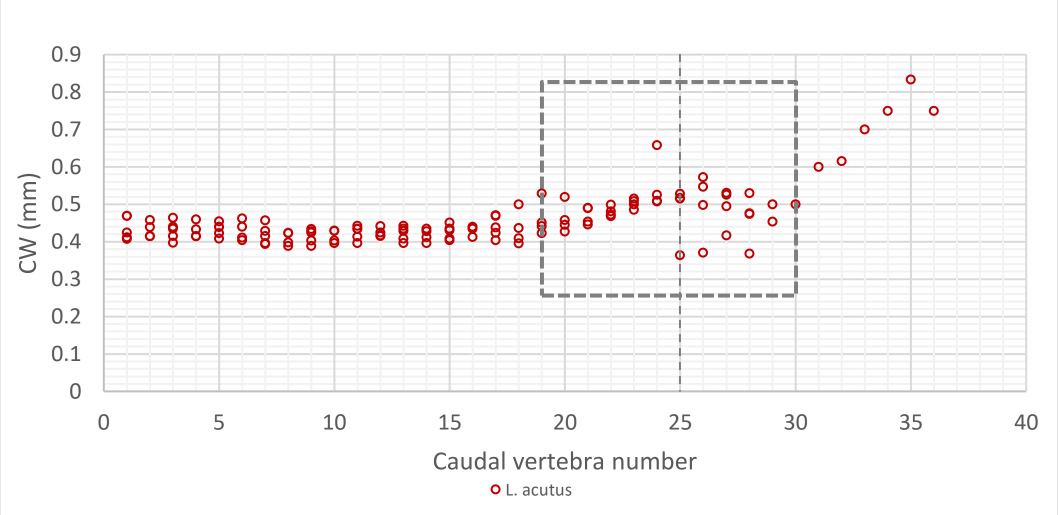

Figure 104 CW in caudal vertebrae of adult L. acutus

The last transverse processes are recorded around Ca 24 in *L. albirostris*, and the first fluke vertebrae around Ca 31 -32. Within this region, and in particular around Ca 25, the CL/CW ratios and the absolute centrum widths both have values which fall within the range recorded within the archaeological specimen and this species is therefore a possibility (Figure 105- 106).

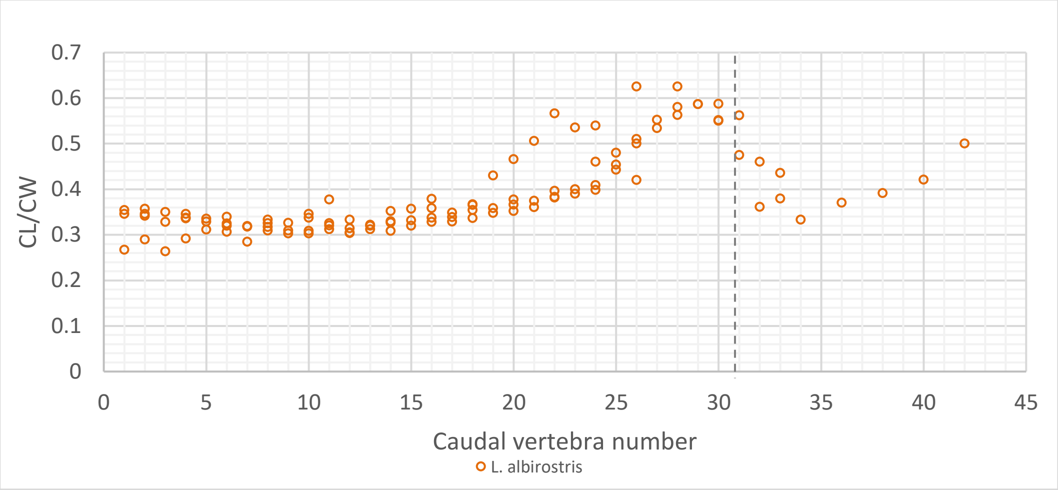

Figure 105 CL/CW in caudal vertebrae of adult specimens of L. albirostris

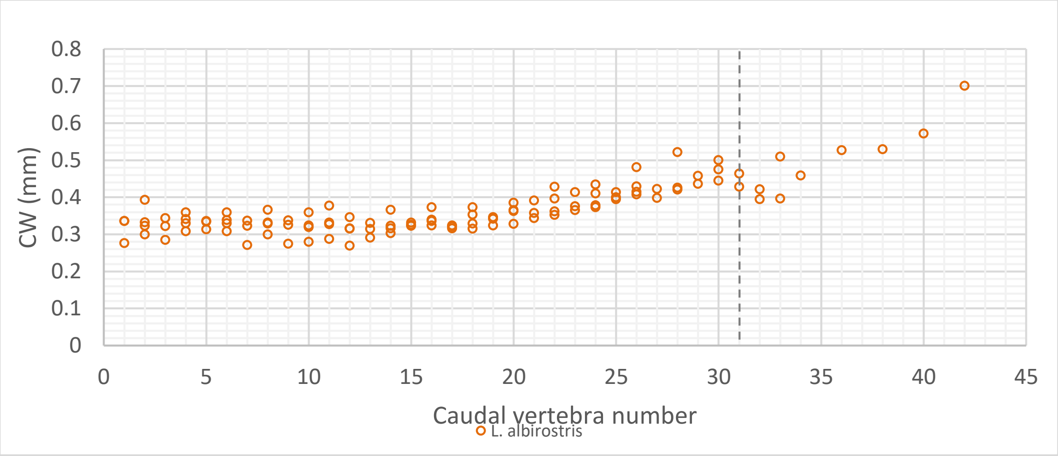

Figure 106 CW in caudal vertebrae of adult L. albirostris

In *P. phocoena* the first fluke vertebra is situated around Ca 18 – 20, and the last transverse processes appear at around Ca 13. Within this region the CL/CW ratio is generally greater than in the archaeological specimen (generally 0.6 and above), and the absolute CW lower (30mm and below) (Figure 107 – 108). This species is therefore unlikely.

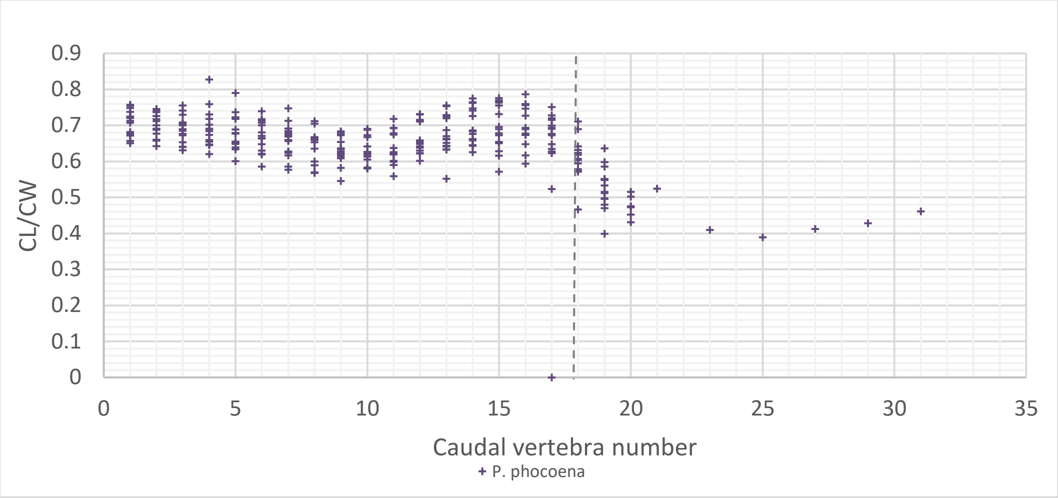

Figure 107 CL/CW in caudal vertebrae of adult specimens of P. phocoena

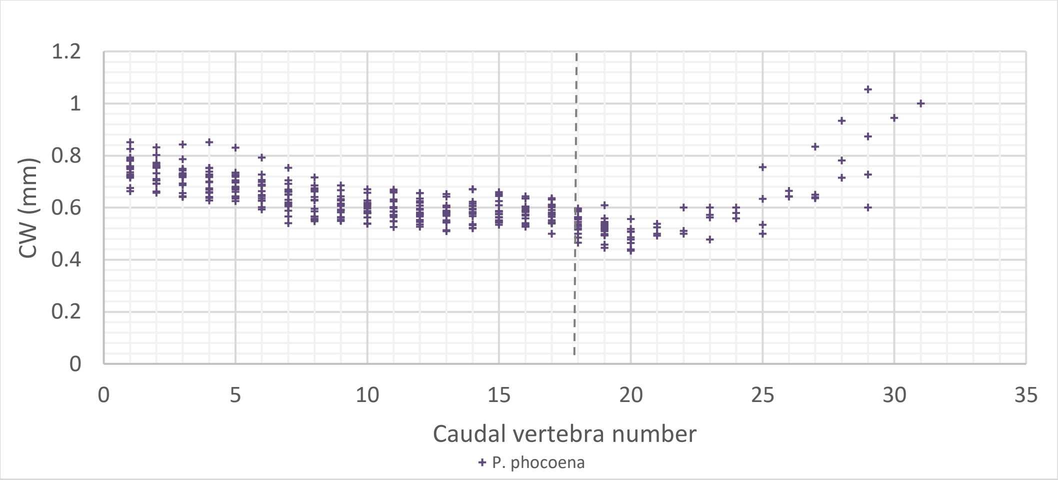

Figure 108 CW in caudal vertebrae of adult P. phocoena

2.1.3 IDENTIFICATION

The morphometric evidence indicates that the vertebra is likely to be from a specimen within the genus Lagenorhynchus. Species within the Lagenorhynchus genus can primarily be differentiated by consideration of the relative NPH/ CL. However, as the neural process does not survive within the archaeological specimen (either due to the position along the spine or breakage), no further identification is possible.

2.2 VERTEBRA (CONTEXT 2907; SF 5356)

The bone is identified as an incomplete mid-thoracic vertebra and is fused on both faces (Figure 109). The processes are absent. ZooMS analysis was undertaken on this bone and identified it as Delphinoidea, however, morphometric analysis can refine this identification.

Table 42 provides details of the dimensions of the vertebra.

Dimension	Measurement
Centrum Length	75 mm
Centrum Height	87 mm
Centrum Width	98 mm
CL/CH	0.86

Table 42 Measurements for vertebra (2907; SF 5356)

Figure 109 Thoracic vertebra (SF 5356)

The dimensions of the vertebra are plotted by the black cross on Figure 110. The ratio of centrum length to height (0.86) indicates that the bone is likely to be from *O. orca.* While Figure 110 indicates the specimen may have been a small one, the following figure (111) demonstrates that the ratio of CL/CH is within the normal range for mid thoracic vertebrae of the killer whale which are lesser than those of other Orcininae.

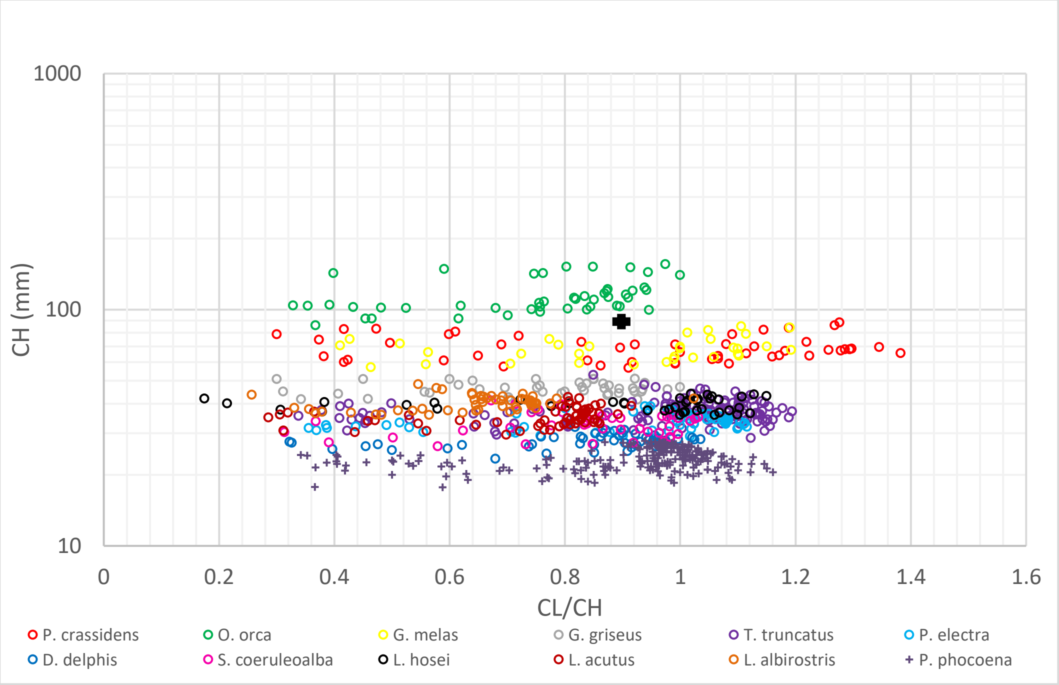

Figure 110 CL/CH and CH in thoracic vertebrae of adult delphinoids. Y axis is depicted with a logarithmic scale

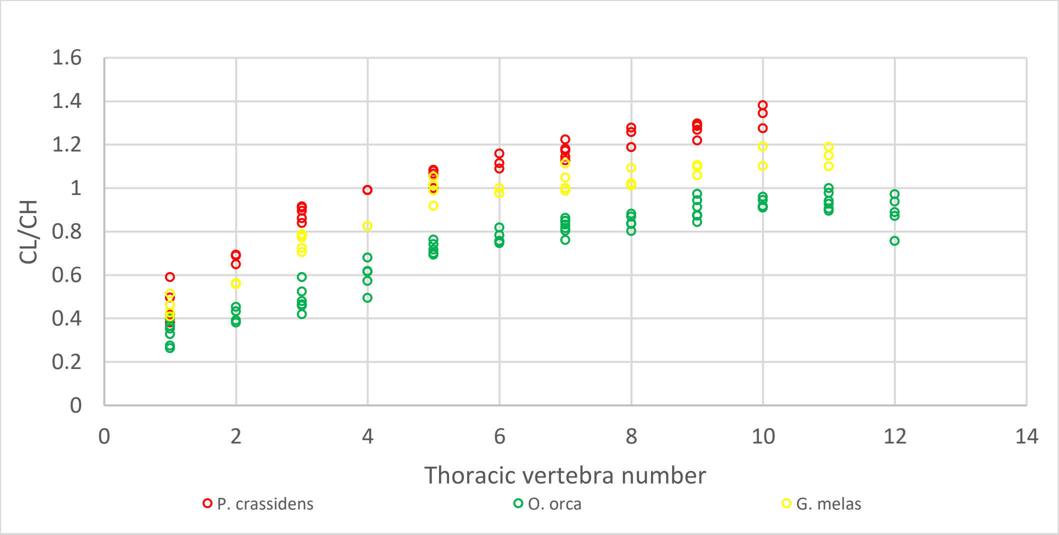

Figure 111 CL/CH in thoracic vertebrae of adult and young Orcininae

2.3 VERTEBRA (CONTEXT 3181; SF 5109)

The bone is identified as a caudal vertebra (Figure 112). It is near-complete but with one side missing. The bone also has a small area of burning on base (ventral aspect). CL and CH are complete (CW may be missing a very small area but is also largely complete). The neural spine is missing but cancellous tissue exposed in this area indicating that this process was once present. However, the form of the exposed area of cancellous bone indicates that the neural arch is likely to have been very small or indistinct. Transverse processes are not present. CW is less than CH and the cranial face of the vertebra is convex. Arterial foramen are present. All information supports identification of the bone as an immediately pre-fluke caudal vertebra.

Table 43 provides details of the dimensions.

Dimension	Measurement
Centrum Length	110 mm
Centrum Height	151 mm
Centrum Width	133 mm
CL/CH	0.73

Table 43 Measurements for vertebra (3181; SF 5109)

Figure 112: Dorsal aspect of the vertebra (SF 5109) demonstrating arterial foramen, absence of transverse processes and breakage indicating the former presence of a neural spine with small or no neural canal

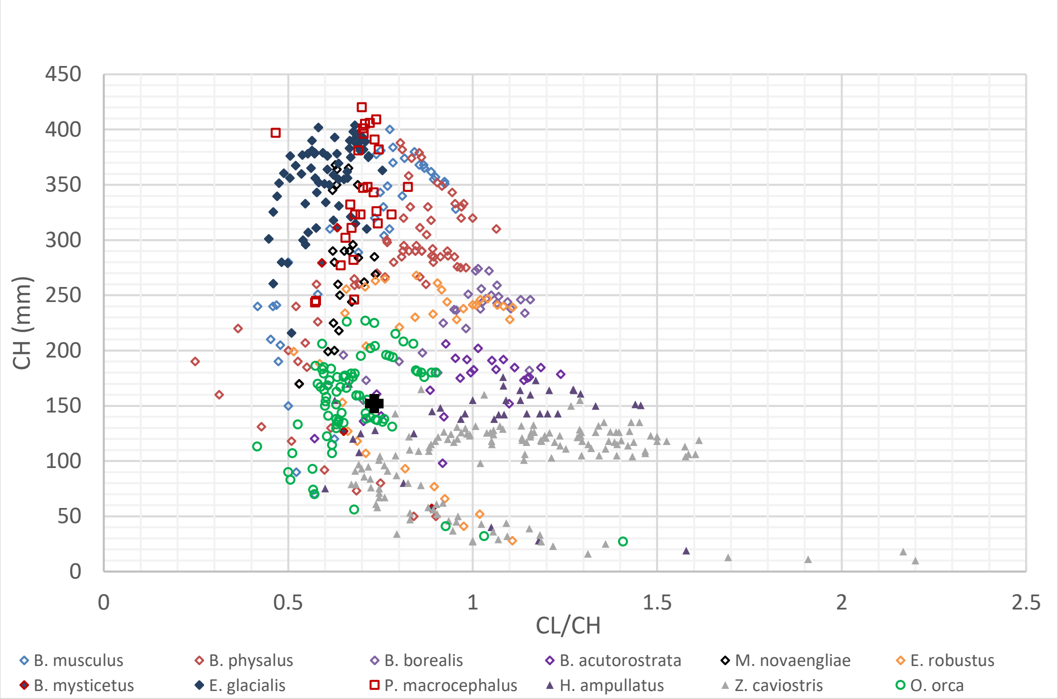

Figure 113 CL/CH and CH in caudal vertebrae of adult cetaceans

The size of the vertebra rules out all smaller species (including all Delphininae, Phocoenidae, Kogiidae, Monodontidae, all species within the genus Mesoplodon and Orcininae with the exception of *O. orca*). Figure 113 demonstrates the CL/CH ratio and centrum height of the archaeological specimen compared with all other species. The balaenids have much lower CL/CH ratios and have more substantial arterial foramen than the archaeological specimen and thus can be ruled out. Due to the large size and ratio differences along the caudal region assessment of the precise position along the spine provided more reliable comparisons amongst other species.

2.3.1 COMPARISONS WITH MYSTICETI

A number of the larger species can be ruled out on the basis of size. For *B. musculus* and *B. physalus* the first fluke vertebra occurs at around Ca 16-17/18 in while the last transverse processes occur around vertebra Ca 10 in *B. musculus* and around Ca 11 in *B. physalus.* In the post-transverse processes, pre-fluke caudal region all vertebrae of *B. musculus* and *B. physalus* have centrum heights of 250mm or greater (Figure 114), and are therefore at least 100mm larger in CH than the archaeological specimen. Likewise, the fluke begins around Ca 10 in *M. novaengliae* and Ca 13/14 in *E. robustus* (Figures 115 and 116), and the preceding vertebrae of both species are larger than the archaeological specimen. CL/CH ratios are also generally lower in *M. novaengliae*. Thus, these species can also be ruled out.

The location of the first fluke vertebra in *B. borealis* is recorded between Ca 12 and 16 (Andrews 1916; Slijper 1936; Struthers 1889). Generally, the preceding vertebrae are larger than the archaeological specimen, though for specimens in which the fluke vertebrae begin from Ca 16 the preceding vertebrae (Ca 14-15) are within the range of the archaeological specimen in terms of both their centrum heights and CL/CH ratio (Figure 117 -118). For *B. acutorostrata* the fluke begins at between Ca 9 and Ca 12, indicating that this species too is a possibility (Figure 119 - 120).

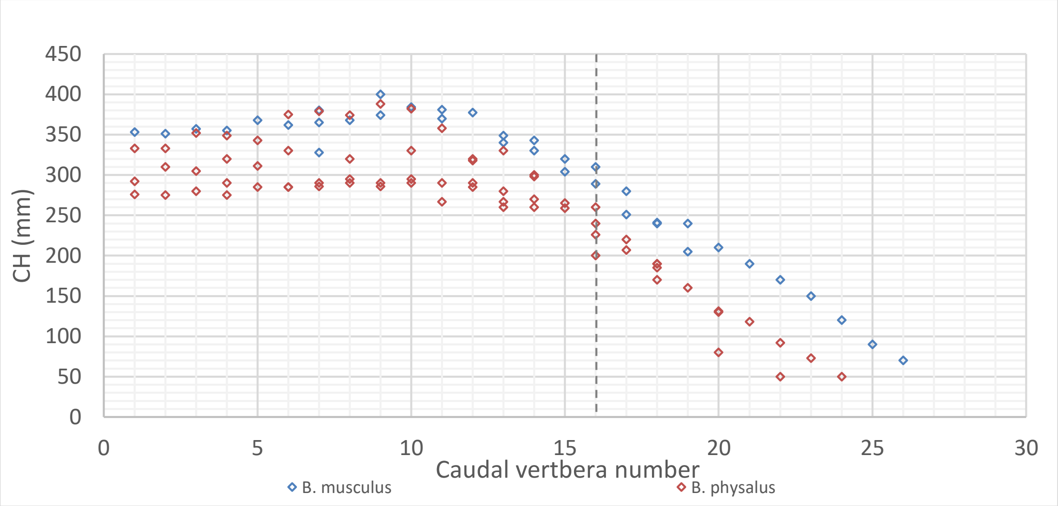

Figure 114 CH in caudal vertebrae of adult specimens of B. musculus and B. physalus

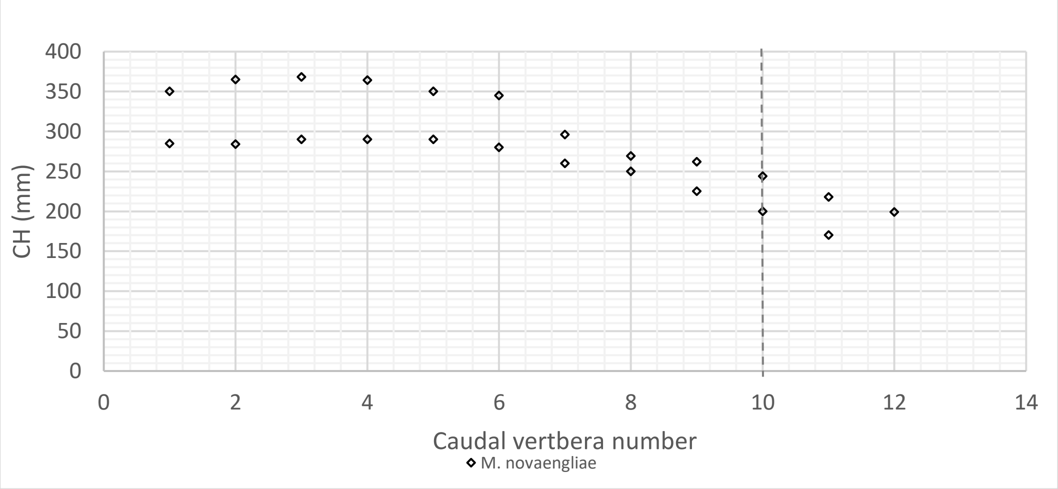

Figure 115 CH in caudal vertebrae of adult specimens of M. novaengliae

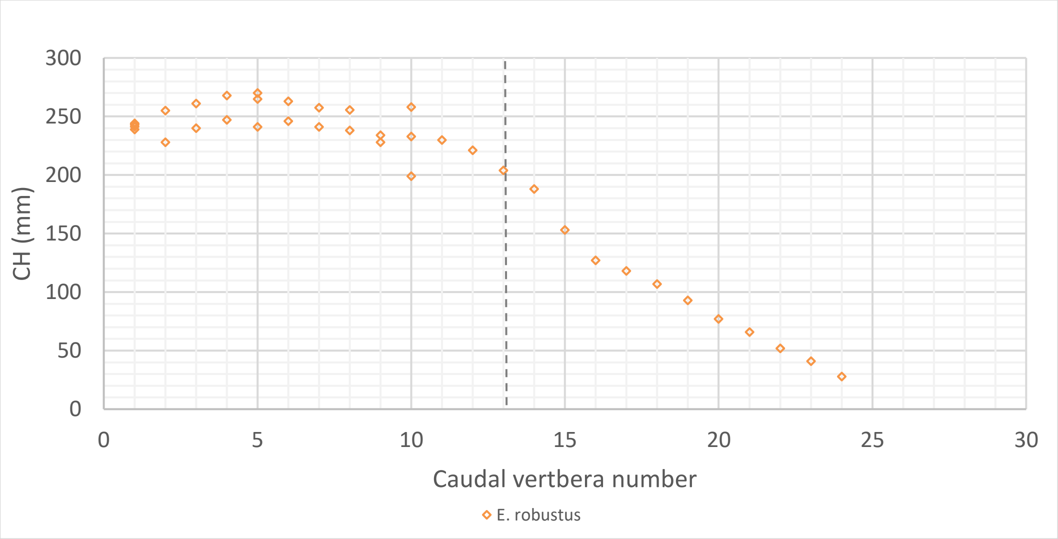

Figure 116 CH in caudal vertebrae of adult specimens of E. robustus

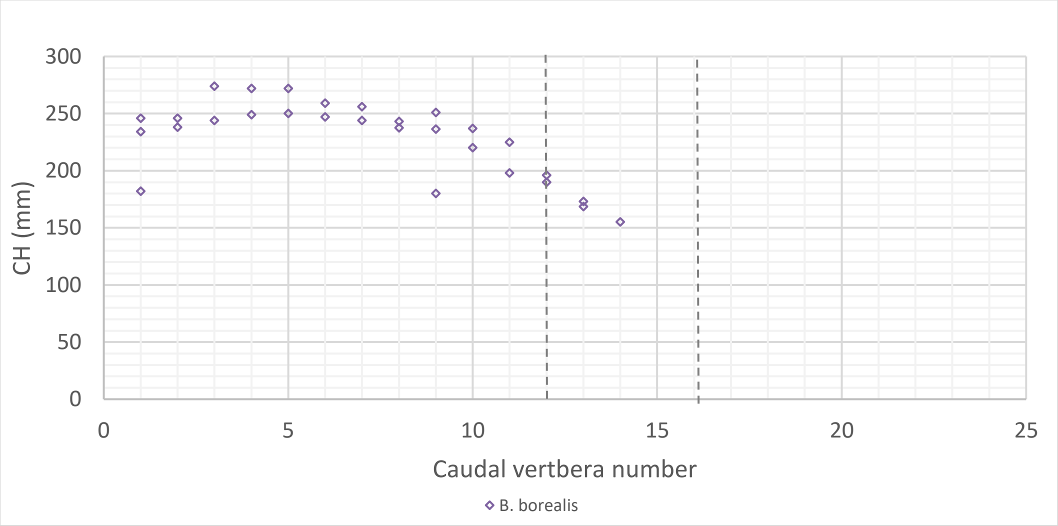

Figure 117 CH in caudal vertebrae of adult specimens of B. borealis

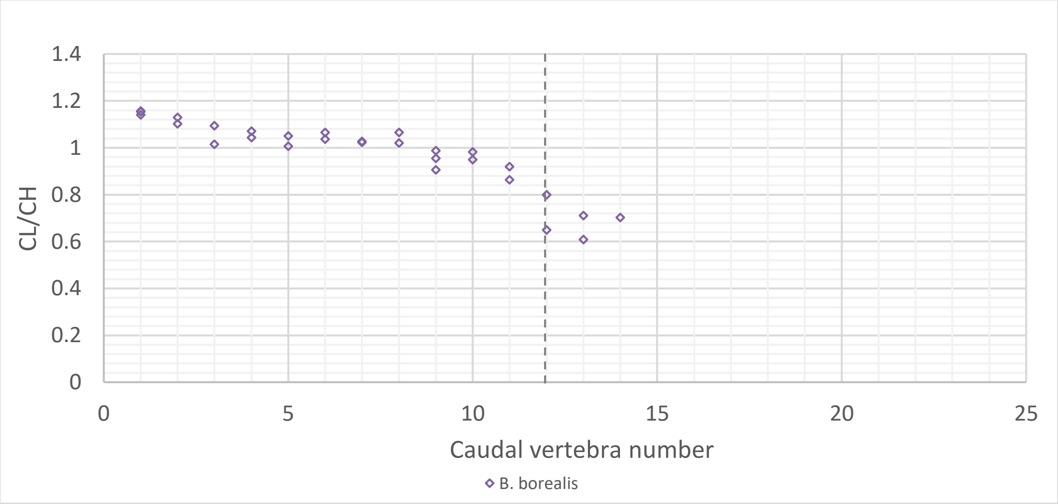

Figure 118 CL/CH in caudal vertebrae of adult specimens of B. borealis

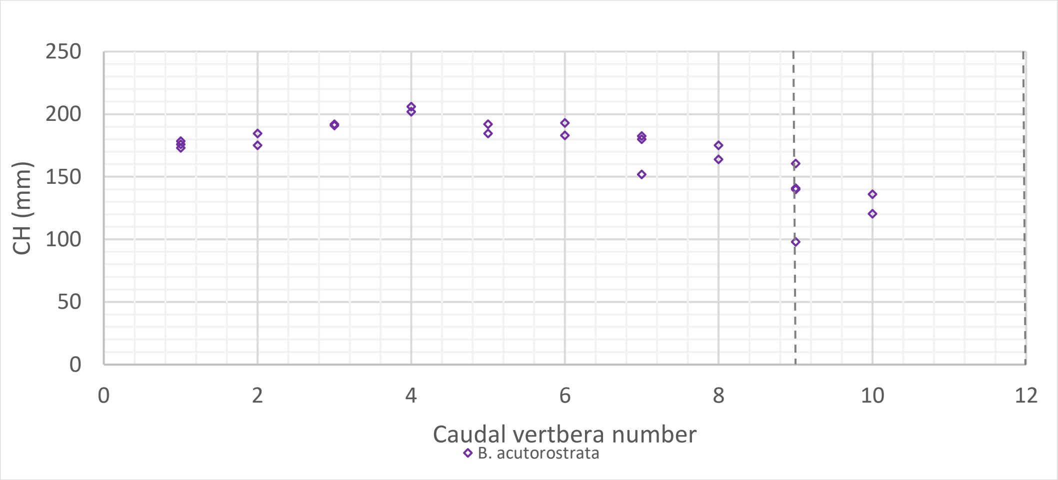

Figure 119 CH in caudal vertebrae of adult specimens of B. acutorostrata

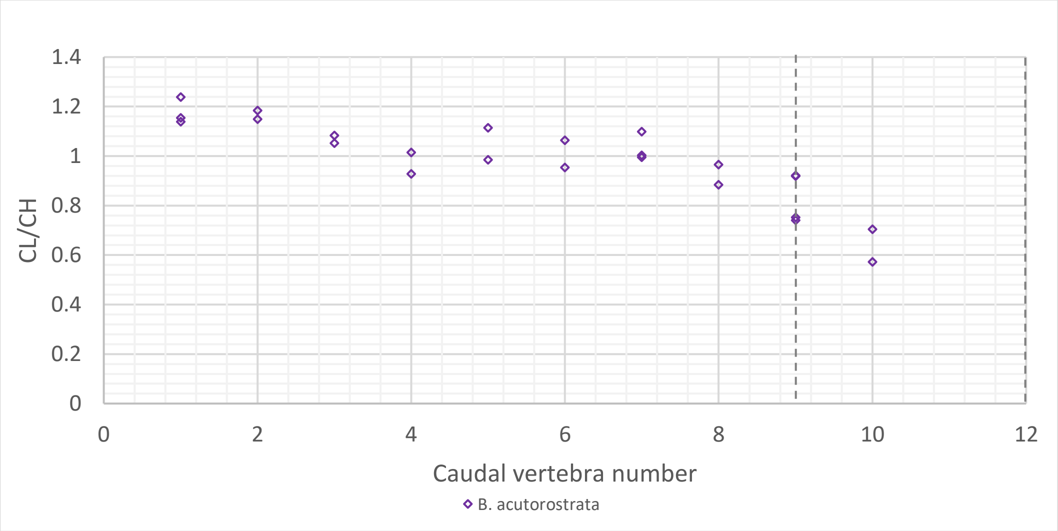

Figure 120 CL/CH in caudal vertebrae of adult specimens of B. acutorostrata

2.3.2 COMPARISONS WITH ODONTOCETI

Of the remaining Odontoceti which may be a possibility, the first fluke vertebra of *P. macrocephalus* occurs around Ca 12- 15. The vertebrae preceding this region generally have much greater centrum heights than the archaeological specimen, and CL/CH values are generally slightly lower, and thus this species is not likely (Figure 121).

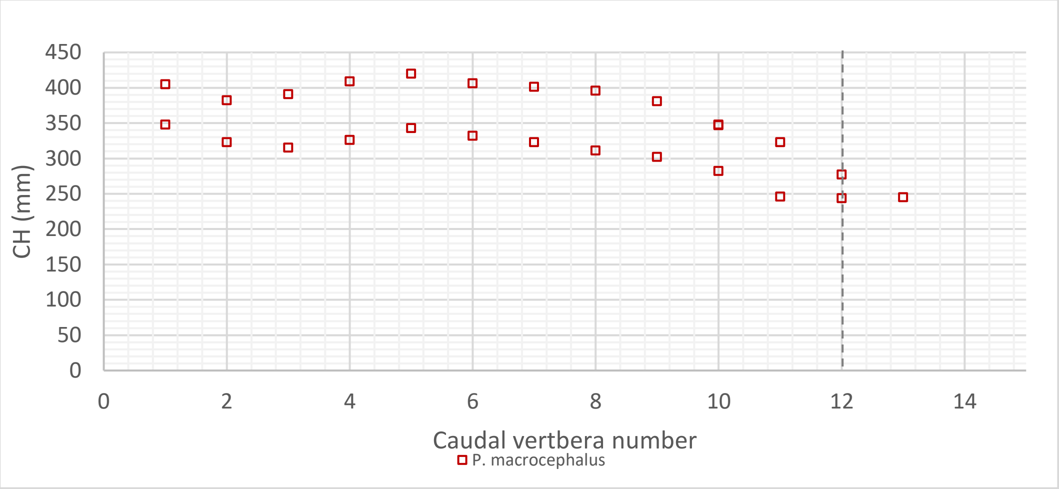

Figure 121 CH in caudal vertebrae of adult specimens of P. macrocephalus

The first fluke vertebra is situated between Ca 12 and Ca 14 in specimens of *H. ampullatus* and *Z. caviostris*. The CL/CH ratios and centrum heights of the immediately pre-fluke caudal vertebrae make these species a possibility (Figure 122– 123). However, the general form of the archaeological specimen, and in particular the form of the arterial foramen and grooves differs from those species. Additionally, the cancellous bone exposed on the dorsal aspect of the vertebra which marks the former location of the neural process differs from what would be expected in the beaked whales. In those species the metapophyses are situated to the sides of the neural spine and would therefore likely leave a different scar following removal. Ziphiidae also tend to exhibit a strong muscle attachment running in a cranio-caudal direction and situated toward the dorsal aspect of the bone above the dorsal exit point of the arterial foramen. No evidence of this muscle attachment was observed in the archaeological specimen. Additionally, there is a higher degree of convexity in the face of the vertebrae in this region in the Ziphiidae compared with the archaeological specimen.

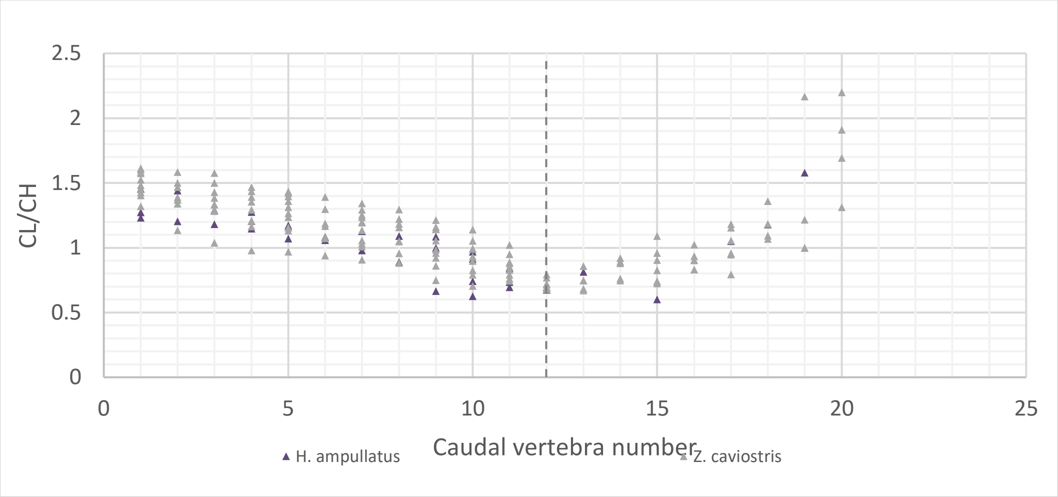

Figure 122 CL/CH in caudal vertebrae of adult specimens of H. ampullatus and Z. caviostris

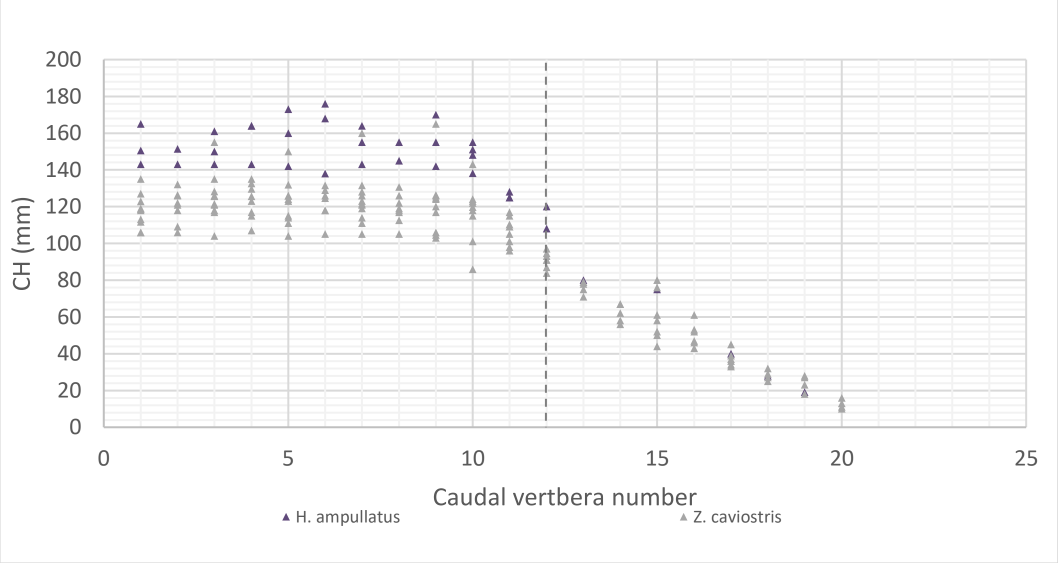

Figure 123 CH in caudal vertebrae of adult specimens of H. ampullatus and Z. caviostris

The first fluke vertebra occurs at around Ca 16 in *O. orca.* However, neural spines are last evident around Ca 11-12, and the last transverse processes appear around vertebra Ca 9-10, indicating that the area of interest is around Ca 10 – 12 (indicated by the dashed box on Figures 124- 125). The CL/CH ratios and centrum heights are around the same range as recorded in the archaeological specimen.

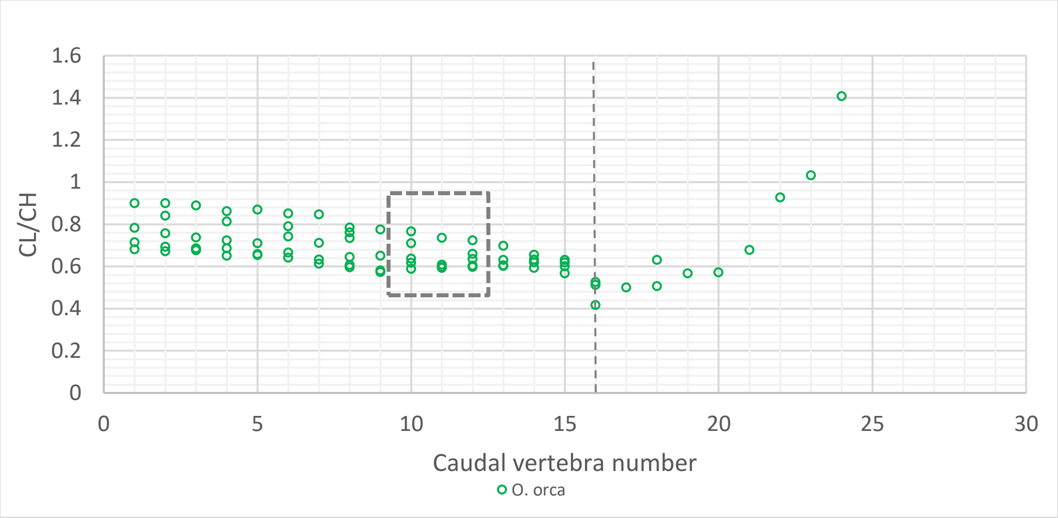

Figure 124 CL/CH in caudal vertebrae of adult specimens of O. orca

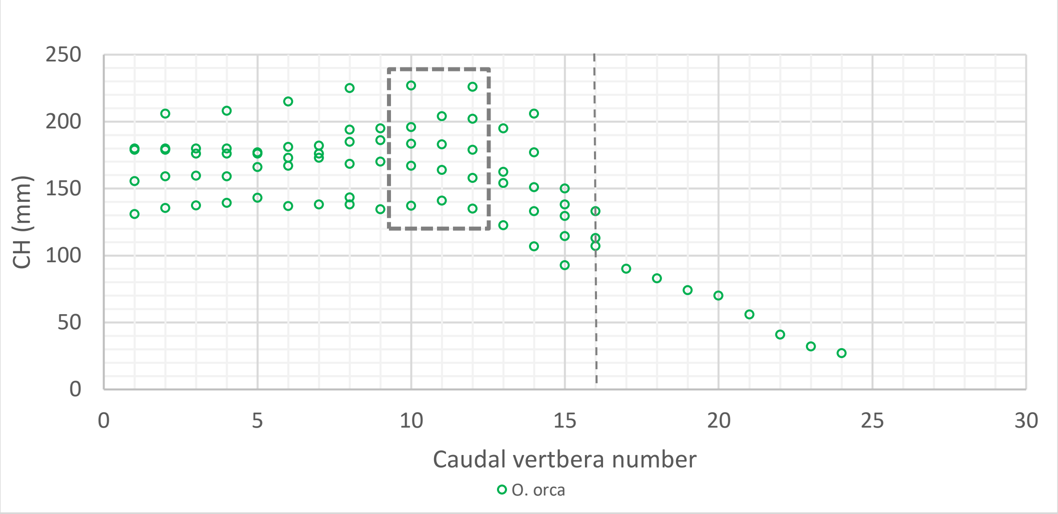

Figure 125 CH in caudal vertebrae of adult specimens of O. orca

Figure 126: Top is Ca 11 from a laser scan of a specimen of O. orca recorded by Port Townsend Museum (source: https://ptmsc.org/boneatlas/). Bottom is the archaeological specimen (SF 5109).

2.3.3 Identification

The dimensions and ratios of the recorded *O. orca* specimens make this species a possible candidate, along with the smaller balaenopterids. There are a number of ways to distinguish between these groups. Slijper (1936) found that Mysticeti and Odonotoceti could be distinguished on the basis of differences between the layout of their arteries, which result in a difference in the location of the arterial groove running from the aorta (which runs below the spinal column), to the blood vessels situated within the spinal canal. In the anterior lumbar region both Mysticeti and Odonotoceti the groove runs behind the transverse processes of the vertebrae. However, while in Odontoceti the groove is also located behind the transverse processes in the posterior lumbar region and in the caudal region this differs from the location of the groove in the posterior lumbar and caudal regions of Mysticeti. In Mysticeti the groove runs anterior to the transverse processes in the posterior lumbar and anterior caudal regions (Slijper, 1962). Possible indications of a groove were observed in the archaeological specimen, running in an anterior direction. However, the indications were very slight and were not considered to represent clear unequivocal evidence.

The form of the neural process can also be informative. Removal of the neural process in the archaeological specimen has reduced the possibilities for identification though the removal scar may provide some clues. *O. orca* have elevated metapophyses in the lower lumbar and caudal regions, and in the region situated caudal to the last transverse processes the base of the neural spine is narrow, owing to the elevated position of the metapophyses (which are greatly reduced and almost imperceptible at this location). The wider base of the neural process observed by the exposed cancellous tissue left by its removal, appears to suggest lower metapophyses leaving a wider base at the cranial end of the vertebra, suggesting the specimen is less likely to be from *O. orca* (Figure 126). However, again this evidence is not clear.

Overall, it was not possible to determine the species from which this bone was derived, and an identification of medium to large cetacean is given.

Identifications for other fragments of vertebrae are set out within Table 44.

Context	SF	Description	Overall Dimensions			Centrum dimensions			Neural process dimensions						Transverse Process dimensions		Photograph	Identification
			H	W	L	CL	CH	CW	NPH	NSH	LNS	MPH	HNA	BNA	BPtr	GLPT		
1512	-	Vertebral fragment. Part of one process remains and parts of both the cranial and caudal centrum faces. Neither side is fused. Process measurements cant be taken as process is broken and incomplete. Size indicates medium or large cetacean. Stippled fusion pattern supports Mysticeti identification.	85	33	51	51	68*	35*										Mysticeti
803		Thoracic vertebra, incomplete. Centrum near complete, both faces unfused. One neural arch lamina partially present and transverse process on the same side also partially present. Slight burning on one side. Radial fusion pattern indicates Odontoceti. Beaked whales can be ruled out on basis of form and CL. Delphinoidea indicated on basis of form and size. Ratio of CL/CH can be gauged even without discs. This one has a relatively short CL. CH is too large for Phocoenidae (and individual not yet fully grown). In range of small to mid-sized Delphinid.	69*	69*	26	26	41	49*	21+					31+				Delphinidae
1790		Lower thoracic or early lumbar vertebra. Faces unfused. complete but one face has been gouged (?) out. Neural arch laminae partly present but broken off toward the apex of the arch. Bases of both transverse processes also present. Radial fusion pattern indicative of Odontoceti and size indicative of smaller species: delphinoidea. The specimen is sub adult and already larger than most Delphininae and the Phocoenidae indicating mid-sized delphinid. Centrum near Laminae of neural arch thicken in the manner seen in *G. melas.*	65*	100*	30	30	40*	56	27*					30	100*	19*		*G. melas*

1299		Part of centrum and base of one transverse process (indicated by arterial groove). Radial fusion pattern indicates Odontoceti. GLPT and CL are indicative of a small cetacean; Delphinoidea.	25*	41*	37	37	27*	12*								27		Delphinoidea
412		Vertebra. Part of centrum and base of one process. No dimensions are complete but face is fused. Size of the fragment indicates it originated from a medium sized or large cetacean.	80*	55*	31*	31*												Medium or large cetacean
2211	3965	Mid to late pre-fluke caudal vertebra. Both faces unfused. Centrum largely complete but sides missing, removed past the line of the arterial foramen and as such not possible to tell if transverse processes were present. Neural arch present neural spine broken. Size of the neural arch and presence of foramen indicates a late pre-fluke caudal vertebra. Radial fusion pattern indicates Odontoceti and general CL (despite lack of discs) indicates delphinoid. Centrum height is too great for P. phocoena, indicating that this is from a Delphinidae.	40	70	40*				19*					6				Delphinidae
1369		Vertebral fragment. One centrum face survives and can be seen to be fused, other does not survive and neither do processes. Heavily burnt. Identification not possible as insufficient features survive.																Cetacean

407		Lumbar vertebra. Centrum complete and both faces unfused. Radial fusion pattern indicates Odontoceti. Bases of neural arch and transverse processes are present but remainder missing. Chop mark at the base of one transverse process. The most complete vertebral epiphysis from this context can be refitted to this vertebra. With this disc refitted the CL is 32mm. It can be assumed CL would be approximately 34mm with both discs refitted. So CL/CH would be 0.58. Although sub adult this places the measurements and ratios within the anticipated range for Delphininae. Too large to be Phocoenidae. The form of the bone also differs from larger delphinids (Orcininae) due to the larger spaces these species have behind the neural arch laminae and other aspects of form and robust nature. Not identified to species level due to the ontogenetic changes to CL/CH in Delphininae. However, CH indicates a larger Delphininae.	70*	80*	30	30	58	60						24				Large delphininae
407		Lumbar vertebra. Centrum complete and both faces unfused. Radial fusion pattern indicates Odontoceti. Bases of neural arch and transverse processes are present but remainder missing. Large delphininae (see above for explanation)	55*	83*	30	30	55	65									See above (right)	Large delphininae
1704		Vertebra. Fragment of the upper part of a vertebra. Likely thoracic or early lumbar due to the breadth of the neural arch. Only one partial centrum face survives, and the disc is fused to this though fusion lines are still evident indicating relatively recent fusion. ZooMS ID Delphinoidea (Orca/Harbour P/ Dalls P/ White sided dolphin). Size indicates that this is too small for O. orca. Bone too incomplete for further identification, thus classified as small delphinoid.	24*	28*	19*	19*	18*	27*						14				Small delphinoid

2907	5356	See description in text above.	90*	120	75	75	87	98										*O. orca*
1413	3501	See description in text above.	104*	124*	87	87	88	95						19				*G. melas*
3181	5109	See description in text above.				110	151	133										Medium to large cetacean
2377	4698	See description in text above.				31	58	66			18	50	35	25				Large delphininae (G. griseus or T. truncatus)

US (CH01)		Centrum near complete and unfused on both sides. Stubs of transverse and neural processes present but all broken off near to base. Caudal vertebra. Arterial foramen present. Radial fusion pattern indicates Odontoceti and size indicates delphinid. Centrum length can be gauged even in the absence of discs and displays shortening characteristic of delphininae. Centrum width and height are too large to be from any of the smaller delphiniae, suggesting either T. truncatus or G. griseus. Form of the arterial formamen (relatively large) supports this, distinguishing T. truncatus and G.. griseus from other Delphininae.	71	80	33	33	65	70						7				Large delphininae (G. griseus or T. truncatus)
469		Vertebral process identified as blue whale using ZooMS.	27*	95*	300*													B. musculus
2476	5024	Fragment of neural process including neural arch laminae and part of neural spine. Base of the neural arch lamina is present on one side and thus the HNA can be reconstructed. BNA is likely to be lower than in the original as only half of the other neural arch lamina is present. NSH is incomplete. Metapophyses not present indicating species with regional metapophysis loss. Together with the size of the bone this indicates Delphininae.								31*			32	25*				Delphininae

1002M		Fragment of a vertebra made from the side of the centrum. No dimension is complete. Identified by ZooMS as B. musculus.				82*	57*											B. musculus.

Table 44 Identifications of cetacean vertebrae from Cladh Hallan

2.4 VERTEBRAL EPIPHYSES

Creation of a methodology for the identification of vertebral epiphysis was not an initial aim of this work. However, during the course of this research some features of use for the identification of vertebral epiphyses became evident. In particular fusion patterns were observed to be a reliable means of distinguishing between Odontoceti and Mysticeti. The former have epiphyses with fusion patterns characterised by a radial appearance, while the latter appear either stippled or pitted, with occasional evidence of radial patterning on the outer edges of the discs (see Figures 127 - 129). This feature was found to be of greater value for identification than other features including dimensions. Epiphyseal disc thickness, for example, was hypothesised to bear a relationship with species, however, when thin vertebral epiphyses were sampled using ZooMS some were found to be from Mysticeti. Figure 129, for example, represents a small vertebral epiphysis fragment from Cladh Hallan (context 1210) with a thickness of 3mm. ZooMS sampling demonstrated that this bone was derived from a Minke or Sei whale, despite the thin form of the epiphysis. The stippled fusion pattern corresponds with this identification, demonstrating the greater utility of fusion patterns for identification compared with measurements of epiphyseal thickness. Other dimensions also vary greatly along the length of the spine.

Figure 127: Example of the stippled fusion pattern of Mysticeti vertebral epiphyses all identified as blue whale using ZooMS

Figure 128: Radial patterning on the vertebral epiphysis of an Odontoceti (identified as Delphinoidea using ZooMS)

Figure 129: Example of the stippled fusion pattern of Mysticeti vertebral epiphysis identified as Minke/Sei using ZooMS

These observations were of use when identifying vertebral epiphyses from Cladh Hallan and Bornais and have fed into the results. All identifications are included within Appendix 4 and 5.

3 BORNAIS

The following sections give details of vertebrae from Bornais.

3.1 VERTEBRA (CONTEXT 722; SF 2171)

The bone is a mid-thoracic vertebra. The centrum is present and burnt and cut on one side. The processes are all absent. ZooMS identified the bone as *B. physalus.* This concurs with the morphological evidence which shows that on the basis of size and shape the bone falls within the range of recorded fin whales. The CL/CH ratio and centrum height of the archaeological specimen is recorded on Figure 130 below by the black cross. Table 45 provides details of the dimensions.

Dimension	Measurement
Centrum Length	216 mm
Centrum Height	220 mm
Centrum Width	300 mm
Breadth of neural arch	105 mm
CL/CH	0.98

Table 45 Measurements for vertebra (722; SF 2171)

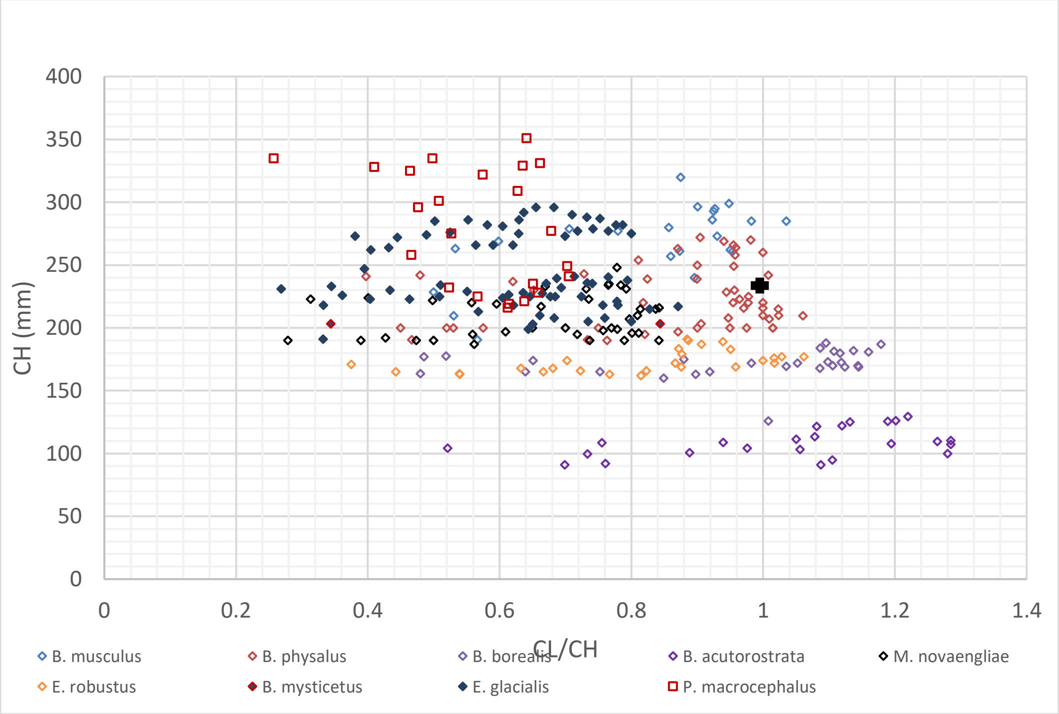

Figure 130: Centrum length and height ratio and absolute dimensions showing specimens recorded as part of this thesis and the archaeological specimen (SF 2171)

3.2 VERTEBRAE (CONTEXT 2356)

Two likely articulating early to mid-caudal vertebrae were recorded from context 2356 (Figure 131). The centrum was largely complete on one of the vertebrae, however, the processes were missing though their bases remained. Both centrum faces were fused. The second of the two vertebrae was missing one face. The remaining face has a fused disc. Arterial foramen were absent on both vertebrae, but arterial grooves are present and incised strongly on both.

Figure 131: Range of cetacean vertebrae from Bornais including the two caudal vertebrae from 2356 on the left

Table 46 provides details of the dimensions.

Dimension	Vertebra 1	Vertebra 2
Centrum Length	23 mm	16* mm
Centrum Height	30 mm	30 mm
Centrum Width	34 mm	35 mm
Breadth of neural arch	4 mm	
BPTr	14* mm	14* mm
CL/CH	0.77	-

Table 46 Measurements for vertebra (2356)

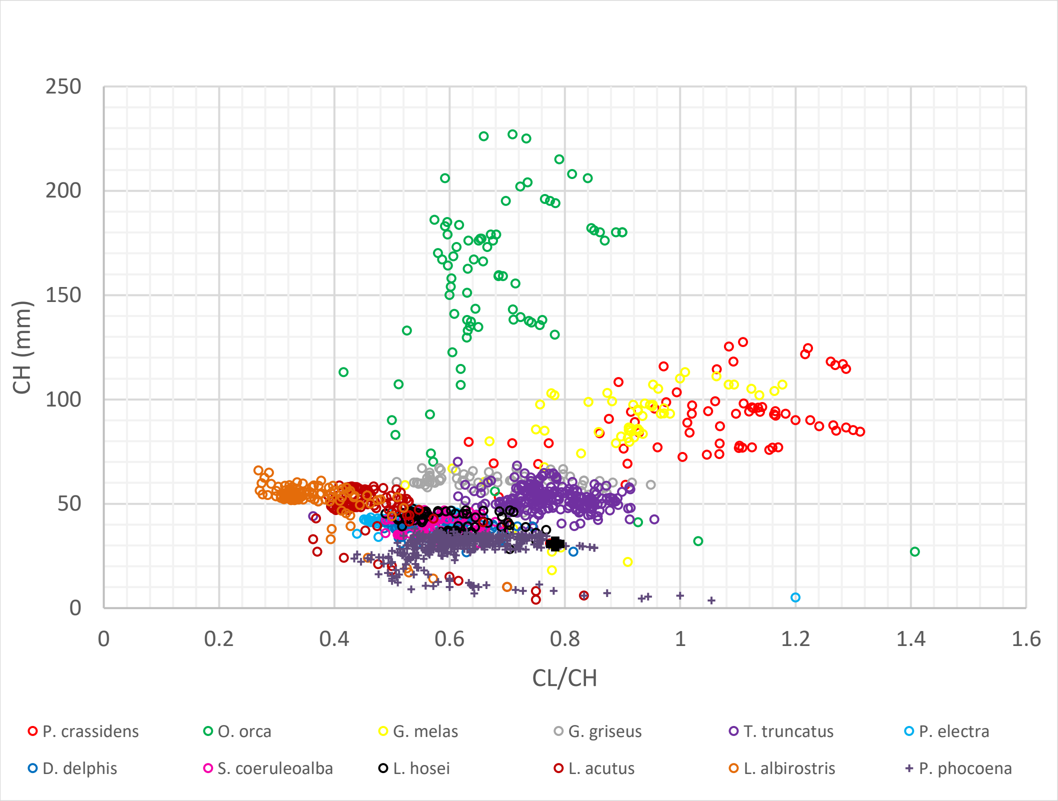

Figure 132 CL/CH and CH in caudal vertebrae of adult Delphinoidea

The size and ratios are indicative of a smaller delphinoid (archaeological specimen shown with a black cross on Figure 132). A more precise identification can be made when the exact region of the spine is considered (i.e. early to mid caudal). The size and ratios demonstrate that the vertebrae are likely to be from *P. phocoena* (Figure 132- 134). The strong incision of the arterial grooves supports this identification. Absence of arterial foramen indicates that the vertebrae is from Ca 1 – 7, as from c. Ca 8 in *P. phocoena* arterial foramen are present.

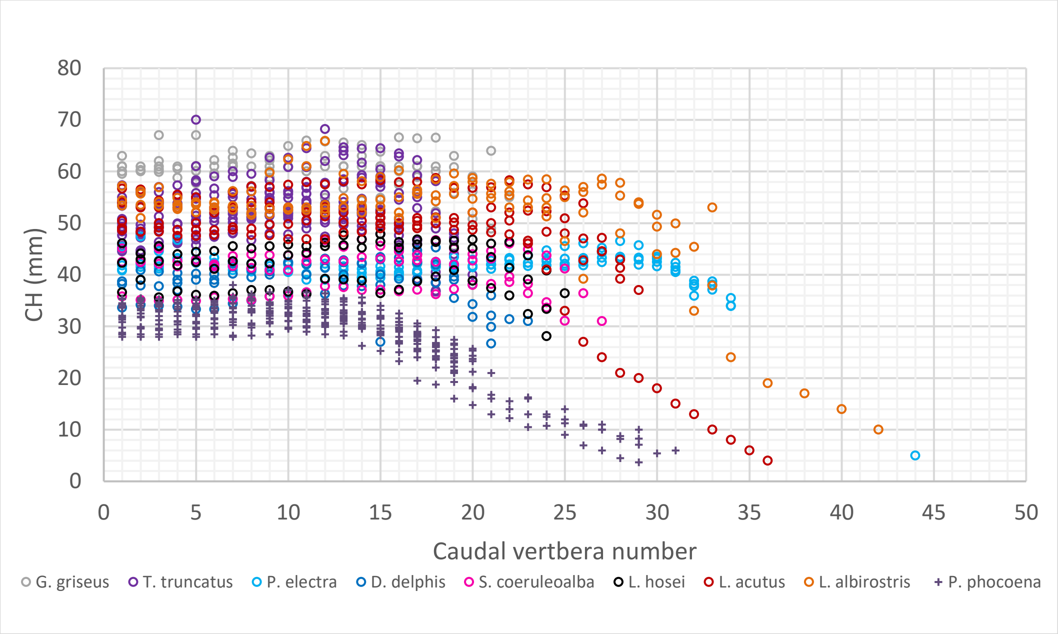

Figure 133 CH in caudal vertebrae of adult specimens of small delphinoids

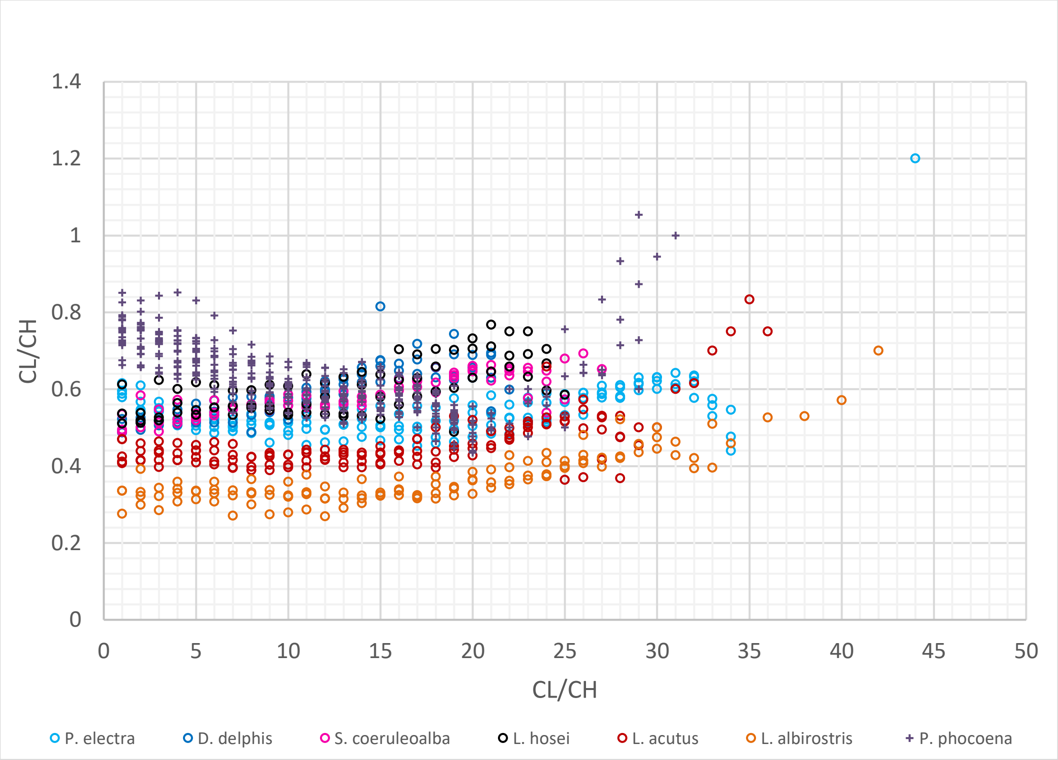

Figure 134 CL/CH in caudal vertebrae of adult specimens of small delphinoids

3.3 VERTEBRAE (CONTEXT 1795)

Two thoracic vertebrae were recorded from this context (Figure 35). One has a single centrum face surviving and has a fused disc on this face. The other face is missing and cancellous tissue is exposed. The bases of both neural arch laminae are present but the extents of the process are missing.

On the second vertebra both centrum faces are present and the discs are fused but the centrum has a portion missing. The base of one neural arch lamina survives. The vertebrae are from the early to mid thoracic region.

Dimension	Vertebra 1	Vertebra 2
Centrum Length	30* mm	24 mm
Centrum Height	33 mm	29 mm
Centrum Width	36 mm	27* mm
Breadth of neural arch	18 mm	-
CL/CH		0.83

Table 47 Measurements for vertebra (1795)

Table 47 provides details of the dimensions. Broadly the centrum height and length indicate the bones are both derived from a smaller delphininae, however, it is not possible to provide a more precise identification due to the close overlap between delphininae in the thoracic region, and the incomplete form of the bones (Figure 135– 137).

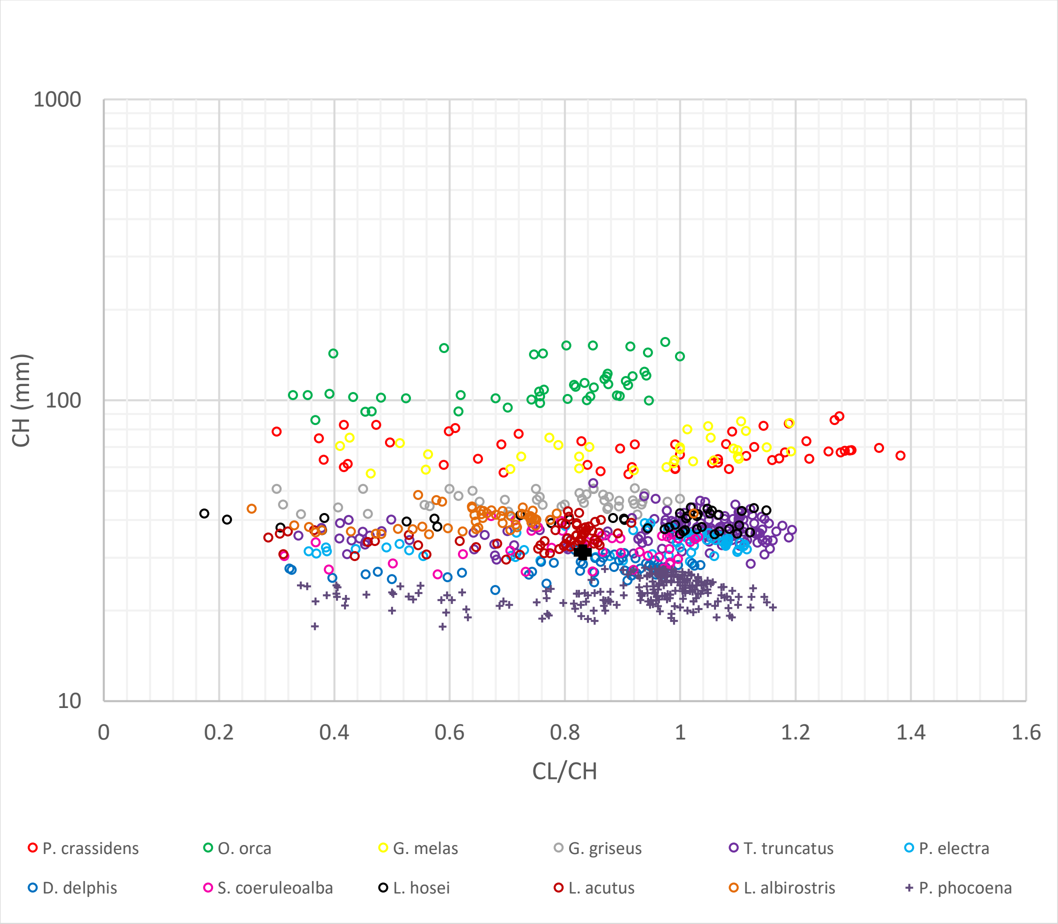

Figure 135 CL/CH and CH in thoracic vertebrae of adult delphinoids. Y axis is depicted with a logarithmic scale

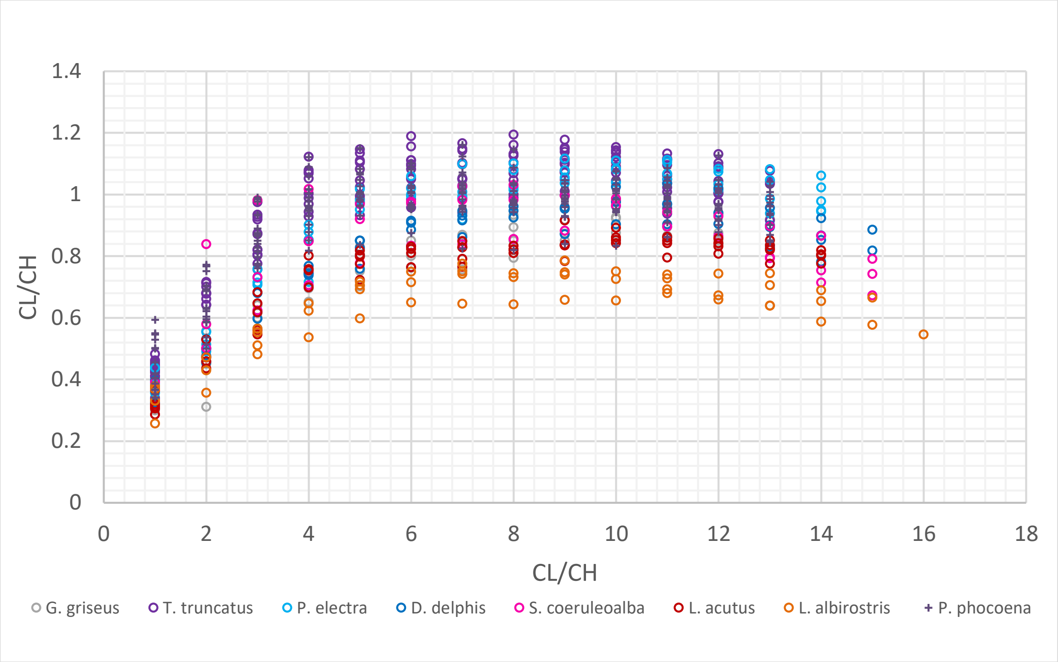

Figure 136 CL/CH in thoracic vertebrae of adult Delphininae

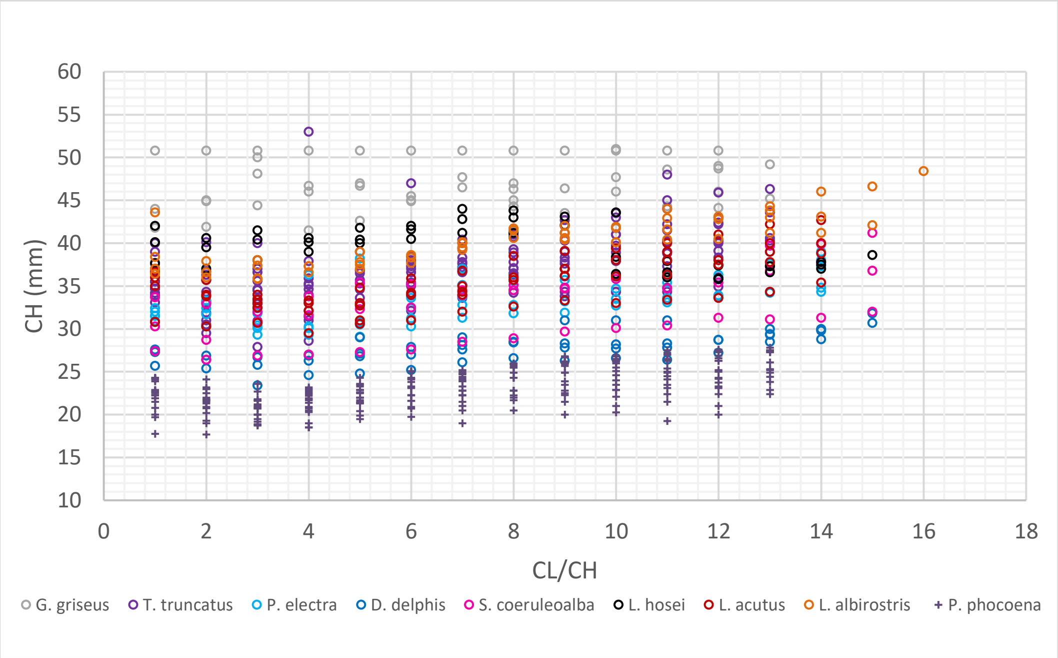

Figure 137 CH in thoracic vertebrae of adult delphininae

3.4 VERTEBRA (CONTEXT 9)

The bone is identified as a caudal (fluke) vertebra (Figure 139). Half of the vertebra survives, with one arterial foramen indicating it is either the left or right side. The vertebra has been broken/chopped down the centre (dorso-ventrally) and the other half does not survive.

Centrum height and length are therefore largely complete, but centrum width is incomplete. ZooMS identified this bone as Delphinoidea. Table 48 provides details of the dimensions.

Dimension	Measurement
Centrum Length	36 mm
Centrum Height	53* mm
Centrum Width	30* mm
CL/CH	c. 0.7

Table 48 Measurements for vertebra (9)

Assessment of the size of the bone indicates that it falls within the range for a number of Delphinoidea (Figure 135). However, when the precise position of the bone is considered. i.e. within the fluke region, the bone can be identified as from *O. orca* and is likely derived from the region around Ca 21 (see Figure 124 and Figure 125).

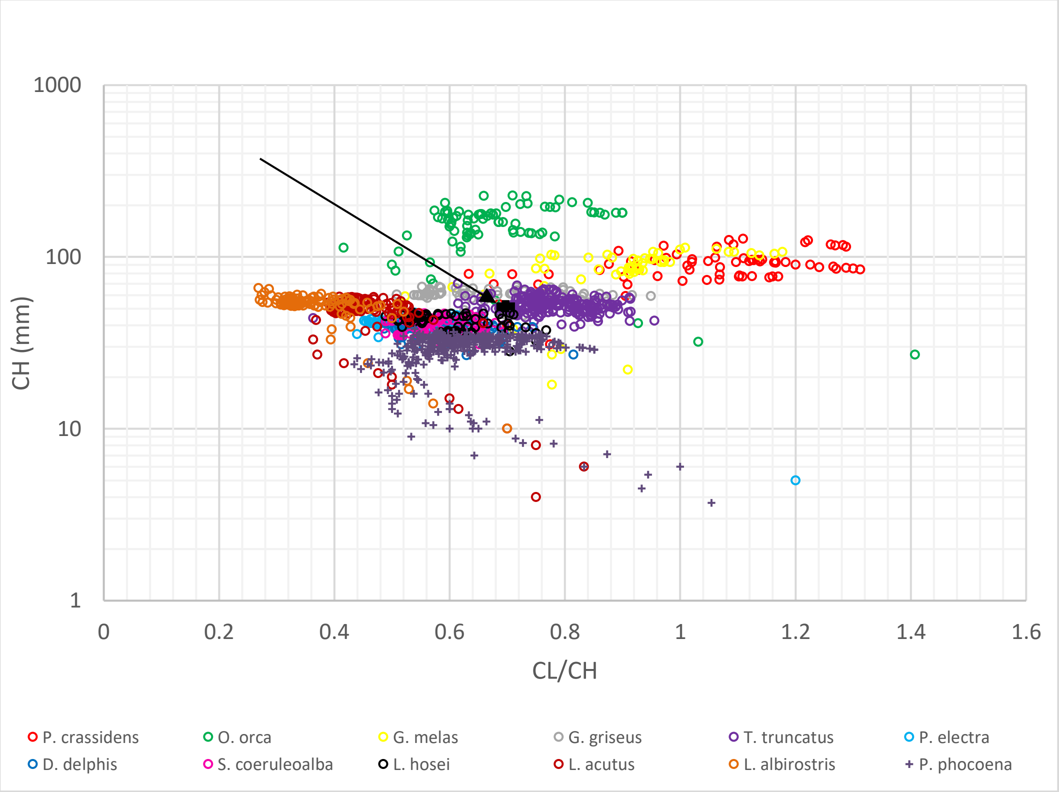

Figure 138 CL/CH and CH in caudal vertebrae of adult Delphinoidea. Y axis is depicted with a logarithmic scale

Figure 139 Fluke vertebra from context 9

Identifications for other fragments of vertebrae are set out within Table 49.

Context	SF	Description	Overall Dimensions			Centrum dimensions			Neural process dimensions						Transverse Process dimensions		Photograph	Identification
			H	W	L	CL	CH	CW	NPH	NSH	LNS	MPH	HNA	BNA	BPtr	GLPT		
576		Chopped part of vertebral centrum. Part of centrum evident, unfused. Base of a process also survives. All measurements represent incomplete dimensions. Radial fusion pattern indicates Odontoceti.	64	26	13	13*	64*	26*										Odontoceti
2356		See discussion in above text. Vertebrae on left of the photo.	*37	45*	23	23	30	34						4				P. phocoena
2356		See discussion in above text. Vertebrae on left of the photo.	34*	50*	23	16*	30	35										P. phocoena
1795		See discussion in above text. Vertebrae on top left of the photo.	40*	38*	30*	30*	33	36						18*				Small delphininae
1795		See discussion in above text. Vertebrae on top left of the photo.	28*	23*	24	24	29	27*										Small delphininae
1649		Very small vertebra. Faces both unfused. No processes surviving, uncertain if this is because they are broken or because the vertebra originated in the caudal region. Radial fusion pattern indicates Odontoceti. No further ID possible.	30*	25*	13	13												Odontoceti
1257		Thoracic vertebra. One centrum face survives and has a fused disc. Other face is missing and cancellous tissue exposed. Burnt. Centrum height indicates that the bone is from a delphinoid.	28	21*	24*	24*	28	21*									No photo	Delphinoidea

1637		Possible vertebral fragment. One unfused face evident. No other surviving morphological features and no complete measurements. No detailed identification.	32*	21*	25*	25*												Cetacean
17		Lumbar vertebra. Very small, unfused and discs not present. Extremely short centrum length. Transverse process bases also indicate a cranial inclination as seen in Delphininae, with arterial groove behind creating a slight notch. Extreme shortening of the centrum and cranial inclination of processes are indicative of Delphininae. No further identification possible as the bone is small and from a juvenile.	25*	50*	12	12	24	27						8*		10		Delphininae
1474		Thoracic vertebra. Centrum present but has been partially removed by chopping on one side. Both neural arch laminae survive in part, one to a greater height than the other and includes partial transverse process. The vertebra is likely from the early to mid thoracic region (c. Th. 4 – 8). On the basis of form and size the vertebra is identified as from the Delphinidae.	65*	67*	24	24	35	38*						33				Delphinidae
2414		Very small vertebra. Faces both unfused. No processes surviving, uncertain if this is because they are broken or because the vertebra originated in the caudal region. Radial fusion pattern indicates Odontoceti. No further ID possible.	22*	19*	12	12												Odontoceti

1512		Cervical vertebra. Centrum is present with two fused discs, though fusion lines are still evident. Lower part of one lamina remaining, other missing. Bottom right in photograph. Size indicative of Delphinoidea but due to variability in cervical fusion amongst these species no further ID is possible.				5	25	29										Dephinoidea
789		See text in discussion above.	37*	49*	25	25	30	33						8				P. phocoena
1616		Early caudal vertebra. Full CH is missing as ventral aspect is absent. Both centrum faces present and unfused. Neural arch incomplete but location of metapophyses survive, these are greatly reduced. Neural arch and neural spine inclined cranially. Base of one transverse process survives and also appears to be inclined cranially. Discs are not present but CL is very low. Generally the bone appears to be from a Delphininae. No further identification possible as the bone is from a juvenile.				12	31*	34*				23	6	5				Delphininae
2210		Broken section of cetacean vertebrae, epiphysis fused. Likely to have been chopped for formation into this form. Identified as balaenopterid by ZooMS (Minke/Sei).	82*	45*	24*	24*												Balaenopterid

863		Broken vertebral centrum with epiphyseal disc fused. Large piece of mainly cancellous cetacean bone, one side is compact tissue. Largest side has been shave, sides appear to be split away. Surface of compact tissue has a number of irregular chop marks. Identified as *B. musculus* by ZooMS.	99*	44*	91*	91*												*B. musculus*
1618		Caudal vertebra. Both centrum faces are unfused and a radial fusion pattern is exposed indicating Odontoceti. Bone has been perforated. Sides abraded and not possible to determine if processes were once present. None survive now. Arterial foramen present and relatively large indicating mid to late caudal region. CW and CH likely near complete but not quite due to abraded surfaces. ZooMS identified the bone as Delphinidae.				17	31*	31*										Delphinidae
581		Vertebral process. Origin uncertain though likely transverse process and measured as such. Fusion surface (unfused) at the tip of the process indicates younger individual. ZooMS ID indicates Delphinidae but too small to be from the larger Delphinidae (Orcininae) and identified as delphininae. ZooMS ID indicates Delphinidae.													75	22		Delphininae
1474	5508	Chopped section of vertebra. One side is burnt and burnt pieces have fallen off the main element. However, these can be refitted and the full centrum length can be restored. Measurements taken when refitted. Centrum width and height are both incomplete. Part of a process survives. The centrum length is relatively short (68mm) from the form of the bone this indicates a position in the early thoracic region. ZooMS identified this to Mysticeti (fin or balaenid). These species have very different early thoracic vertebrae and the bone can				68	95*	95*								43		*Balaenidae*

		be clearly identified as deriving from a balaenid based on the form of the processes in this region.																
1753	5268	Caudal vertebra. One side is complete and fused, and the other has been hollowed out and centrum length is incomplete. Based on the BNA the vertebra appears to be a lower caudal one, but pre-fluke. The ventral aspect of the vertebra is also missing so CH is incomplete. No indication of transverse processes. Neural arch is present but small, with the upper parts damaged so not possible to see the extent of any neural spine. Absence of transverse processes and small neural arch correlates with lower caudal position. CL to arterial foramen is 53mm, likely half of length of complete CL. Likely large or medium sized cetacean. Further identification not possible due to missing CL/CH and other features.				71*	145*	137						12				Large or medium sized cetacean
2133	604	Vertebral fragment. Part of the centrum remaining including centrum length. Both faces unfused. No evidence of processes. Heavily worked/degraded. No identification possible.				115	109*	60*										Cetacean
1526		Apex of a neural arch from a large cetacean. Identified as *B. physalus* by ZooMS.							190*		101*							*B. physalus*

1754	5552	Large vertebral process, mainly in one piece with two smaller pieces broken off. Identified as *B. physalus* by ZooMS.																*B. physalus*
1518		Vertebra. Too degraded and fragile to measure. Identified as *P. macrocephalus* by ZooMS.																*P. macrocephalus*
374	1321	See discussion in above text.	180*	270*	120	120	109	136					45	34		77*		Balaenopterinae
304		Thoracic vertebra. Centrum length incomplete, only one face surviving. General size indicative of small delphinoid. Insufficient evidence surviving for further identification.				16*	23	37										small delphinoid
9		See description in text above.				36	53*	30*										O. orca
9		Fragment of cetacean vertebra. Medium cetacean based on size. No detailed assessment possible due to incomplete form.	99*	36*	57*	57*												Medium sized cetacean

308		Thoracic vertebra. Centrum length, width and height incomplete. Form indicates small delphinoid.					20*	35*										small delphinoid

Table 49 Identifications of cetacean vertebrae from Bornais

Appendix 7: Full dataset of measurements of cetacean vertebrae from reference collections and published sources

See spreadsheet titled: Appendix 7_Morphometric data collected from reference collections and published sources